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Full Paper

TRIPLE BOTTOM LINE: ITS RELEVANCE TO THE CONSTRUCTION INDUSTRY

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ABSTRACT

Environmental economists since the 1960s have advocated the need for public participation for the purpose of achieving a balance between social, economic and environmental values. TBL is a burgeoning discipline using many of the characteristics of these earlier methodologies, but with a greater emphasis on the trimorphic unifying relationships of social, economic and environmental characteristics.

As the major urban centres of Australia are expanding a larger number of buildings are imposing greater impact on all aspects of the environment. The period of a few 'great' buildings, normally constructed under the auspices of government, has long passed being replaced by a plethora of high rise commercial buildings and 'MacMansions' in the suburbs which encroach on the built and natural environment.

Increased community concerns must be addressed before future environmental imposing developments occur. To this end the Triple Bottom Line Research Initiative [TBLRI], at the University of Western Sydney is researching means of measuring social, economic and environmental values within the context of the construction industry. This paper summarises research into the use of water as an environmental currency or measure, and the social and environmental impacts of re-using water onsite rather than remote disposal.

This research is an extension of value assessment techniques developed over 20 years using TBL techniques for both built and natural environments. In each instance this research has been part of higher degree programs. The purpose of this research is to facilitate a standard of pre and post construction evaluation assessments, incorporating the scientific elements of measurement, replication and prediction.

RESEARCH REVIEW

Brennan [1993] presented an ambitious attempt to harmonise current, uncoordinated and pragmatic approaches to heritage conservation with the analytical framework provided by economics. This work permitted a more rational basis for decision-making by addressing heritage evaluation from the political-philosophical, historical and utilitarian viewpoints. It presented an overview and appraisal of valuation methodologies while examining the theoretical basis for assessing societal heritage values.

In addition to discussing the role of government, its bureaucracy and associated legislative processes in the allocation of resources for heritage purposes, it also identified whether public attitudes (or values) attributed to built and natural heritage items could be objectively measured and ranked using accepted methods and whether these measuring procedures could be scientifically replicated.

The implications for the building and construction industry of the TBL estimation model based initially on the above heritage evaluation process is that it allows for pre and post construction estimations across different eco-systems and where necessary inter-temporally. This composite approach is facilitated by the employment of water, in its various qualities, as a common factor of environmental performance – i.e., the eco-currency. Whereas energy has been spasmodically proposed by economists as an ecological currency from the 1950s or so, its application has not been successful. Water as an ecological currency on the other hand has the advantage of not only being a form of energy, but it also has the capacity to be monitored for changes to ecological quality; a measurement that is difficult to achieve with energy (*vide* for example, Costanza 1991).

Methods of determining community values using non-monetary evaluation methods were appraised to assess the feasibility of collecting and measuring community heritage values. An outcome of this aspect of the research was the development of mathematical models to provide measurement and replication of non-monetary valuation methods. These models utilised the works of Brown [1984], Lancaster [1966; 1971] and Meddis [1984]. The result was the development and testing of a computer-based heritage-ranking model 'HertRank'. An important attribute of HertRank was its facilitation of estimating the relative significance of alternative measures of heritage values. The results of HertRank clearly demonstrated the superiority of this planning tool.

HertRank research was expanded to include environmental and economic attributes over the next decade [Brennan 2001]. This research examined the economic and social outcomes of State Environmental Planning Policy No. 14 - Coastal Wetlands, (SEPP14) 1985 by examining the impact of this environmental policy. Central to the research was the adoption of multi-variant perspectives contained within a common timeframe, based on theoretical, empirical and survey research. This holistic approach identified four main stakeholder groups directly associated with its implementation - landholders, enforcement agencies, government and the broader community and associated outcomes arising from government intervention.

There are two relevant outcomes of this research to the building industry; the first was the formulation of the concept of 'custodial taxation' a theory that provides policymakers with an improved understanding of the benefits and costs implicit with inter-generational bequest issues [passing of environmental benefits from one generation to another] based solely upon property rights transfers, entirely dependant upon ecological criteria.

The second outcome was the advancement of 'attribute analysis' developed in HertRank in its application to the natural environment. The revised ranking model, called EVALUATE, incorporated the philosophy of applying a lateral approach to sustainable development principles [Brennan, *et al*, 1992; Jones and Brennan, 1997]. EVALUATE considered habitat, hydrological and geomorphologic characteristics, consumptive and non-consumptive values and non-physiological attributes.

HertRank and EVALUATE each were constrained by their dependence on two-dimensional matrix formats. While the models could be used to provide input data for traditional triple column Triple Bottom Line [TBL] analysis, the mathematical structure was not conducive to simultaneous and dynamic analysis as discussed by Brennan and Patterson [2004].

TRIPLE BOTTOM LINE?

At the risk of oversimplification, TBL arises from the Global Reporting Initiative [GRI], whose mission is to develop and disseminate globally applicable sustainability reporting guidelines [Global Reporting Initiative, 2000]. These guidelines can be used by organisations reporting on the economic, environmental, and social dimensions of their activities, products and services, in particular those in the construction industry. Since its inception, the GRI has worked to design and build acceptance of a common framework for reporting on the linked aspects of sustainability in a way that presents a clear picture of:

- human activity;
- ecological impact of business;
- facilitate informed decisions about investments, purchases, and partnerships.

However, TBL is subject to varying interpretations concerning content, evaluation and reporting criteria, a situation not resolved by the Commonwealth Government's guidelines [Environment Australia, 2003]. Currently TBL applications range from a relatively simplistic triple column accounting process that reflects a historic performance to a complex dynamic forecasting model. The complexities in providing meaningful TBL analysis has long been recognised, particularly regarding environmental valuation criteria [e.g. Krutilla and Fisher, 1976; Knetsch, 1993]. Table 1 exemplifies these complexities by summarising a matrix of conflicts of various community values expressed before the Land and Environment Court of NSW in relation to a north coast development.

Table 1. Conflict-Matrix: NSW Land and Environment Court, 1996

CONFLICT ISSUES	STAKEHOLDERS (a)					
	Resource Users	Consent Authority (b)	Interest Groups		Lobbyists	
	Tagget (Defendant)	Developer (c)	Council	Conservation groups	NSWF A	Members of Parliament
1. Bund Wall						
remove	S	O	O	O	S	X
raise height	O	S	S	S	O	X
Lower height	O	O	S (d)	O	S	X

2. SEPP14						
Livestock	S	X	O	O	S	S
Drainage	S	X	O	O	S	S
Horticulture	S	X	O	O	S	S
Development	-	S	X	O	S	S
Conservation	O	O	S	S	O	S
3. Existing use rights						
Drainage	S	X	O	O	S	X
Livestock	S	X	S	O	S	X
Cropping	S	X	O	O	S	X
4. Classification Methods						
Aerial	O	X	S	S	O	(e)
Photography	O	X	S	S	O	X
Soils categorisation	O	X	S	S	O	X
Flora significance						
5. EPA Act						
Devel.	O	-	S	S	O	X
consent	O	-	S	S	O	X
Upgrade BLM drain						

s= support; o = objection; - no opinion or opinion not expressed, but is interested party; x = not an interest party. (a) the court is considered a stakeholder in all issues; (b) with the concurrence of the Minister; (c) Krekelberg quay development and bund wall development; (d) Council altered its position (TSC 1994); (e) investigation requested by the Minister. Data Sources: Bannon, J. (1992); Tagget (various documents); Frank, R. (1994); Parker, (1993); Mobbs, M. (1992); Brennan and Patterson (1993). [Source: Brennan, 2001].

Notable from Table 1 is the inconsistency of values between parties across the various issues – that is to say, the various values were dynamic and were dependent on factors outside the attributes that related to a particular physical issue. The situation presented in Table 1 becomes more complex when community values are assessed over time. Comparative analysis between two periods was undertaken using a statistical method developed by Brennan [1997].

This method performs temporal comparisons using two dimensional matrices of any size. Brennan [1997] compared two 32 x 32 matrices by deriving an index of frequency distributions on a question-by-question basis employing the statistical principles underlying the Kolmogorov-Smirnov tests. Entitled the Public Prioritisation Index (PPI) it is calculated using the following model:

$$PPI_i = \left(\left(\frac{(|(Mo_{2i} - Mo_{1i}) - (Me_{2i} - Me_{1i})|)}{1 - (K_{2i} - K_{1i})} \right) * (S_{2i} - S_{1i}) \right) * 10$$

Where:

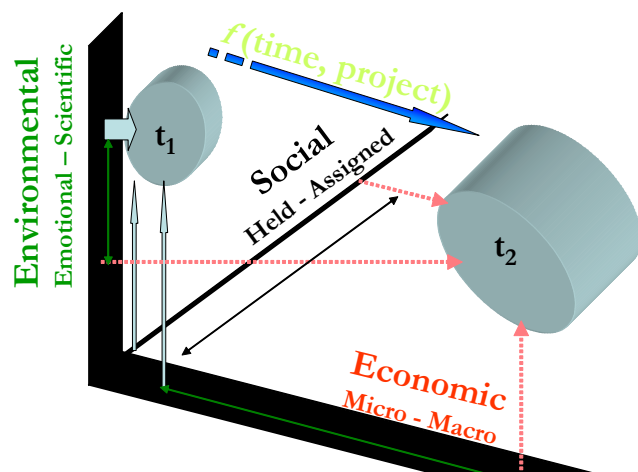
- PPI = Public Prioritisation Index for the temporal period *i*
- i* = the *i*th observation of the *n* choices
- Mo_x = Mode for period *x*,
- Me_x = Median for period *x*

K_x = Kurtosis for period x
 S_x = Skewness for period x

Rationale underlying this index includes the change in positioning of the significant frequency distributions, the mode and the median, over two time-periods. Measuring the temporal changes of the mode (highest frequency occurrence) and median (midpoint of frequency occurrence) in absolute terms, this expression is weighted by [a] the change in the kurtosis (a surrogate for variance) and [b] the skewness that shows the direction of the movement.

The importance of the PPI is that it facilitates measurement of the movement of community values where these community values may be of particular lobby [protestor] groups, clients of developers, or evidence before the environment courts. Such measurement is becoming more critical for residential and civic construction projects as the community is better informed and able to communicate more effectively by use of electronic media such as the Internet and e-mail.

3D Representation of Triple Bottom Line Assessment



Valuing the Environment

Combining the developments outlined above it is now theoretically possible to construct the temporal-dynamic TBL model as presented by Brennan *et al* [2004] and illustrated in Figure 1 and apply it to the built environment; it is this model that is used in the remainder of this paper. However, while the economy is relatively easily measured in monetary terms, and social values by numerous inquisitorial techniques, the measuring of environmental values remains a contentious issue. Economists have developed numerous methods over the last half century with some, such as the Environmental Evaluation System and TBL, [albeit in an undefined format] gaining a degree of recognition and popularity. To address the difficulties associated with environmental valuation Brennan *et al* [2003] offer the novel approach of using water as an 'Eco-currency'. They posit that the determination of environmental values should be able to parallel the basic theories developed for the money economy by providing 'common denominator' assessments, based on inter-environmental values whether at the micro or macro levels of analysis [Brennan *et al*, 2003].

Figure 1: TBL represented as a composite trimorphism illustrating changing values, including environmental ideals [After Brennan and Patterson, 2004].

Succinctly, they assert that water quality and quantity is the currency facilitating Triple Bottom Line [TBL] environmental assessment in a parallel manner to gold being the natural element that underpinned the monetary system i.e. 'Recognition that non-oceanic water has real economic value is reinforced by governments

legislating to control this resource where an economic good is dichotomous to the notion of a Free Good. An extension of these government actions is that water does have value in its own right, as well as providing value to other natural elements [e.g. Brennan and Watson, 2000]'. Table 2 contains a basic comparison of traditional monetary theory with the proposed Eco-currency, indicating that the established monetary theories can be adopted to fulfil a new need, albeit becoming irrelevant in the modern paperless economy.

Table 2: A Simple Comparison of the Monetary System and Eco-Currency

Criteria	Money	Eco-Currency
Legal Tender	Gold standard – based on weight Gold Index – based on weight Gold measured in carats	Water – based on volume, weight, mass Water measured in living support systems
Interest	Return to capital – usually in terms of % return Normally related to risk regarding the return of capital and interest payments – low risk low return	% Change in quantity or variety of living organisms supported and how these relate to risk and health Improved environmental outcomes, including the reduction of risk to flora, fauna and micro-organisms
Capital	Monies used in store for the purpose of security or investment potential	Storage in soils and other natural environments Risk management – drought proofing Potential resource for return – ie water consumption
Trading	Stock Market Futures Market	Water licence trading Carbon Credit type scheme Transfer of Development Rights – move demand from Sydney to other less risk prone areas
Taxation	Direct Indirect	Licences to use, reuse or dispose of water within the ecosystem Monitoring activities and correction requirements

Underpinning Table 2 is the application of traditional monetary theory including that, in the short-term, the supply of money was fixed, with variations to availability being determined by a number of human controlled factors.

Similarly, water supply is fixed (all natural resources are finite - as illustrated by the water cycle), but, has the capacity to measure changes in the supply at a particular time and space – i.e. dams relocate water from one use to another, with associated opportunity costs [loss of free flowing rivers], returns to capital [drought proofing] and depreciation [alteration to adjoining land uses]. While it is argued that water is not a homogeneous product, neither is money with real and well defined hierarchy of national currencies as illustrated by the international exchange rate. However, each currency functions within their respective environments fulfilling the critical role of facilitating exchange of value. What money is to the economy, water can be to environment valuation as it is the common dominator that becomes 'stronger' with

good eco-systems and 'weaker' in degraded eco-systems. This characteristic allows natural resource valuation to occur in both natural and urban areas, or in combination, specifically for the purposes of this paper to the built environment and its associated construction industry, a characteristic not catered for in previous methods [e.g. Winter and Lockwood, 2004].

TBLRI Estimation Model

Over the last two years the Triple Bottom Line Research Initiative, University of Western Sydney, has been developing a TBL estimation model that encompasses the one and half decades of research outlined above. The format of this research is summarised in Figure 2. Stage 1 comprises research into the availability of raw data sources, while Stage 2 utilizes the algorithms developed by HertRank and EVALUATE. Stages 1 and 2 have also initiated research into methods of deriving alternative data, including the innovation and development of the 'eco-currency' concept.

Stage 3 is the modification of sophisticated multi-dimensional software to perform the complex multi-array raw-attribute and derived ranked data into an analytical format that facilitates temporal and sensitivity ['what-if'] estimation that in a variety of formats provides stakeholders with reliable information that is relevant to their needs and interests including for construction developments. This process is symbolically represented in Figure 3.

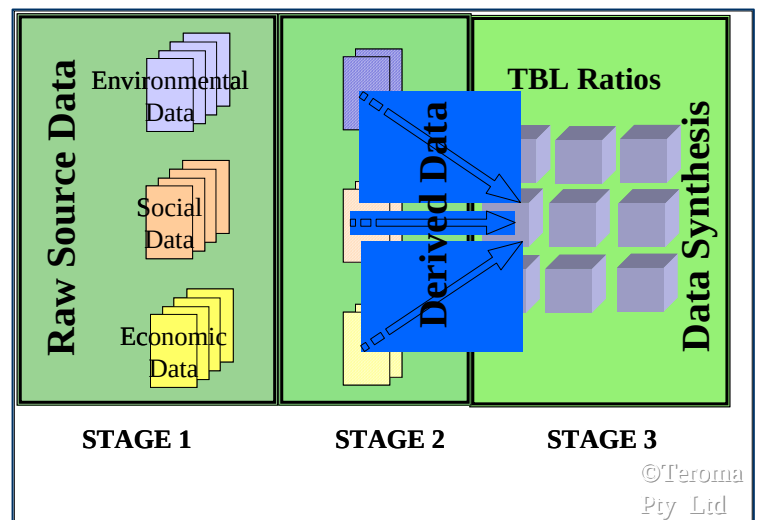
CONCLUSIONS

It has been noted above that there is need to collect data for each of the main TBL classifications, including temporal series and inter-geographic levels, as well as from landowners, developers and the wider community. This part of the analysis requires a sophisticated computer 'black-box' processing ability, as each part of the process has the likelihood of interacting with any of the other parts.

The implications for the building and construction industry of the TBL estimation model presented is that it allows for pre and post construction estimations across different eco-systems and where necessary inter-temporally. This composite approach is facilitated by the employment of water, in its various qualities, as a common factor of environmental performance – i.e. the eco-currency.

While community values estimation techniques are incorporated into the TBLRI model, it has the additional advantage that community attitudes can be measured over two time periods. This form of measurement is of importance for large and/or controversial projects such as the Australian Defence Industries [ADI] site at Penrith

Figure 2: Diagrammatic representation of the collection, derivation and application of data within the TBL framework.



in New South Wales where community support/objection appears to vacillating over time.

Figure 3: The complex multi-dimensional structure undertaken by sophisticated computer processing to provide TBL inter-temporal and multi-resource analysis.

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CAPTURING AND MAINTAINING THE CLIENT'S REQUIREMENTS

Full Paper

ASSESSING OWNERS' ROLE IN IMPROVING CONSTRUCTABILITY OF CONSTRUCTION PROJECTS IN INDONESIA

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ABSTRACT

Constructability is an approach that links the design and construction processes, which can lead to significant savings in both cost and time required for completing construction projects. Improving constructability of construction projects is the responsibility of all project stakeholders, ie owners, designers and contractors. However, as the owners have the most authority in enforcing the implementation of constructability, the owners' awareness of the benefit of improved constructability is the most important. Project owners must be aware that the decisions that are made in the initial stages of planning and design are difficult and costly to change once construction begins. This paper present the study performed on the construction project owners in Indonesia in regard to their current constructability practices and its impact on the project performance. The study, which used survey questionnaires, shows that Project owners in Indonesia do have some understanding of the importance of constructability. However, the traditional approach to project delivery, which is the preferred method by most of them, limits their option for involving construction personnel in the pre-construction phases. There were few significant differences between public sector owners and private sector owners, and among owners who developed different types of project, in their approach to constructability. Project owners improved their project performance by clearly stating their project objectives, project designers improved project performance by interfacing with construction personnel during preparation of design, and contractors improved project performance by providing the designers with timely construction input.

Key Words: Constructability, Project owner, Indonesia, project performance

1 INTRODUCTION

1.1 CONSTRUCTION INDUSTRY IN INDONESIA

The construction industry in Indonesia is a relatively young industry. However, it has grown significantly since the early 1970s. Its contribution to the GDP increased from 3.86% in 1973 to above 8% in 1997. Although it experienced a contraction of almost 40% in 1998, due the economic crisis in the country, the construction sector contribution has started to grow again since then. It constitutes about 60% of gross fixed capital formation and the number of people has increased significantly from 413,000 in 1978 to about 4.2 million in 1997. Many construction projects are awarded on a competitive basis using the traditional approach. In this approach, professional designers and constructors are engaged in separate contracts. The contractors are usually not involved until the designs have been completed. The separation of design from production in the construction process has led to a certain amount of isolation of the professionals from technical development in construction industry (Wells 1986). This division has also been suggested as being responsible for the lack of constructability of the construction projects (Griffith 1984), which was cited as a reason for projects exceeding budgets and schedule deadlines. (Construction Industry Institute Australia 1992) By separating construction from design function the project stakeholders are ignoring opportunities of significant savings in project cost and completion time resulting from the careful interaction of planning, design, and engineering with construction (Tatum, Vanegas et al. 1986).

1.2 CONSTRUCTABILITY DEFINED

The concept of constructability in the US or buildability in the UK emerged in the late 1970s, which evolved from studies into how improvement can be achieved to increase cost efficiency and quality in the construction industry. It is an approach that links the design and construction processes. In this paper the constructability is defined as 'the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve the overall project objectives' (Construction Industry Institute 1986). It emphasizes the ability to construct and the importance of construction input to all project phases. The Construction Industry Institute (CII) in the US has developed Constructability Concepts to stimulate thinking about constructability and how to make it work. The CII has also shown benefits of implementing constructability, especially in terms of project cost and schedule. In implementing improvement in constructability, the study by the Australian Construction Industry Institute (Francis, Sidwell et al. 1996) suggests that it is important to consider the uniqueness of the construction industry in a specific country.

Improving constructability of construction projects is the responsibility of all project stakeholders, ie owners, designers and contractors. However, as the owners have the most authority in enforcing the implementation of constructability, the owners' awareness of the benefit of improved constructability is the most important. Construction projects stakeholders, especially owners, must be aware that the decisions which are made in the initial stages of planning and design are difficult and costly to change once construction begins. This paper present the study performed on the construction project owners in Indonesia in regard to their current constructability practices and its impact on the project performance. This study was conducted using a questionnaire survey.

2 CONSTRUCTABILITY SURVEY

As suggested by Tatum et al. (1986), the awareness of the project owners were measured in terms of their responsibilities for constructability improvement. The awareness was measured on how construction project owners performed their responsibilities relating to the constructability of their project, which include:

- Setting the project objectives and priorities;
- Building and leading the project team based on the contractual approach selected, and leading the team effectively by fostering a team approach on a project;
- Making constructability a project concern by emphasising early cost influence, using constructability to meet project objectives, insisting on early construction involvement in major decisions, and resolving conflicts based on project objectives.

From one hundred questionnaires distributed to project owners, 40 responses were received consisting of 28 public sector owners and 12 private sector owners. Of these forty respondents eight developed infrastructure projects, eight developed industrial projects, twenty developed building projects and the other four developed residential projects. Table 1 summarises the different types of project developed by the different types of owner.

Table 1 Different types of project developed by different types of owner respondents

Type of Project	Type of Owner		Total
	Public sector	Private sector	
Heavy engineering	8	-	8
Industrial	4	4	8
Buildings	12	8	20
Residential	4	-	4
Total	28	12	40

The data collected from the constructability survey were analysed using statistical analysis software, SPSS 9.0 for Windows. Inferential statistics analysis was used to measure differences between variables and to measure association between variables. The measure of differences was used to analyse the differences in the current constructability practices among the project owners in different types of company, project and project delivery system. The measure of association was used to analyse the influence, if any, of the current constructability practices on the project performance. Since the collected data were in nominal or ordinal form, non-parametric tests were selected. The following tests were used to measure the differences between variables: (Bryman and Cramer 1997)

1. **Chi-square test** for two or more unrelated samples.
2. **Mann-Whitney U tests** for two unrelated samples to assess the significant differences when ordinal variables are used.
3. **Kruskal-Wallis test** for three or more unrelated samples to test for significant differences when ordinal variables are used.

Non-parametric correlation analysis was used to measure the association between variables. As most of data used in the analysis are ordinal variables, the **Spearman correlation coefficient** was selected.

For both the test of differences and the test of associations, the confidence level used was 95%, or the probability level (p-value) of 0.05. Differences or correlations are significant when the p-value is 0.05 or lower.

2.1 PROJECT PLANNING

The questionnaires distributed to construction project owners consist of four parts. The first part is about their roles in the project planning in regard to constructability. These roles are based on their responsibilities for improvement of constructability as suggested by Tatum et al. (1986). Those responsibilities include: defining the project objectives; stating the project priorities; the inclusion of commitment to finding the most cost effective means to meet project objectives; using project objectives as criteria in making major decisions; and considering new design approaches and construction methods.

Most of the respondents claimed that they had clearly stated their project objectives, especially the traditional project objectives of cost, time, quality and safety. These are logical responses, as defining project objectives is the first step in the overall project planning process.

All owners claimed that they had also clearly stated their project priorities and had used the project objectives as criteria in making major decisions. Most of them stated that they had included a statement on commitment to finding the most cost-effective means to meet the objectives, and in doing so they had included a consideration of new design approaches and/or construction methods.

The Mann-Whitney U test was used to assess how the different types of owner approached the overall project planning. There was no significant difference between the public-sector owners and the private-sector owners in their role/practices in the project planning related to constructability improvement, except for clearly stating project quality objectives. The mean rank¹ comparison between the two types of project owner indicates that the public sector owners gave a higher rating to consideration of project quality objectives than the private sector owners did.

A Kruskal-Wallis test was conducted to assess the approach to project planning in the different types of project. There was no significant difference in approaching the overall project planning among the owners in the different types of project except for variable defining the project objectives priority and considering new design approaches and construction methods. The mean rank comparison between these variables and the type of owner suggests that the industrial project owners are more likely to clearly state the 'other' project objectives, while the infrastructure and residential project owners are more likely to consider new design approaches and construction methods.

¹ The mean rank is the sum of ranks divided by the number of cases from the test of significant difference using unrelated samples, ie Mann-Whitney U test and Kruskal-Wallis test

2.2 SELECTING AN APPROACH TO PROJECT DELIVERY

In the second part of the questionnaire the project owners were asked about their approach to project delivery. This approach is important for owners in terms of improvement in constructability, as it will determine the options for early involvement of construction personnel. Although it is possible to improve constructability under any contractual approach, the unique elements of the project and any special opportunities for increasing constructability should be considered in selecting both the contractual approach and the type of contract (Tatum, Vanegas et al. 1986).

Twenty-three of the owners used the traditional approach to delivering their projects. Seven delivered their projects using the owner-builder approach, and six selected the design-construct approach. Other project delivery approaches include the design-manage, the construction management, and the general contractor as construction manager.

Table 2 presents the cross-tabulations between the type of owner and the project delivery approach selected by the owner, as well as between the delivery approaches and the type of project. This table shows that public-sector owners were more likely to deliver their project using the traditional approach, whereas delivery methods selected by private-sector owners vary from the traditional approach to the design-construct approach.

Table 2 Project delivery approaches selected

Project Delivery Approach	Type of owner		Type of Project			
	Public (%)	Private (%)	Heavy Eng. (%)	Industrial (%)	Building (%)	Residential (%)
Traditional	71	25	75	38	50	100
Owner-builder	7	42	0	12	30	0
Design-construct	11	25	0	50	10	0
Others	11	8	25	0	10	0
Total	N= 28	N = 12	N = 8	N = 8	N = 20	N = 4

Table 2 also shows that heavy engineering construction projects tend to be delivered using the traditional approach. This is not surprising, as this type of construction is usually owned or developed by government institutions. Residential construction projects are also most likely to be delivered using the traditional approach. One of the main reasons could be that the construction of this type of project would be determined by market conditions. The owners who develop industrial projects prefer the design-construct approach. The types of project delivery approach in building construction projects vary from the traditional approach to the construction management approach. However, the traditional approach is still the preferred delivery method.

Table 3 shows the cross-tabulation between the types of owner and the phases of the project when they start to integrate construction inputs, as well as the method of incorporating the inputs. This table also shows when and how construction inputs are integrated in the different types of project.

Table 3 Method of incorporating construction inputs

Begin to incorporate construction input during this stage	Type of owner		% of Total	Type of project			
	Public %	Private %		Heavy Eng. %	Industrial %	Building %	Residential %
Conceptual	21	67	35	12	50	45	0
Design	47	33	42	12	38	45	100
Procurement	7	0	5	13	0	5	0
Construction	25	0	18	63	12	5	0
Total	N = 28	N = 12	N = 40	N = 8	N = 8	N = 20	N = 4
chi-square	9.12			21.9			
p-value	0.03			0.01			
Method of early construction involvement							
In-house	36	17	30	25	50	10	100
Consultant	50	75	58	38	50	80	0
CM	7	8	7	12	0	10	0
Contractor	7	0	5	25	0	0	0
Total	N = 28	N = 12	N = 40	N = 8	N = 8	N = 20	N = 4
chi-square	2.80			24.36			
p-value	0.42			0.00			

Thirty-five percent of the 40 owners stated that they had integrated construction inputs as early as the conceptual planning stage. Forty-two percent started to incorporate construction inputs in the design stage and five percent in the procurement stage. The other eighteen percent delayed construction input until construction itself began.

The most common method used by the owners to integrate the construction inputs was by involving construction personnel through their design consultant (58%). Another common method was by using their own construction personnel (30%). Only 5% of the owners engaged contractors' personnel to provide construction inputs, and the other 7% of the respondents used the services of construction management firms.

There is a significant difference in the phase where the respondents start to incorporate construction input. The private-sector owners are more likely to incorporate the construction input as early as the conceptual planning phase, whereas the public-sector owners tend to delay this input to the design phase.

In heavy engineering construction projects, it is more likely that construction personnel are involved only in the construction phase. This is a logical consequence of most heavy engineering constructions being owned/developed by public sector owners, who are more likely to deliver their projects using the traditional approach. In industrial construction projects, the owners tend to incorporate the construction input as early as the conceptual planning phase. The complexity of the projects may

contribute to the early construction involvement, which is usually facilitated by the design-construct type approach. In building projects, the construction input is also incorporated early in the project life cycle. However, most of the inputs are provided by the construction personnel of the design consultant, as the traditional approach is still the preferred method of project delivery. In the residential construction projects the construction inputs are most likely to be incorporated in the design phase, and they are mostly provided by the owners' construction personnel.

In responding to questions about their approaches in selecting the project delivery method, most owners stated that they had assigned key individuals who had appropriate experience to the project team. They had also considered that being receptive to construction input was one of the important criteria in selecting a project designer and had established a pre-construction plan in developing their project. However, many of the owners did not feel strongly about provision of early involvement of construction personnel in selecting their contractual approach. This is one probable reason that many of them still preferred to use the traditional approach where in-house personnel or design consultant personnel provided early construction inputs.

The Mann-Whitney U test was used to assess how the different types of owner approached the selection of project delivery methods. There was no significant difference between the public-sector owners and the private-sector owners in approaching the project delivery method, except for considering the provision of early construction involvement. The mean rank comparison shows that it is the private-sector owners who are more likely to give a higher consideration to the provision of early involvement of construction personnel when selecting the project delivery method. The Kruskal-Wallis test, which is used to assess the differences in project delivery selection approaches among the owners in the different types of project, shows that there is no significant difference among the owners in the different types of project in approaching the project delivery selection.

2.3 CONSTRUCTABILITY AS PROJECT CONCERN

The third part of questionnaire given to the project owners relates to their activities in making constructability a project concern. These activities include: emphasising the importance of 'early cost influence' to the project team, including the designer and the contractor; using constructability to meet project objectives; insisting on involvement of construction personnel in major decision making; resolving conflict based on project objectives; and maintaining lessons-learned files from completed projects.

Most of the owners made or at least tried to make constructability a project concern. Most of them used the project objectives to solve project conflicts and insisted on construction involvement in making major decisions. They also stated that they maintained lessons-learned files of completed projects. Most of the owners emphasised the importance of early construction input and tried to use constructability to meet project objectives.

The Mann-Whitney U test was used to assess differences in implementing these activities between the two types of owner. There are significant differences between the two types of project owner in making constructability a project concern. The private sector owners put more emphasis on early cost influence and inclusion of construction involvement in major decision than the public sector owners. However, the public-sector owners are more likely to maintain the lessons-learned file from

their projects. A probable reason is that public-sector owners are more likely to build or develop more projects as part of the provision of public infrastructure.

The Kruskal-Wallis test results on the differences in making constructability a project concern among the owners in the different types of project show that there is no significant difference between different types of project.

2.4 PROJECT PERFORMANCES

In the last part of the questionnaire the owners were asked about their project performances relating to project schedule, project cost, project quality and project safety. For project time and cost performances, the respondents were asked to describe their project performances as behind schedule/exceeding budget, within schedule/budget, or ahead of schedule/less than budget.

Forty-one percent of the owners stated that their projects had been completed behind schedule. Fifty-one percent had completed their projects within schedule, and eight percent completed their projects ahead of schedule. Fifty percent of the owners stated that their projects had exceeded the budget. Forty-five percent of the owners completed their projects within the budget, and the other five percent completed their projects for less than the budget amount.

Most of the owners (>75%) claimed that their project quality and project safety were above average. Although there is a possibility of response bias, these questions were still asked to assess the influence of the current constructability practices among the project owners, if any, on the project performances related to project quality and safety.

The Mann-Whitney U test was used to assess the differences on project performances between the two types of owner. The Kruskal-Wallis test was used to assess whether there were any differences in the project performances in the different types of project and the differences in the performances due to the time of construction input as well as the method of construction input.

There are no significant differences in project performances between the two types of owner. However, there is a significant difference in project time performance for different types of project: the performance of the infrastructure and building project owners is a better than that of the industrial or residential project owners. It is surprising that the project time performance of industrial project owners was lower than those of heavy engineering and building project owners. The reason for this is not clear. As for the residential project owners, one probable reason for this situation was the access to project sites. It is common that land acquisition process for residential project was still on going when the construction phase started. There is no significant difference in the overall project performance due to different phases of incorporating construction inputs or from the different methods of providing construction inputs.

Table 4 summarises the results of the non-parametric correlation analyses between the project performances and the different variables that represent current practices/activities of project owners in regard to constructability. These analyses were performed to identify the influence, if any, of current constructability practices of the project owners on project performances.

Table 4 Non-parametric correlation coefficients for project performances

	F18		F19		F20		F21	
	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
C1a	0.06	0.74	-0.10	0.54	0.23	0.15	0.17	0.30
C1b	-0.04	0.80	0.07	0.68	0.27	0.09	0.34*	0.04
C1c	0.37*	0.02	0.11	0.50	0.30	0.06	0.35*	0.03
C1d	-0.12	0.48	0.13	0.42	0.38*	0.02	0.61*	0.00
C1e	-0.04	0.80	-0.06	0.72	-0.01	0.98	0.04	0.82
C2	0.25	0.13	-0.01	0.95	0.28	0.09	0.33*	0.45
C3	0.41*	0.01	0.04	0.79	0.23	0.17	0.32	0.05
C4	0.16	0.32	0.10	0.54	0.04	0.79	0.23	0.16
C5	-0.15	0.36	0.06	0.73	0.04	0.79	0.13	0.44
D7	0.01	0.95	0.18	0.28	-0.08	0.64	-0.06	0.73
D10	0.28	0.08	0.23	0.16	-0.32*	0.04	-0.15	0.39
D11	0.08	0.65	0.24	0.14	-0.02	0.92	0.01	0.95
D12	0.07	0.66	0.08	0.64	-0.18	0.28	-0.15	0.35
E13	0.02	0.91	0.04	0.79	-0.29	0.07	-0.15	0.36
E14	-0.08	0.62	0.04	0.83	-0.33*	0.04	-0.06	0.71
E15	0.08	0.65	0.18	0.28	-0.02	0.92	0.26	0.12
E16	0.01	0.96	-0.02	0.91	0.13	0.43	0.38*	0.02
E17	0.31	0.06	0.02	0.88	0.20	0.24	0.24	0.15

* correlation is significant for p-values less than or equal to 0.05

This table shows that there are some correlations between current constructability practices and project performances. When project quality objectives (C1c) are clearly stated, this may lead to improved project performance related to project cost (F18) and project safety (F21), and to a lesser extent on project quality (F20). Project cost performance (F18) is also improved when the objective statement includes a commitment to finding the most cost effective means to achieve project objectives (C3). Project safety (F21) is the project performance that is most influenced by current constructability practices. Project safety is improved when project objectives and their priorities are clearly stated (C1b-d, C2), and project conflicts are resolved based on project objectives (E16). Project quality performance (F20) is improved when the project objectives regarding safety (C1d), and to a lesser extent the project quality objectives (C1c), are clearly stated. The analysis also shows that project quality performance decreases when constructability is used to meet project objectives (E14) and being receptive to construction input is used as one of the main criteria in selecting a project designer (D10). The reason for this is unclear.

3 CONCLUSIONS

Project owners in Indonesia do have some understanding of the importance of constructability. However, the traditional approach to project delivery, which is the preferred method by most of them, limits their option for involving construction personnel in the pre-construction phases. The most common methods of integrating construction input were through construction personnel of the project owners or the project designers. There were few significant differences between public sector owners and private sector owners, and among owners who developed different types of project, in their approach to constructability.

Project owners improved their project performance by clearly stating their project objectives, project designers improved project performance by interfacing with construction personnel during preparation of design, and contractors improved project performance by providing the designers with timely construction input. Early contractor involvement reduced constructability problems, which led to an improved project performance.

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PROCUREMENT AND RISK SHARING

Full Paper

AN INVESTIGATION INTO THE LINK BETWEEN HEALTH CARE FACILITY DESIGN AND SERVICE PROVISION

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ABSTRACT

Health facilities represent a significant investment in infrastructure and national wellbeing. Health facilities also represent a unique and complex building type that involves many user groups and consultants, a concentrated use of engineering services, and intense twenty-four hour a day use. In common with other large infrastructure projects, the construction of a major health facility is a relatively infrequent and significant event that generally requires the application of complex briefing strategies and non-traditional procurement methods. This has the potential to decrease the efficiency of the design, documentation and construction process, and increase the unpredictability of project outcomes unless each new project is systematically recorded and that data used to inform future projects. This is not presently the situation.

This paper will describe the preliminary results of an Australian Research Council Linkage-Project conducted in conjunction with Helping Hand Aged Care Inc., Delfin Lend Lease and Spotless Services Limited. The research project used a multiple embedded case study research method to develop a comprehensive picture of the relationship between procurement processes, the post-occupancy provision of health services, and resident quality of life in three aged care facilities. The evidence presented will include a description of the research method and summary of the data collected through documentary analysis, observational studies and self-report surveys from two of the facilities used in the study. As with recent research into office environments (Leaman and Bordass, 2000), the findings indicate a strong link between the design of the physical environment and the capacity of service providers to provide efficient and effective health care. The findings further suggest that both the briefing and documentation phases are critical factors in the development of efficient and responsive physical environments. The research ultimately aims to provide economic benefits through improved worker productivity and a reduction in post occupancy alterations to the physical environment. The authors also intend to extend the research into studies of major hospital facilities.

Keywords: health service quality, building performance and productivity

AN INVESTIGATION INTO THE LINK BETWEEN HEALTH CARE FACILITY DESIGN AND SERVICE PROVISION

1. INTRODUCTION

In 1976, 9 per cent of the Australian population was aged 65 years or older. In 1996 this age group had increased to 12 per cent of the population or 2.2 million people. One in five of these were aged 80 years or older. By 2016, this group will represent 16 per cent of the population, some 3.5 million people. One in four will be 80 years or older (ABS, 1998a). As Australia's population ages, the number and proportion of people in this 80 years and over 'older old' age group will increase. People aged 85 years or more are projected to increase from 1.2 per cent of the population or 224,000 people in 1998, to 2.0 per cent or 440,000 in 2021, and 3.8 per cent of the population or 920,000 people by 2041 (ABS, 1998b). As older persons tend to be high users of health services, it is anticipated that this ageing population will have a significant impact on the Australian health budget over the next fifty years. Although only 12 per cent of the population, people aged 65 years and over currently account for about 35 per cent of expenditure on health (Bishop, 2000). This is per capita approximately four times higher than the rest of the population. They are admitted to hospital more often and they stay longer (AIHW, 1998a). A specific aspect of this expenditure is residential aged care. The Federal Government spent \$2.7 billion in 2000 for 132,000 people in residential aged care facilities (ABS, 1998b). Given the high capital investment and need for more and increasingly flexible residential care facilities, it is vital that design standards are developed that meet the expanding needs of aged Australians.

This paper will describe the preliminary results of an Australian Research Council Linkage-Project conducted in conjunction with Helping Hand Aged Care Inc., Delfin Lend Lease and Spotless Services Limited. The paper will initially outline the research method used to develop an understanding of the relationship between procurement processes, the post-occupancy provision of health services, and resident quality of life in three aged care facilities. The paper will then provide a summary of the data collected through documentary analysis, observational studies and self-report surveys from two of the facilities used in the study. Preliminary findings indicate a strong link between the design of the physical environment and the capacity of service providers to provide efficient and effective health care. The findings further suggest that both the briefing and documentation phases are critical factors in the development of efficient and responsive physical environments. The research ultimately aims to provide economic benefits through improved worker productivity and a reduction in post occupancy alterations to the physical environment.

2. BACKGROUND

Residential care is available for older people who are no longer able to live at home. There are two main types of residential aged care in Australia, nursing home (high) and hostel (low) care. Generally, nursing homes have provided 24 hour nursing care and accommodation services, while hostels have provided accommodation services and assistance with daily tasks such as dressing and bathing. Since October 1997, residential care services have been administered and funded under one system. While some nursing homes and hostels will continue to specialise in high care, low care or dementia, an increasing number of facilities offer the full continuum of care, and allow residents to remain in one place as their care needs increase (Bishop, 2000). The target national high care place rate in 1998 was 40 places per 1,000 persons aged 70 years and over. The projected growth in the 85 years and over group means that more residential care will be needed over the next forty years (AIHW, 1998b).

Design of residential facilities has evolved from the past 'institutional' model to a more 'domestic' approach. Home-like architecture and interior finishes, decentralised layouts

and a flexible regime of care, aim to create an environment that promotes independence in all aspects of a residents' daily life (Russell and Sauran, 1991). Home-like environments provide all the support needed in terms of staff, physical aids and disability access but create a more domestic environment in which people feel familiar and empowered (SRFAC, 1997). This move to home-like environments resulted from a combination of the Federal Government's *Aged Care Act 1997*, which dictated new standards for residential aged care buildings, and the increased frailty of new admissions to residential care. As older people have a mixture of care requirements, a method of housing them in the same building is needed where new facilities catering for low or medium levels of care are designed in anticipation of future higher levels of care. People may keep their room for the rest of their life and receive extended services as their dependency increases (Quayle, 1999). The increasing variation in care provision was recognized with the introduction in 2002 of a separate classification for aged care facilities in the Building Code of Australia (BCA). Aged care facilities were previously classified as either Class 1b – Hostels, or Class 9a - Health Care Buildings (ABCB, 1996), neither of which adequately addressed variations in the level of care actually provided in the majority of facilities. In addition to the provisions of the BCA, an Australian certification program for residential care facilities has been developed to ensure high quality care for the receivers of aged care services. The *Certification Procedures for Residential Care Services* was introduced in 1997 and revised in 1999 (CDHAC, 1999). The procedures focus on the physical quality of residential aged care buildings in addition to service quality. Access to Commonwealth funding is a strong incentive for service providers to achieve certification.

Even though residential care facilities are a considerable economic cost to Australia, and demand for these facilities is expected to increase, evaluation of residential care design and its role in enhancing the quality of living and work environments is scant. That the quality of a living environment can significantly impact on psychological and physical well-being, and the corresponding cost of health care, is not being disputed (Coulson, 1997; Schwarz, 1997) but it is apparent that the issues that define a quality living environment are yet to be adequately established. Research has commenced to understand the microenvironment, including lighting, acoustics, colour, pattern and room size (Calkins, 1988; Harr and Kasayka, 2000; Teresi et al, 2000) but there is little published research on the evaluation of less quantifiable design issues (Coulson, 1997). This includes the capacity of a physical environment to be progressively adapted to changing care needs and the role of physical environments in supporting or inhibiting the provision of quality care. Although some design guidelines exist and form part of the building accreditation framework, further research is required to evaluate the use of these guidelines and to anticipate future developments (Albert and Logsdon, 2000). The situation is compounded by the fact that architects are not generally paid to undertake post-occupancy evaluations of their design work, and many treat post-occupancy evaluation information as commercial in confidence. This seriously reduces the understanding of the effectiveness of design innovation and limits a broader contribution to the design body of knowledge that might provide economic and social benefit to other areas of the health care sector.

3. RESEARCH AIMS

The research project described in this paper is significant because of the considerable and growing capital investment in aged care facilities, and health care facilities in general. The implications of inappropriate design are expensive post-occupancy modifications to newly completed facilities, excessive operational costs, reduced staff productivity and inadequate service provision. The research aims specifically to:

- a) identify and describe the issues that impact on residential care design
- b) develop design strategies that improve the capacity of the physical environment to:
 - progressively adapt to changing resident care needs, and
 - support the efficient and effective provision of quality care, and
- c) inform certification and design standards.

4. RESEARCH STRATEGY

The research project adopted a five stage research strategy shown in Figure 1. The strategy will be applied to the following three case studies, the first two of which have been completed and the preliminary results are described later in this paper:

- Case Study 1 – an 83 bed residential care facility at Mawson Lakes, Adelaide. The project was purpose built and completed in 2003.
- Case Study 2 – a 98 bed residential care facility at Ingle Farm, Adelaide. The project was completed in 1994 and involved the adaptive re-use of former education buildings.
- Case Study 3 – eight independent living units at North Adelaide. The project is currently under construction and due for completion in late 2004.

All facilities are managed by Helping Hand Aged Care Inc. with outsourced linen services currently being provided at Mawson Lakes and Ingle Farm by Spotless Services. Spotless Services have the capacity to provide additional services including catering should further outsourcing be considered appropriate. Mawson Lakes is a major a Delfin Lend Lease community development in Adelaide's northern suburbs. Analysis of the North Adelaide independent living units will help to identify additional issues that impact on the provision of services to people in their own homes. As mentioned above, this phase of the project is yet to be completed.

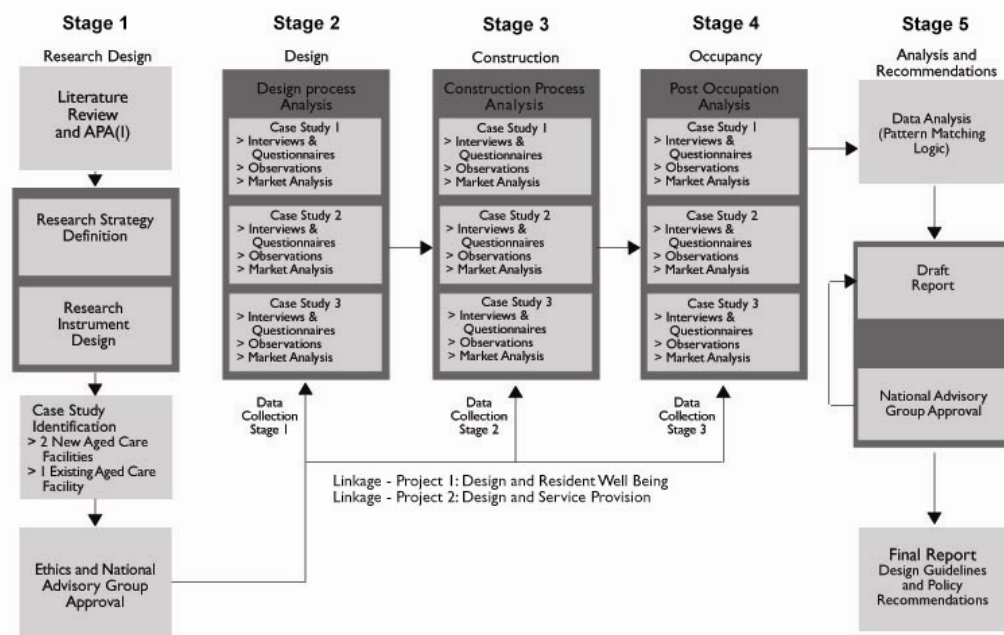


Figure 1: Research Strategy

4.1 RESEARCH FRAMEWORK

4.1.1 Conceptual Framework

Building projects are complex and multi-dimensional in their technical and managerial dimensions. They involve the coordination of a variety of building industry professionals pertinent to a particular building type, statutory authorities that administer legislative requirements, and client bodies, generally expert in their particular field but not necessarily experienced in building procurement. As a response to this complexity, the project uses a descriptive and exploratory approach combining qualitative and quantitative measures in a multiple embedded case study. Case studies are best suited to projects that attempt to investigate inter-related phenomenon in changing real-

life contexts where it is difficult to isolate the phenomena being studied from its context (Yin, 1994). The use of multiple cases enables specification of the population, control over extraneous variation, and definition of finding generalisation limits (Eisenhardt, 1989). Embedding the case study enables consideration of a variety of stakeholder views. The use of multiple sources enables data and significant issues to be triangulated within a broader context (Denzin and Lincoln, 2003; Yin, 1994; Patton, 1990). The project also uses a variety of data collection techniques outlined as follows:

- *Document analysis* – document analysis involves the review and interpretation of written texts within a defined understanding of their immediate context (Denzin and Lincoln, 2003). Two types of documents were analysed, documents regulating the aged care industry such as governmental and agency policy, and statutory legislation, and more specific architectural documents relating to each case study. The architectural documents included meeting agendas and minutes, design briefing letters and documents, design drawings and contractual correspondence. A registered architect undertook the analysis of the architectural documents because of their technical specificity. The document analysis was used to determine the principle factors impacting on the design and construction process, and to establish formal and informal communication structures.
- *Structured observations* – structured observation is where certain activities or physical evidence are selected for observation and recording. This allows a limitation on the activities or physical evidence being observed, and a clear definition of them prior to the start of data collection (Denzin and Lincoln, 2003; Kane, 1985). Direct as against participant observation, involves the researcher as passive observer recording the defined behaviour pattern or physical evidence. Direct observation was used to determine work activity patterns in designated spaces, and physical adaptation and patterns of wear at each case study site. This was used to augment evidence from the document analysis in relation to decision-making during the design, construction and post-occupancy stages. This was also used to augment self-report survey data in relation to design efficiency and effectiveness.
- *Self-report surveys* – interviews and questionnaires are forms of self-report survey used to determine the feelings and opinions of research participants on an identified topic (Stewart and Shamadasani 1990). Semi-structured interviews were used together with a questionnaire that included structured and open-ended questions. With the semi-structured interview, all respondents were asked a series of pre-determined questions. Unlike a structured interview however, the semi-structured interview allowed for some elaboration around each question and concluded with an open-ended question (Denzin and Lincoln, 2003). Interviews were conducted with case study staff and residents, visiting service providers and architects. All interviews were taped, transcribed and studied for recurrent themes leading to summative findings.

The use of a variety of multiple sources of evidence increases the research validity by providing for further detailed triangulation of results (Denzin and Lincoln, 2003; Gillham, 2000; Yin, 1994). Final design guidelines and recommendations are yet to be developed but this will occur within a soft systems framework, an action research methodology that assumes any recommended interventions will take into consideration the multitude of interacting systems surrounding the problematic situation being investigated (Checkland, 1999).

4.1.2 Sampling Framework

Two residential aged care facilities and eight independent living units were considered a representational sampling of the total number of aged care facilities constructed each year in South Australia. The two residential facilities are of similar size and constructional complexity but vary in age (one new and purpose built the other existing and an adaptive re-use). The two residential facilities also vary in location, design parameters and the management structure applied to the procurement process.

4.2 RESEARCH METHOD

4.2.1 Stage 1 – research design

Stage 1 established the academic and management frameworks for the project. This involved an examination of current aged care legislation and design guidelines together with an analysis of recent national and international literature to situate the project within the current research and practice environment. A National Advisory Group was established to provide advice on the research direction and to assist in the dissemination results. Appropriate case studies were also identified as part of this stage and the various research instruments designed.

4.2.2 Stage 2 – evaluation of the design process

Stage 2 of the project initially identified the various parties with a stake in the final outcome of each case study's design process. Stage 2 also considered the impact of the legislative guidelines, government policies and funding parameters identified in Stage 1 on the design process for each case study. The patterns of communication and decision-making developed during the design stage were then assessed and a 'rich picture' of the relationships between stakeholders and other factors constructed (Checkland, 1999). Data collection methods included document analysis and semi-structured interviews with aged care facility managers and architects.

4.2.3 Stage 3 – evaluation of the construction process

Stage 3 of the project used similar document analysis and self-report techniques employed in Stage 2 to analyse and evaluate the construction stage of each case study. The documents analysed included those relating to the contract administration of each case study. For various reasons, the document analysis in both Stage 2 and 3 for the two residential care facilities was limited to those documents held by the client organisation. Semi-structured interviews with facility managers and architects were used to further clarify the roles and structures assumed during the construction stage.

4.2.4 Stage 4 – post-occupancy evaluation

Stage 4 used similar data collection techniques as Stage 2 and 3 to measure outcomes of the design and construction process in terms of the match between the original design brief and the end product. The documents analysed included those relating to facility accreditation and management processes, and to maintenance schedules, building alterations and/or repairs undertaken since occupation of the facility. Two types of structured observation were undertaken. The first involved a physical survey of the building fabric to record any post-occupancy variations to the original design and signs of unusual wear or failure of the building fabric. The second involved a descriptive survey and tracking study of user behaviour patterns to reveal circulation paths and patterns of use (Sanoff, 1994). Both the document analysis and the structured observations were used to determine areas where an unsuccessful match between the design brief and end product had occurred, or where changed care requirements had resulted in a formal physical intervention to amend a perceived problem. Two self-report techniques were also used in this Stage. Interviews were used to establish general user perceptions of the physical environment and questionnaires were used to further clarify and expand on these perceptions (Leaman and Bordass, 2000). The structure of the self-report surveys was determined by analysis of the key observations established in the previous document reviews and observational studies. Only those capable of giving informed consent participated in the surveys. Participation was also voluntary. Semi-structured interviews were conducted with facility residents, staff, visiting service providers, managers and architects. The questionnaire was administered to facility staff and visiting service providers.

Similar Stage 2, 3 and 4 analysis is yet to be conducted on the eight independent living units in North Adelaide.

4.2.5 Stage 5 – analysis and recommendations

Stage 5 draws on the data collected in Stages 1, 2, 3 and 4 to develop design guidelines and recommendations for changes at the policy level to support improved productivity and quality of life in residential aged care facilities. On completion of the eight independent living units in North Adelaide, the data will be analysed using pattern-matching logic which relies on the initial development in this case of rival theoretical propositions about the link between policy and design outcomes. Each rival explanation will involve the definition a pattern of predicted independent variables with the independent variables that make up each rival explanation being mutually exclusive (Yin 1994). The draft guidelines will:

- a) establish critical design parameters impacting on the efficiency and effectiveness of residential aged care facilities, and
- b) provide a basis for the management of the briefing process between users, design consultants, statutory authorities and contractors during the design and construction phases.

A program of workshops with design consultants and aged care professions will be used to test the guidelines and develop recommendations for changes at the policy level. The recommendations will be presented at a forum of key industry stakeholders and following consensus, a set of key recommendations and design guidelines for the provision of residential aged care facilities will be developed. The recommendations will feed into future health and aged care policy development and the procurement of design and construction services for aged care facilities.

5. RESULTS

5.1 DOCUMENT ANALYSIS

A review of the client held documents relating to the design and construction of the Ingle Farm and the Mawson Lakes residential care facilities was undertaken during April and May 2004. Documents for the older Ingle Farm facility were considered to be too incomplete for any meaningful analysis. Documents for the Mawson Lakes facility were also incomplete but they presented a more substantial picture of the relationship between the client (Helping Hand Aged Care Inc.) and the architect. They more specifically provided an indication of the areas of the facility that required the most development and amendment throughout the design and construction process. A total of ninety-four documents were recorded as relating to elements that had the potential to promote or inhibit physical flexibility and/or service provision. The documents were dated from 14 June 2001 to 21 May 2003 and included general correspondence, minutes of design and site meetings, and building contract related correspondence including requests for information, instructions and notices. Content analysis revealed that the dominant design elements were *access*, the *kitchen* and *laundry*. The occurrence of each document type is summarised in Table 1.

Table 1: Number and Location of Design Element References

Design Element	Document Type				Total
	General Correspondence	Design Minutes	Site Minutes	Contract Notices	
Access	3	14	2	2	21
Kitchen	2	12	1	2	17
Laundry	2	5	1	0	8

5.2 STRUCTURED OBSERVATIONS

Observational studies of the kitchens at Ingle Farm and Mawson Lakes were conducted on 17 March 2004 and 15 April 2004 respectively. Both studies were undertaken during the peak activity period between 8.45am and 1.45pm when work flow patterns for each individual working in the space was recorded at fifteen minute intervals. Delivery access was considered to be poor at Ingle Farm in particular in terms of security and direct access. Food is prepared in the kitchen at Ingle Farm and plated up in remote serveries while at Mawson Lakes, food is prepared and plated up in the main kitchen. In terms of layout, cooking equipment is arranged against a wall at Ingle Farm. Like the wall benches, equipment is not mounted off the wall and therefore difficult to clean behind. Cleaning under benches is also difficult. Floor mounted kettle drum boilers are deemed to large and rarely used. Bench space is perceived to be adequate but island benches and additional utensil racks were added after the initial fit out. The kitchen was generally clean and well maintained but mobile trolleys cluttered the area during food service and post-lunch dishwashing and cleaning. The Ingle Farm kitchen layout and an example work flow pattern are shown in Figure 2.

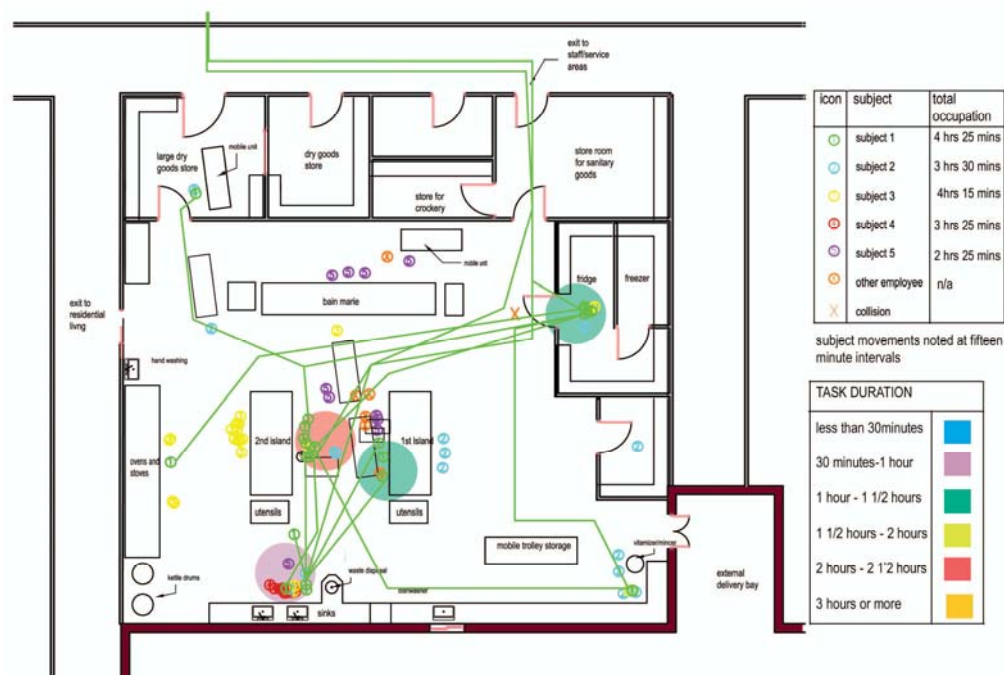


Figure 2: Ingle Farm Kitchen Layout and Example Work Flow Pattern

At Mawson Lakes, cooking equipment is arranged against a central fire wall. As with Ingle Farm, cleaning behind the equipment and benches is difficult. Difficulty was observed for most staff when preparing food because of a lack of bench space. Of the number of sinks provided only 3 were used regularly during the observation duration. The kitchen was generally clean and well maintained but again becoming cluttered with serving trolleys during food service. The Mawson Lakes kitchen layout and an example work flow pattern are shown in Figure 3.

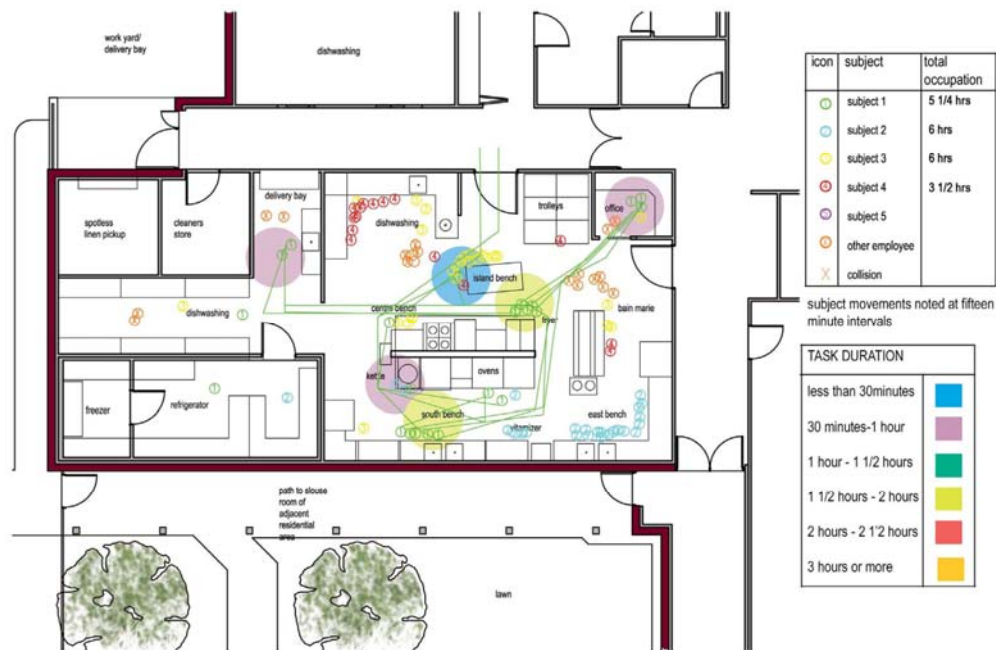


Figure 3: Mawson Lakes Kitchen Layout and Example Work Flow Pattern

5.3 SELF-REPORT SURVEYS

Two types of self-report survey were conducted between November 2003 and May 2004. The first involved thirty-nine semi-structured interviews conducted with nine residents, sixteen staff, five managers and seven visiting service providers at the two residential aged care facility case studies. Two architects involved in residential aged care facility design were also interviewed. Content analysis of the factors that each respondent thought were important in residential aged care facility design revealed a number of key concepts. The dominant themes that emerged were the overlapping concepts of *functionality*, *flexibility* and *consultation*.

Functionality was defined as fitness for purpose in relation to those design elements that have the potential to promote or prohibit physical flexibility and/or service provision. Functionality as it affected service provision was considered more important than general aspects of design such as interior finishes. Design flexibility was a recurrent theme often linked to functionality. This combination was particularly evident for residents and managers who were looking to personalise space and to maximise the capacity for ageing in place respectively. Consultation was the third major concept. A lack of consultation was linked to perceived problems associated with design functionality. This concept was associated primarily with nursing and logistics staff who felt they had expertise that was not utilised. Managers, who had been more involved in the consultation process, considered that a formal post-occupancy evaluation would be a useful management tool. The architect respondents also commented that clients tended to assume that their architect was familiar with the requirements of the building type and that there were standard design responses to the building type. The key concepts are summarised in Table 2.

Table 2: Interview Summary

Interview Group	No.	Key Concepts
Residents	9	<i>Functionality</i> – more concerned about service provision than facility design <i>Design flexibility</i> – desire to personalise space and to have sufficient space for personal possessions <i>Socialising flexibility</i> – option to socialise or not
Staff (Nursing)	9	<i>Functionality</i> – design for efficient work flow patterns and sufficient space for larger pieces of equipment <i>Security</i> – sufficient security especially after hours <i>Privacy</i> – needed for administration duties and breaks
Staff (Logistics)	7	<i>Functionality</i> – design for efficient maintenance and work flow patterns <i>Consultation</i> – sufficient consultation during design stage <i>Storage</i> – sufficient space for maintenance equipment
Management	5	<i>Finance</i> – expensive to build and operate <i>Design flexibility</i> – accreditation and ageing in place <i>Consultation</i> – post-occupancy evaluation needed
Visiting Service Providers	7	<i>Functionality</i> – building legibility/navigability, sufficient space, equipment and parking
Architects	2	<i>Consultation</i> – client assumes the architect is familiar with the building type <i>Quality/cost</i> – limited by the project budget

The second self-report survey involved a questionnaire administered to eight respondents working in the kitchens at Ingle Farm and Mawson Lakes. There were four male and four female respondents with ages varying from under twenty to under fifty. Seven respondents spent between 21 and 40 hours per week in the kitchen. One worked less than ten hour per week in the kitchen. Respondents were asked to rate the quality of environmental factors (light, sound, temperature, air flow and humidity) and practicality of use against a five point Likert scale. An open-ended question calling for any additional comments was also included. There were no significant trends evident in the responses and none of the participants responded to the open-ended question. The results of the environmental questionnaire are summarised in Table 3.

Table 3: Questionnaire Summary

Location	No.	Environmental Factor	Results				
			very poor 1	2	3	4	very good 5
Ingle Farm	5	natural light			2	1	2
		artificial light		2	1	2	
		noise level			2	1	2
		temperature		1	2	2	
		fresh air flow			3	1	1
		humidity			1	4	
		practicality		1	1	1	2
Mawson Lakes	3	natural light	2		1		
		artificial light			1	1	1
		noise level			3		
		temperature		1		1	1
		fresh air flow		1		2	
		humidity		1	2		
		practicality				1	2

6. DISCUSSION

The preliminary results presented in this paper indicate a number of useful themes for future aged care and broader health facility design. Firstly, access, the kitchen and the laundry appear to be design elements that dominate the design stage of the procurement process. The research indicates that these are critical to the capacity of the final built product to support efficient and effective service provision. Secondly, specific aspects of building functionality and flexibility such as storage, spatial personalisation and design for work flow efficiency, are perceived to be important design elements by residents and staff. Finally, consultation is considered to be essential to the development of a facility that supports the efficient and effective provision of aged care services. The initial communication between client and architect, and architect and staff as the design brief is developed, would appear to be a critical aspect of the consultation process. The Mawson Lakes document analysis revealed that the majority of communication related to three dominant design elements – access, the kitchen and the laundry. Of further significance is that the majority of the client-architect communication occurred during the design stage. This would indicate the importance of defining design issues early to avoid later costly contract amendments. Client and architect experience with the design process and building type would also appear to be an important factor in achieving this early resolution of potential design problems though the research would also indicated that further consultation with staff might enhance this. The client and architect for the Mawson Lakes facility had previously worked together. The architect also had previous experience with the building type. A further factor that is that a post-occupancy evaluation carried out on one site only, might not immediately uncover design inefficiencies. Nothing in the self-report surveys indicated significant differences between the two sites. Only through comparisons of the evidence gathered through the observational studies were design deficiencies detected at Ingle Farm for example. It would appear that a formalised approach to the conduct of post-occupancy evaluations which can then be shared across facilities and fed back into the briefing process is critical to improving the capacity of residential aged care facilities to support service delivery.

The project has limitations in that it is based on a relatively small sample making it difficult at this point to draw consistent generalisations that might be applied to other new facilities. Differences were apparent in the efficiency of the kitchen and allied health areas. Staff at Mawson Lakes for example spent less time undertaking critical activities in the kitchen such as dishwashing. The clarity of the work zones and walkways at Mawson Lakes also improved the efficiency of staff measured in terms of specific task duration. Deeper exploration of decision-making structures is necessary however to more fully understand the results of the design development process. The project is also limited by the breadth and depth of data gathered. The document analysis for example was limited to those documents held by the client organisation. Documents held by both the client and the architect should be reviewed in future to provide a better understanding of communication processes and the project history. Of particular interest is the impact that client and architect experience has on design briefing. Detailed study of areas such as dining rooms, reception spaces and laundries were also not undertaken as part of this project.

7. CONCLUSION

The increasing number of older people in the Australian population will lead to greater demand for residential aged care. Trends also indicate that this demand will increasingly be for flexible facilities that enable ageing in place. This research project represents an initial exploration of those design factors that have the potential to promote or inhibit physical flexibility and/or service provision in residential aged care facilities. This paper has presented a description of the research method, and a summary of the data collected through documentary analysis, observational studies and self-report surveys from two residential aged care facilities. The preliminary findings affirm recent research into office environments (Leaman and Bordass, 2000), that indicate a strong link between the design of the physical environment and the capacity of service providers to provide efficient and effective health care. The research has identified a number of elements as potential problem areas in terms of design complexity and end user satisfaction. The findings further suggest that the briefing phase in particular is critical in the development of efficient and responsive physical environments. By identifying these design issues, this research aims to provide economic benefits through improved worker productivity and a reduction in post-occupancy alterations to residential aged care facilities. The authors also intend to extend the research into studies of major hospital facilities.

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INTERNATIONAL INNOVATION

Full Paper

A BUILDING SUSTAINABILITY ASSESSMENT FRAMEWORK

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ABSTRACT

This paper describes a sustainable building framework developed to facilitate:

- Definition of service needs, goals and outcomes at project initiation;
- Design integration to avoid overlaps/confusion over the project life cycle;
- Detail of the supply chain for procurement, considering life cycle impacts;
- Delivery of accreditation for construction handover and in-use operations;
- Design-for-deconstruction credits for future recovery/re-use at disposition.

The intent of the theoretical framework is to support decision-making through better definition, communication and assessment of sustainable solutions over the building life cycle. It evolved from efforts to characterise stakeholder needs of building environmental assessment (BEA) tools that were found to focus on physical metrics and lack:

- Support for stakeholder decision making;
- Integration of whole of life considerations from early investment planning;
- Consideration of policy development and pre/post-occupancy assessment
- Functionality measures for operational service delivery.

This framework is depicted as five modules in series, with provision for vertical and horizontal integration on an Information and Communications Technology (ICT) platform. The ICT provides for interactive linkage of characteristic application typologies at process points considering temporal and physical development life cycles. To illustrate potential deliverables, examples are shown where the framework was applied to prototype BEA technology, for which it was initially developed.

Keywords: Building Sustainability Assessment Framework

1. INTRODUCTION

This paper describes a building sustainability assessment (BSA) framework developed alongside a prototype building environmental assessment (BEA) tool founded on a 3D object-oriented CAD information and communication technology (ICT) platform. The framework evolved from efforts to characterise and resolve issues in meeting stakeholder needs for BSA applications. After introducing the context, prototype, scope and methodology the paper:

- Critiques basic tool theory and life cycle thinking;
- Reviews characterisations of user needs for such applications;
- Discusses early findings and introduces the framework's key modules; and
- Predict BEA tools leverage off object-oriented CAD ICT platforms.

1.1. BUILDING SUSTAINABILITY ASSESSMENT

In the context of ecologically sustainable development (ESD) and building design, Sarja (2002) argues that buildings are long lasting products of our society that need sound ecological management. Indeed, it is commonly accepted that building greenhouse emissions (GGE) as shown in Figure 1 need such management. Jones et al (2003) reported the building sector GGE share in 1999 was 22% of the total with residential and commercial operations dominant.

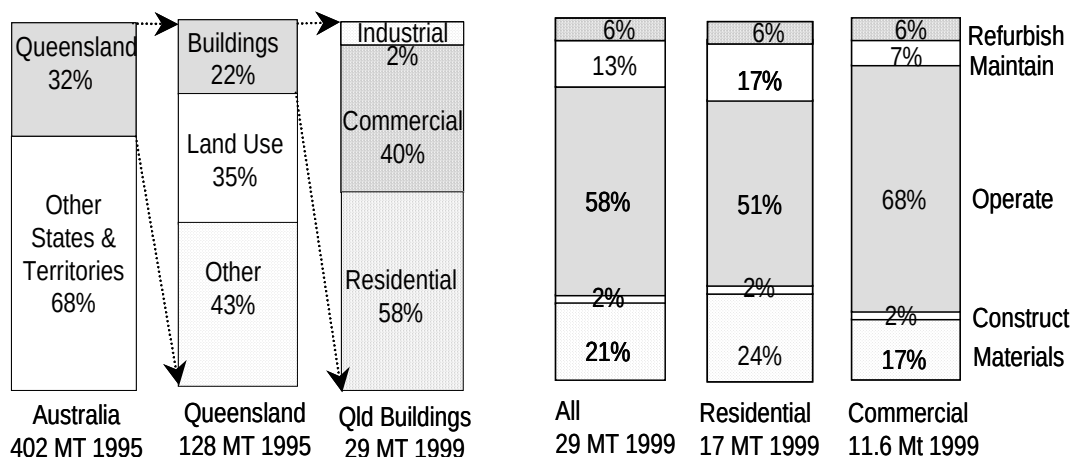


Figure 1. (a) Building National Share GGE and (b) QLD Building Phase Share GGE

More sustainable building to reduce such environmental as well as social and economic impacts involves coordinating stakeholder needs across an array of criteria. Sarja (2002) argues that such design criteria include:

- Social aspects of welfare, health, safety and comfort;
- Functional and economic aspects of use incorporating flexibility;
- Technical aspects of serviceability, durability, reliability; and
- Ecological aspects of resource depletion and pollution abatement.

To consider a building (for ESD in parenthesis) users apply such tools as:

- Classing systems for (sustainable), premium and typical accommodation;
- Rating systems to compare (sustainable), best and typical operations;
- (Environmental) condition assessment in procurement and tenancy;
- Acquisition systems to support policy direction in a corporate portfolio; and
- Benchmarks and labels of (sustainable), best and typical operations.

Cole et al (2000) and Tucker et al (2003) stress that addressing sustainability issues requires professionals to work through increasingly complex problems while instigating new systems to overcome difficulties in gathering, analysing and verifying knowledge. Watson (2004) and Seo (2002) reveal increasing demand for detailed design performance appraisal, a uniform level of broad information, and tools that use new environmental, social and economic costing methods.

1.2. A PROTOTYPE BEA TOOL CALLED LCADesign

In response, the CRC for Construction Innovation funded development of a software tool, with the aim that it should become the preferred environmental appraisal tool for Australian commercial buildings. This software tool is called LCADesign, an acronym for life cycle assessment (LCA) with computer-aided design (CAD). It provides environmental and economic cost assessment of commercial building design across planning and checking applications. LCADesign is automated to obtain data directly from 3D CAD object-oriented models from a comprehensive information and communications (ICT) platform. The software calculates and reports design impacts via the Express Data Manager that links information from CAD models to life cycle inventory and environmental impact indicators databases.

1.3. AN ICT PLATFORM FOR A NEW THEORETICAL FRAMEWORK

A critical aspect is the ICT platform from which LCA Design leverages its function. The concept of integrating disparate programs, in a hub, to share information effectively is not new. However, creating a hub and facilitating its use for various outputs would be much more difficult without such a platform. Barton et al's (2002) argues that BSA requires consideration of impacts throughout the building life cycle. So to consistently facilitate decision-making LCADesign had to feed both forward and back between phases of definition, design, detailing, delivery and deconstruction.

Apart from the ICT platform, a theoretical framework was needed to provide reference points for and inform connections to databases, data managers and CAD models. Such a framework, called LCADevelop, emerged as an integrated set of modules as depicted in Figure 2.

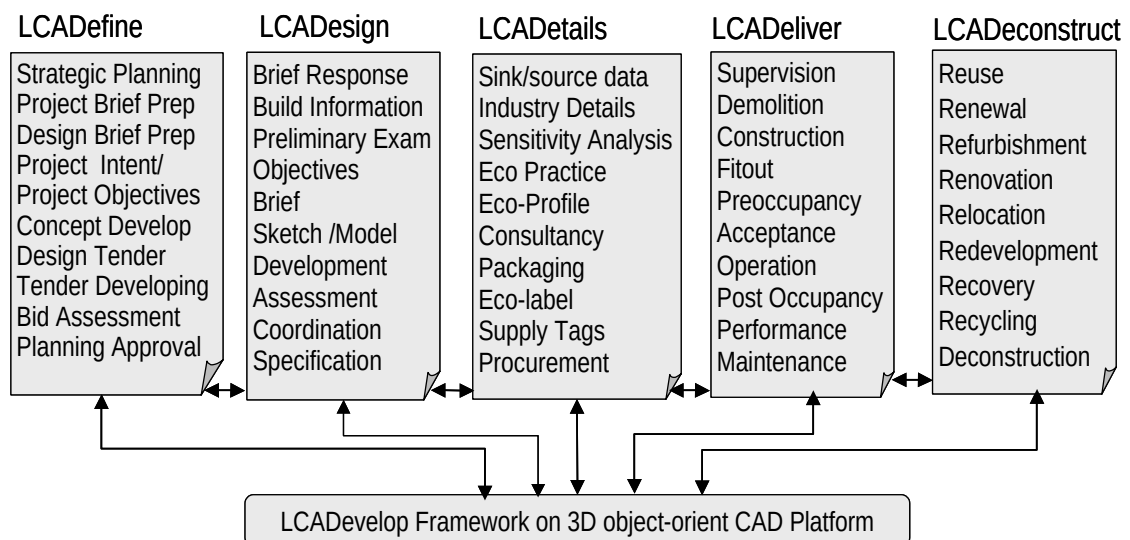


Figure 2. LCADevelop Framework for BSA Tools

2. SCOPE AND METHOD

The framework's theoretical foundation evolved from interrelated work including:

- Reviews of theory related to BEA and BSA tool development to date;
- Reviews of leading international and national tools;
- Consultation with stakeholder groups; and
- Assimilation of background knowledge with that acquired in this process.

Tools listed in Table 1 were evaluated to gain an understanding of:

- Their attributes, functionality and stakeholder coverage;
- Professional users and their need for various applications; and
- Features and functionality needed to meet such user needs.

Table 1 Building Environmental and Sustainability Assessment Tools Studied

Source	Building Environmental Assessment Tools and Reference to Developer
Europe	Ecoprofile NBI (2002), BEAT DBUR (2002), GreenCalc NIBE (2002), Life Cycle Simulation Tool (EQUER) EMCEP (2002), ECO-QUANTUM IVAM (2002)
USA	Leadership in Energy & Environmental Design (LEED), USNAGBC (2002) Building for Environmental & Economic Sustainability (BEES) NIST (2002)
Canada	Green Building Tool (GBTool) NRC (2002), Green Globes CEE&EEC (2004), ATHENA Environmental Impact Estimator TASMI (2002)
Britain	BRE Environmental Assessment Method (BREEAM) BRE (2002a), BRE Material Environmental Profiles BRE (2002b), Environmental Estimator (ENVEST 1) BRE (2002c), ENVEST 2 BRE (2003)
Japan	Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) JSBC (2002)
Australia	Green Star AGBC (2004), Evergen CSIRO (2002a), AccuRate CSIRO (2002b); National Building Environment Rating Scheme (NABERS) Environment Australia (2002); LCA In Sustainable Architecture (LISA) BlueScope Steel (2002).
NSW	Australian National Building Greenhouse Rating scheme (NBGR) by SEDA (2002), Building Sustainability Index (BASIX) DIPNR (2002), LCAid DPW&S (2002), Environmental Performance Guide For Building (EPGB) DPW&S (2002)
Victoria	EcoSpecifier RMIT & Eco-Recycle Victoria (2004), House Energy Rating First-Rate SEAV (2002)
QLD	Guideline for Ecologically Sustainable Office Fitout (GESOF) Qld Govt. (2002), Ecologically Sustainable Asset Management (ESSAM) Barton et al (2002)

Studies that characterised tool applications and their capacity to meet user needs across asset, design, project, and building lifecycles were reviewed considering:

- Findings of Seo (2002), RMIT et al (2002) and Watson et al (2003);
- User applications over the full life cycle from cradle to cradle;
- Evaluation of deliverables by temporal and physical life cycles;
- Stakeholder applications against potential tool deliverables;
- Gaps between user needs and tool attributes/applications; and,
- Prospective plug-in tools needed for their work to fill such gaps;

Characterisations were then considered from previous and new studies including:

- Architectural design process reviews by Watson (2004);
- Building product supply chain and industry studies by Mitchell (2004); and
- ENVEST2, GESOF, ESSAM, Greenstar and NABERS tools.

3. BASIC THEORY AND CHARACTERISATION

Watson (2004) defines tools as things that make a job easier or more efficient and argues that BEA tools should:

1. Act as a bridge between assessment and user tasks to be undertaken;
2. Connect different professions, ideologies and essential paradigms;
3. Provide direction and facilitate clear communication; and,
4. Structure and streamline information.

Direction and communications, for example, is facilitated as tools clarify definitions, aims, objectives, policy, strategies and tactics and provide material for presentation and outcome reporting.

Watson classes BEA tools mainly as checklists, manuals, eco-labels, blueprints, scoring systems, computer based guidance, building component lists, LCA and eco preference lists. While such tools should be comprehensive and flexible, Cole (2000) warns they must be practical and cost effective. And furthermore they must use accepted criteria and apply transparently consistent methodology.

Barton et al (2002), Jones et al (2004), Lovins (2004) and Todd et al (2001) all stress that it is critical to identify successful intervention points in the process before applying effort to integrate key environmental strategies. This is because whole of life strategies apply at each point in time and pre-existing as well as subsequent operations need assessing, for example in design for cleaner production, adaptive re-use, and disassembly.

Watson (2004) argues the key to ensure BEA tool adoption is their facilitation of:

- Interaction with stakeholders throughout the project delivery process;
- Adoption of high level principals untypical in computer based guides;
- Structuring as tool suites around environmental theory to meet all criteria;
- Packaging of tool types to suit particular occupancy scenarios;
- Criteria restructuring to accommodate design support;
- Best practice building design as well as building operations;
- Support for decision-making and communicating of outcomes and
- Assessment provided in a life cycle framework with benchmark impacts.

3.1. REDEFINING LIFE CYCLE THINKING

Barton et al (2002) and Lovins (2004) assert that compared to the linear norm, life cycle thinking applied in decision-making drives more objective strategic planning to better economic and environmental outcomes. Sarja (2002), Watson (2002 and 2004), Mitchell (2004), Jones et al (2003) and Watson et al (2004) all stress that a holistic life cycle structure is required for built environment decision-making.

The RMIT (2002) study found the term building lifecycle loosely covers the planning and design development process from cradle-to-grave. Rather than management of asset, facility, design, construction and in use processes it is asserted that BEA tools have drawn on life cycle theory developed around a primary industry sector picture of mines, factories, consumer goods and transportation. It is to be expected then with life cycle terminology poorly defined that key BEA elements would remain undifferentiated and associations obscured.

The BSA framework was founded on Steve Watson's (2004) life cycle theory that defines life cycle phases as being temporal or physical in nature. He differentiates the building's physical life cycle from actions over a temporal life cycle in design processes and asset planning that go to build it. His physical life cycle relates to material flows in forming objects and his temporal life cycle to sequencing of decisions as shown, for example in Figure 2. With physical and

temporal processes each essential for ESD, the framework, depicted in figure 2 was structured around temporal building life cycle processes considering the physical operations in material acquisition from and disposal back to the earth.

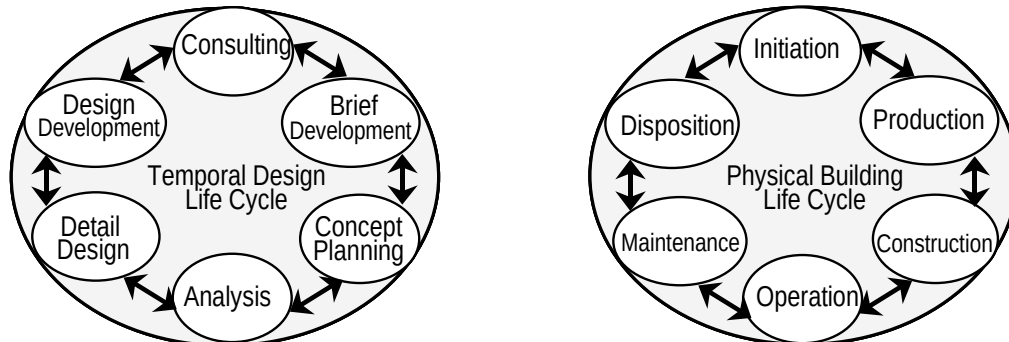


Figure 2 Concept Diagrams of (a) Temporal Design and (b) Physical Building Life Cycles

4. RESULTS AND DISCUSSION

In current sustainability practice a fundamental user requirement is for clear communication to be derived from a common national platform. This requires adoption of a common language between disparate professions with fundamentally different application needs. Seo (2002) found existing tools and frameworks were focused on physical metrics and most lacked:

- Comprehensive support for stakeholder decision making;
- Integration of whole-of-life considerations from investment planning;
- Consideration of policy development or pre/post occupancy assessment;
- Functionality measures for operational service delivery; and
- Flexible outputs for the broad range of potential users.

Watson (2004) found tools did not cover critical applications to address, such as:

- Stakeholder needs and relationships in the built environment;
- Different contexts in relation to the building industry; and,
- Local environmental, and standard social and economic criteria.

As shown in Table 2, a reconfigured set of results from Seo (2002) and Folient et al (2004), some tools focus on one or two phases rather than most which by itself is not an issue if they reflect stakeholder policy, position, scope and timeframe. Without a common language, however, the use of separate tools to achieve life cycle coverage was found to add confusion to already complex tasks.

Table 2 BEA Tool Life Cycle Coverage

BEA Tool	Plan	Design	Use	Dispose
CASBEE, GBTool, BREEAM, Green Star				
Evergen, EPGB, BRE Profiles, BASIX, LCAid				
LEED, Ecoprofile, BEAT, Greencalc, EQUER, Envest, LISA				
ATHENA and Green Globes, AccuRate				
BEES, Eco-Quantum, EcoSpecifier				
NABERS, NBGR, Firstrate				

Watson's (2004) argument that BEA tools must act to bridge service delivery needs, professional applications, management systems, design and construction processes as well as occupant psychology was supported by overall results. Few

tools applied to brief development or concept planning and the focus of most was design. Potential to provide applications for managers, owners, purchasers, operators and occupants was considerable with features required for:

- Alignment with ESD principals and policy
- Enhanced user assessment of product impacts over the full life cycle and
- Comparisons against best building practice performance benchmarks.

Watson (2004) showed BEA tools providing design professionals the means to:

- Appraise design performance against sustainability criteria;
- Document/ template briefs, specifications, contracts and evaluation; and,
- Interact across framework, guideline and checklist applications.

4.1. REDEFINING APPLICATIONS BY LIFE CYCLE

To make informed decisions BEA stakeholders need to assess upstream and downstream operations but as Watson (2004) and others point out, understanding of the building lifecycle varies significantly. Stakeholders require tools with appropriate applications in the early as well as later project phases as in the variety shown in Table 3 where, for example, investment tools may be used to benchmark and communicate policy, whereas in construction scheduling and certification tools are common.

Table 3 Professional Tools by Application and Phase

Stakeholder	Profession	Communication	Documentation	Phase
Investor	Broker, Client	Feasibility Study	Policy, Benchmark	Investment
Owner	Corporate, Family	Policy and Class	Classing System	Acquisition
Developer	Urban, Builder	Bid, Estimate	Development Apps.	Development
Manager	Facility, Portfolio	Strategy, Standard	TQM System	In-use
Planner	Portfolio, Asset	Guide, Benchmark	Guide, Benchmark	Planning
Purchaser	Labeling, Costing	Brief/Tender	Bid Assessments	Procurement
Provider	Logistics, Marketing	Market Analysis	Campaigns	Initiation
Designer	Architect/Interior	Design, Model	Blueprints/Plans	Design
Consultant	Engineer, Research	Data, Efficiency	Reports	Operations
Surveyor	Quantity	Specification	Bills of Quantities	Procurement
Supplier	Plant Control	Label, Profile	Label, MDS	Procurement
Manager	Project, Site	Schedule,	Project Plans	Construction
Builder	Commercial	Plan, Certification	Construction Plan	Delivery
Operator	Facility & Building	Manual	Manuals	Occupancy
Occupant	Tenant, Owner,	Tenancy Checklist	Checklists	Commission

As Barton et al (2002) conclude, unless they embody ESD requirements then as most commonly occurs tools will exclude ESD by their application. This is critical from the earliest phase in which BEA tools need to provide investment policy, benchmarks and rating applications. This is because timing is critical with prior allocation to master plan, infrastructure, orientation and budget limiting later opportunities. As Lovins (2004), Watson (2004) and Jones et al 2003 all stress, by the time designs have developed it is already far too late to integrate most sustainability initiatives that Watson argues must be viewed:

- Professionally from a lifecycle perspective to understand the true situation;
- Holistically in context considering occupants and never in isolation; and,
- As cyclic concepts that need early consideration and budget allocation.

Table 2 showed that 16% of the BEA tools, Seo and Folient et al reviewed, covered four phases, 48% did three, 24% applied to two and 12% to one only.

None had investment applications or aimed for BSA. A further review of Seo's work revealed most tools ignored extant buildings in-use, fitout, refurbishing and disposal. He found limitations including restricted scope, shallow focus, time-consuming application and inattention to economic or social criteria as well as specificity to country of origin that limits their relevance to Australian conditions.

Some contrast was found in review of newer tools where the ENVEST2, GESOF, ESSAM, Green Star tools covered four phases. The exception was NABERS that fills a void for extant buildings where renewal is critical for ESD, because as Jones et al (2003) report State governments may spend up to 10 times more on existing than new building stock annually. Apart from LCADesign, no newer tools directly assessed economic costs. However the NABERS, GESOF and ESSAM tools considered social or community impacts of, for example, biodiversity and equity. Also BRE (2002a,b, c) Watson et al (2004) show Envest 2 is a component of a large tool kit with some economic and social applications. Newer tools had increased coverage of assessment by phase, economic and community aspects.

So while the worldwide interest in research and development has produced many BEA tools and although Australia may have lagged behind in development, it has not yet inherited the deficiencies in narrow coverage. The newer Australian government and industry-developed tools may also better suit stakeholder applications than earlier ones. Other tool attributes critical for future development of LCADesign were identified, for example, as summarised Table 4.

Table 4 Some Desirable Attributes of BEA Tools

Aspect	Attribute Requirement	Potential Solutions
Coverage	Address whole life building cost issues	Maintenance linked to component life
	Cradle to cradle operational energy	Integrated look up table as in NBGR
	Comprehensive Interior occupancy	Plug-ins for indoor environment
LCA Database	Industry broad acceptance	Industry liaison & information dissemination
	Manufacturer product assessment	Licensed access industry web portal
	Select products in real-time program	Industry web portal used for material impact
Weighting	Use 'ecopoints'/ratings to define impacts	Building industry product eco-labels
Framework	Design performance simulation ability	4D CAD model with plug-ins for data analysis
	Concept design modeling	Link to parametric building design exemplars
	Hierarchical building element structure	Link concept to detail design model
Software	Generic shape/building type choice	Link to parametric building design
	Uses best practice defaults	Industry web portal for logging benchmarks
	Hierarchical building element structure	Advantageous 3D CAD Building and Product

4.2. THE FRAMEWORK

The earliest intent in developing the BSA framework for many types of tools was to facilitate improved definition, guidance, communication and decision-making support throughout the building life cycle. It was developed from reviewing theory, tools and stakeholder opinion and was grounded on the authors' experience and knowledge assimilated in this research to:

- Encompass both temporal and building life cycles;
- Establish a platform for the networking and the exchange of information;
- Facilitate integration of applications of both overview/detail;
- Support asset, design, construction and management professionals and,
- Identify application/format of information useful at key process points.

The emergent framework, then, was founded philosophically on consideration of built shell, interior and engineering systems theoretically as ecological systems. This was essential to facilitate consideration of the numerous up-and-down stream implications over lengthy building life spans and at all technology levels.

Early on, the framework revealed key points where a broad range of stakeholders' economic, social and environmental cost/benefit assessment needs had to be addressed. It has been asserted that in the short and long term, a comprehensive BSA framework, as depicted in Figure 1, requires provision of:

- Enhanced definition of objectives, tender and bid evaluation;
- Performance Assessment over and of the supply chain;
- Development of national tools to assess impacts of construction products;
- Applications for delivery processes from design to end of life; and,
- End-of-life recovery and reuse of material elements.

Recently, the theoretical BSA framework was used to define proposed interactive tool prototypes (automated from a 3D CAD) considering:

- Communication and alignment with ESD principals, policy and planning;
- Technical and linguistic coordination with other BEA tools;
- Comparative assessment against best building performance benchmarks;
- Documentation/templates for briefs specification, contract and evaluation;
- Interactivity with supporting frameworks, guidelines and checklists and
- Plug in tools to meet user needs for in-use assessment on ESD criteria

As a conceptual guide/map to the process of creating sustainable building the framework indicated practical tools needed to stage their cover to apply to:

- Define service needs, goals and outcomes at project initiation;
- Design with outcomes integrated over the project temporal life cycle;
- Detail the supply chain with information on whole of life cycle issues;
- Deliver high quality construction as well as management in-use; and,
- Deconstruct considering recovery credits as apposed to waste.

4.3. MODULES OF THE FRAMEWORK

The authors developed this framework in modules, required for a practical toolbox. This demanded further integration of plug-ins and supplements in the right sequence and level of detail to avoid issues with the current ad hoc, linguistically confusing, separate tools.

The first BSA module called LCADefine as depicted in Table 5 has components to define investment planning targets and setting of project objectives as they occur in project initiation. This is to facilitate up-front acquisition of key information in a project to better inform the planning process.

Table 5 A selection from the LCADefine Module of the BSA Framework

Applications	Requirements	Solutions/Plug-Ins
Asset Planning	Asset Performance Appraisal Vs ESD Criteria	ESSAM supplements
Brief Development	Compare with best practice benchmarks	Rated benchmarks
Design Brief/Bid	Incorporating economic & environmental costing	LCADesign capacity
Tender/ Concept	Documentation/templates for early planning	ESSAM supplements
Bid Assessment	BSA over building development process life cycle	ESSAM supplements

In addition, as shown in Table 6, design tools need to ensure technical and linguistic coordination with other BEA tools and linkage to parametric models.

Table 6 A selection from the LCADesign Module of the BSA Framework

Applications	Requirements	Solutions/Plug-Ins
Design Brief Response	Audit/Assess current codes/standards/contracts	Codes, IAQ, Access
Building Information	Compare all levels design analysis Plug-in tools	Orient, space, light
Preliminary Exam	Design against Sustainability Criteria/Exemplars	Concept, NABERS
Design Intent	BSA through building design process plug-in	Process supplement
Sketch Design	Technical/Linguistic coordination with all tools	Greenstar

As depicted in Table 7, the third element is a procurement module for selecting lower impact products. Called LCADetails, it contains material profiles, supply-chain knowledge and guidance that is currently under-informed compared to other countries with advanced procurement systems, albeit less so in ICT terms.

Table 7 A selection from the LCADetails Module of the BSA Framework

Applications	Requirements	Solutions/Plug-Ins
Procurement	Eco specification & Marketing	EcoProfile & labeling
Sink/source data	On state of domestics sources/sinks	Link to Resources
Supply Chain Detail	Industry Details of best /typical/poor practice	Eco-profiles/practice
Eco Practice Notes	Sensitivity Analysis for improvement opportunity	Service Consultants
Eco Profiles/Labels	Reports of industry sector/product performance	Standardised reports

As shown in Table 8, an LCADeliver module contains applications for project decision-making to ensure that as assessed and specified is delivered.

Table 8 A selection from the LCADeliver Module of the BSA Framework

Applications	Requirements	Solutions/Plug-Ins
Acceptance	Template Project Applications Brief, DA	Eco practice notes
Construction Delivery	Eco specification & Supply affirmation tags	Product eco-labeling
Accommodation Fitout	Project management support applications	LCADesign link GESOF
Pre/Post Occupancy	Project Guides, Benchmarks & Templates	Occupancy checklists,
Maintenance	Whole LCA links with Component Life	ESSAM supplements

Finally, the LCADeconstruct module contains applications to facilitate crediting design for disassembly and industry recovery initiatives for reuse and recycling.

Table 9 A selection from the LCADeconstruct Module of the BSA Framework

Applications	Requirements	Solutions/Plug-Ins
Design Disassembly	Credit recovery and re-use potential	Code LCI to credit reuse
Refurbishment, Reuse	Refurbishment recovery eco practice notes	Rate, guide & checklist
Redevelop, Renewal	Disassembly eco practice notes	Rate, guide & checklist

5. PERSUASIVE TECHNOLOGY

To date, the LCADevelop framework has been employed to identify gaps in tool coverage and as a theoretical foundation for new modules of BSA tool development. The authors have presented this summary of their work for wider audience review in the expectation that it may be equally useful to other practitioners. It may enable practitioners identify gaps pertaining to their own work and facilitate their efforts to compensate with novel applications.

The effects and potential of such novel 3D CAD ICT platforms, new BEA tools such as LCADesign, coupled with BSA frameworks such as LCADevelop need to be reassessed and refined particularly in the light of persuasive technology theory. The authors believe that the developments they have described may well

be better exemplified by the work of others and that together such works can have a more persuasive effect. They share the hope common to sustainability practitioners that aligned developments may link at points, unforeseen by themselves, to evolve together into what is termed influential technology.

6. CONCLUSION

This paper has summarised work undertaken to improve BEA tool structure and attributes providing appropriate features for:

- Communication in planning and strategic decision-making towards ESD.
- Documentation and interactivity with frameworks, guidelines and checklists

The goal was to depict a theoretical BSA framework for integrated tool development so that together they may all that much sooner become adopted as persuasive and enacted as influential technology. The paper described how the framework evolved was given as a basis for a future toolbox inclusive of:

- High quality, whole of life tools for BSA professionals;
- True building environmental, social and economic cost assessment;
- Better capacity to source appropriate goals and benchmarks;
- Increased design support via integration of stakeholder applications; and
- Improved decision-making support to facilitate sustainable building effort;

The authors have depicted a future set of LCAD integrated tools to assess social, functional, economic, technical and ecological aspects of sustainable building.

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INTERNATIONAL INNOVATION

Full Paper

A REGIONAL MODEL FOR INNOVATION AND CULTURAL CHANGE IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

The Northwest Development Agency (NWDA) provides programmes and funding to ensure the sustainable economic development and regeneration of England's Northwest. As such it is a major client of the construction industry both directly, through its estates department (annual spend £320 million), and indirectly as a grant funder with an influence on funding of £1.2 billion. The Centre for Construction Innovation (CCI) is an enterprise centre of the University of Salford, UK. It is also the regional Constructing Excellence centre for the NW of England. As such it is part of a regional and national network of construction and training experts and has recently been awarded a two-year commission from the Northwest Development Agency (NWDA) to deliver a package of training on Rethinking Construction and Better Public Buildings. The project emphasises the NWDA's intention as a client to take the lead in the region in improving the quality and efficiency of the construction industry and shows its commitment to provide better quality buildings and value for money as promoted by the government reports Rethinking Construction and Better Public Buildings. The work involves extensive training and awareness raising, active facilitation of partnering on NWDA strategic sites, auditing of agency projects and assisting in up-dating the approved suppliers' selection criteria.

This paper will show how CCI and the NWDA are determined to use the programme of training to change the way that the industry operates in the region. In order to affect such a cultural change requires involvement and input from staff at all levels from within the NWDA and their strategic partners. To ensure long term change it is vital that the lessons learned becomes the everyday processes of the agency and that a culture of continuous improvement is created. The framework used for this training should be of value to large clients seeking to create a culture of change within their supply-chain.

Keywords: **Innovation; Cultural Change; Construction;**

1. INTRODUCTION

1.1 BACKGROUND

The Centre for Construction Innovation (CCI) is an enterprise centre of the University of Salford, UK. It is also the regional Constructing Excellence centre for the NW of England promoting the strategic objectives of Constructing Excellence. As such CCI is an independent point of reference and advice for organisations and provides assistance in areas such as team integration and partnering; benchmarking, business improvement; and procurement. The Centre brings together a broad range of industry participants in a range of best practice education and training seminars, workshops and in-company events, facilitating change by learning, debate and experience. CCI is a not-for-profit whose goal is to provide the knowledge and tools to create an industry that fosters innovation.

The Northwest Development Agency (NWDA) is a Regional Development Agency (RDA) a Government-sponsored public body set up by the UK Government in 1998. It was established as one of 9 RDAs, to help improve quality of life and economic prosperity across English regions. The NWDA provides programmes and funding to ensure the sustainable economic development and regeneration of England's Northwest. As such it is a major client of the construction industry both directly, through its estates department, and indirectly as a grant funder with an influence on an annual spend of £1.2 billion.

Constructing Excellence was formed in October 2003 by bringing together two unique organisations within the UK construction industry – Rethinking Construction (formed as a result of Egan Report and the Construction Best Practice Programme (Constructing Excellence, 2003). It is funded by the Department of Trade and Industry. It has four main programmes of activity:

- Innovation – identifying and promoting tomorrow's best practice;
- Productivity – improving the competitiveness of the UK construction industry;
- Best Practice Knowledge – creating continuous improvement through the exchange of best practice, and
- Engagement – working with people, business and organisations to change the culture of the industry.

The training programme for the NWDA is therefore a partnership between the above three organisation. As a public body the NWDA recognises that it needs to adopt the principles of Rethinking Construction, the Egan Report and the Better Public Buildings white paper. On a national scale Constructing Excellence has as its main role, on behalf of the UK government, the promotion of this agenda. On a regional level CCI brings together a team to leading experts from the HE sector and from industry to facilitate the adoption of these principles within the NWDA. The principles of Rethinking Construction and Better Public Buildings are detailed below.

1.2 RETHINKING CONSTRUCTION PRINCIPLES

The Rethinking Construction initiative was launched following the report of the Construction Task Force chaired by Sir John Egan in 1998. The 'Rethinking Construction' report identified seven targets for improvement in construction productivity, profits, defect and accident reduction. They include 10% reductions in capital cost and construction time annually, 20% reduction in defects and accidents,

10% increase in productivity and profitability and 10% increase in predictability of project performance (DTI, 1998). This improvement to be achieved by the adoption of drivers for change, specifically: committed leadership, a focus on the customer, integrating process and team, a quality driven agenda, and commitment to people. The Local Government Task Force was established in March 2000 to encourage and assist local authorities to adopt the principles of Rethinking Construction.

As a result of a consultation exercise ('The National Debate: Rethinking the Construction Clients') held in October and November 2001 Rethinking Construction has produced six key guidelines for public sector clients wishing to embrace the principles of Rethinking Construction. These are:

- Traditional processes of selection should be radically changed because they do not lead to best value.
- An integrated team, which includes the client, should be formed before design and maintained throughout delivery.
- Contracts should lead to mutual benefit for all parties and be based on a target and whole life cost approach.
- Suppliers should be selected in adherence to principles of "Best Value" and not by lowest price: this can be achieved within EC and central government procurement guidelines.
- Performance measurement should be used to underpin continuous improvement within a collaborative working process.
- Culture and processes should be changed so that collaborative rather than confrontational working is achieved.

The principles of Rethinking Construction call for clients to work as members of integrated teams with a culture of performance measurement to underpin continuous improvement within a collaborative working process. More than 100 local authorities and other agencies have Rethinking Construction Demonstration Projects, which illustrate the practical application of these guidelines.

1.3 BETTER PUBLIC BUILDINGS

The Better Public Buildings white paper was published in October 2000 and calls for a change in the quality of building design in the public sector. It provides a checklist of do's and don'ts for local authorities to develop a new approach to design quality of any building type. In August 2001 the initiative was confirmed to continue and is charged by the Commission for Architecture and the Built Environment (CABE). THE UK Prime Minister commented "I am committed to encouraging a new age of good design in our public buildings, so that we match the best of that which we have inherited from previous generations" (Better Public Buildings, September 2001).

There are seven principles of urban good design that are stated in the joint DTLR/CABE publication *By Design* (DTLR/CABE, 2000):

- **Character:** to promote character in townscape and landscape by responding to and reinforcing locally distinctive patterns of development, landscape and culture.
- **Continuity and enclosure:** to promote the continuity of street frontages and the enclosure of space by development, which clearly defines private and public areas.

- **Quality of the public realm:** to promote public spaces and routes that are attractive, safe, uncluttered and work effectively for all in society, including disabled and elderly people.
- **Ease of movement:** to promote accessibility and local permeability by making places that connect with each other and are easy to move through, putting people before traffic and integrating land uses and transport.
- **Legibility:** to promote legibility through development that provides recognisable routes, intersections and landmarks that help people find their way around.
- **Adaptability:** to promote adaptability through development that can respond to changing social, technological and economic conditions.
- **Diversity:** to promote diversity and choice through a mix of compatible developments and uses that work together to create viable places that respond to local needs.

Better Public Buildings is trying to eliminate the widely held belief that good design is a costly luxury. Good design can offer many benefits. According to (CABE survey, 2002), three quarters of people believe that the look and feel of well-designed streets helps reduce crime rates. 70% of English people believe well-designed schools improve children's education. As Sir John Egan's report 'Rethinking Construction' demonstrated, best practice in integrated design and construction delivers, better value for money as well as better buildings particular when attention is paid to the full cost of building over its whole lifetime.

2. NWDA TRAINING PROGRAMME

The purpose of the NWDA training programme is therefore to help it to change its working practices and in doing so derive the benefits of the Rethinking Construction targets whilst producing better quality buildings. The NWDA recognises that it can not achieve change on its own but must work with its partners to achieve this. In order to ensure that the programme is taken forward fully, the agency recognises that a cultural change must not only take place within the Agency and its staff, but also with strategic partners, institutions, professional bodies, developers, landlords and contractors.

2.1 PROGRAMME OUTLINE

The NWDA training programme is far more than a series of training workshops. The programme as a whole consists of the following stages that are intended to effect a cultural change within the agency and it's external partners.

- a) The appointment of a board level project champion to ensure that a clear message is given that the agency is fully committed to change. The formation of an Implementation Team to meet monthly to monitor and ensure progress is made.
- b) Internal and External project launch events to achieve 'buy in' of agency staff and partner organisations
- c) Specific training workshops. Twelve, one day training workshops for agency and partner organisation staff. Each workshop to be delivered three times
- d) Update of NWDA project manuals. Each workshop leader to produce guidance notes for inclusion in the NWDA's project manuals. This ensures

- that the lessons from the workshops become embedded in standard NWDA procedures.
- e) Ongoing external awareness events to communicate with the regional industry the changes in practice that the NWDA are committed to as a result of the programme.
 - f) Auditing. As the training programme unfolds CCI will perform an auditing function on NWDA projects to ensure practices are being successfully adopted
 - g) Assistance on two Strategic Sites. CCI to ensure that two NWDA schemes are fully supported and taken from the initial stage to a fully contracted and partnered development which embraces, in so far as possible, all the areas which take into consideration rethinking construction. These sites to provide a demonstration of good practice within the agency.
 - h) Panel partnering. Assistance for the NWDA in the refreshing and selection of its various supply chains.

Taken as a whole it can be seen that the programme is an ambitious attempt to fully embrace change and to significantly alter the working practices of a major funder and influencer of construction activity. In making this change the agency is consciously putting in place a process to drive change and innovation throughout its partner organisations.

2.2 PROJECT TEAM

A key element in the training and facilitation programme is the way that as a regional centre for a Constructing Excellence, CCI has been able to draw upon a wide range of leading industry and academic experts. The organisation itself is lean but by drawing on its networks it brings together a much larger team. In addition to its own staff CCI have drawn upon experts from Constructing Excellence nationally, regional universities (UMIST/Manchester and Salford), independent consultants and industry experts. This is a strength of an organisation such as CCI that is perceived as a neutral support organisation and could be difficult to replicate by a commercial organisation.

2.3 MODULE DESIGN

The NWDA determined the areas for change based around the Rethinking Construction 5-4-7 model for continuous improvement. Using this as the basis for activity, the required training modules were designed to achieve the goal of putting the client at the centre of a Constructing Excellence Network. Each of the modules is designed to impact one or more of the areas within the Quality Model and address the Constructing Excellence agenda for the NWDA and their supply chain.

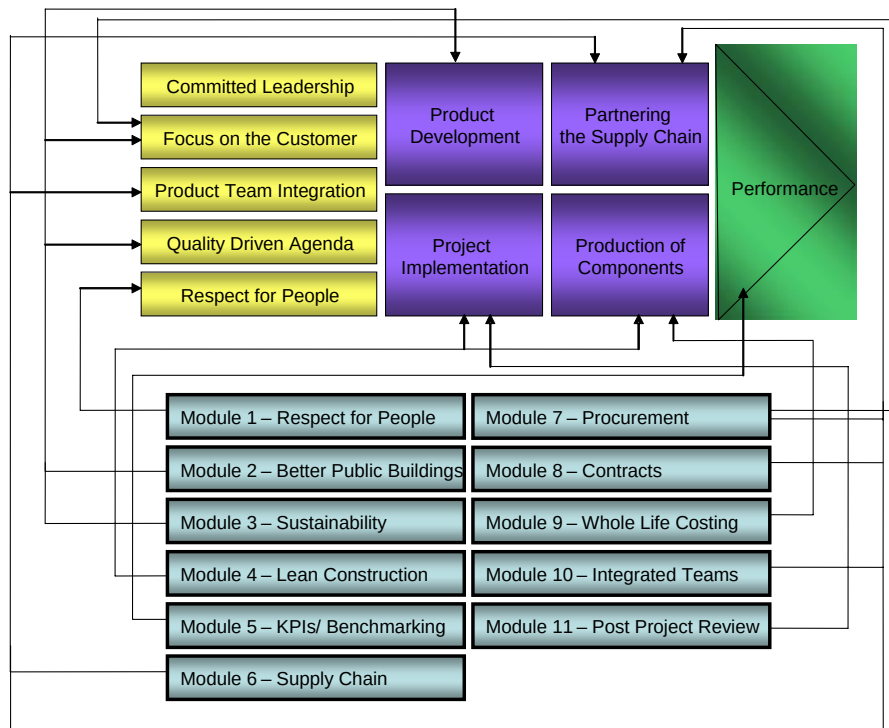


Figure 2.1.1 Mapping of NWDA Training Modules with Constructing Excellence Agenda

2.4 MODULE DELIVERY

Each training event is held over one day with the day is divided into two sections:

Awareness Session – the awareness session is designed to give those individuals who need a broad understanding of the subject matter, but may not be engaged in the day-to-day implementation of the issues. It covers the main principles of the issues, policy drivers and some practical examples of the issues within a real life context.

Workshop Session – the workshop session is designed to give a more hands-on approach to the subject matter. These interactive sessions allow delegates to gain experience in the tools and techniques of the specific subject area.

A list of the workshops and an outline of their content is given below.

Table 2.1.1. Rationale for Each Training Module

Module	Rationale
Respect for People	Respect for People drives the ability of firms to retain and develop staff as well as attract the best new employees into the sector.
Better Public Buildings	Effective projects deliver value to the wider community, and this is driven through an effective and inclusive design process.
Sustainability	Projects must take into consideration issues of

	sustainable construction and communities.
Lean Construction	Project should be delivered as effectively and efficiently as possible, looking to eliminate wasteful processes.
Key Performance Indicators	Performance measurement is vital to drive continuous improvement in construction.
Supply Chain Management	The NWDA is looking for an industry that has sustainable and integrated supply chains.
Procurement	Procurement serves as a driver for many of the issues that Constructing Excellence is promoting. Effective procurement drives good projects.
Contractual Arrangements	New procurement approaches will need new contractual mechanisms to support them.
Whole Life Costing	When considering projects we must understand that the capital cost of a building only represents a fraction of its actual cost. WLC allows us to look at projects through their life cycle.
Integrated Teams	Construction requires teams to be rapidly assembled. We need to understand the drivers for team building within the special context of construction.
Post Project Review	Any effort to drive continuous improvement will review learning to be gathered from previous projects to be applied to future projects.

A training needs analysis was undertaken for the NWDA staff by their Human Resources department. This identified staff internally for specified training. After this an awareness raising event was held to inform all relevant staff, about 150 in total, the change goals of the NWDA and communicate the content of the training in short 10 minute presentations for each of the modules. It was identified that internal staff should account for approximately 30% of the total places at the workshops. To cover the demand for the training and to ensure that both internal staff and partner organisations can participate each workshop is delivered three times. The audience is composed of a large number of disparate stakeholders. This reflects the wide number of organisations that the NWDA deal with through both direct development (NWDA lead projects) and grant aided projects (externally lead projects). In addition, these projects will be split on functional lines based around roles on projects.

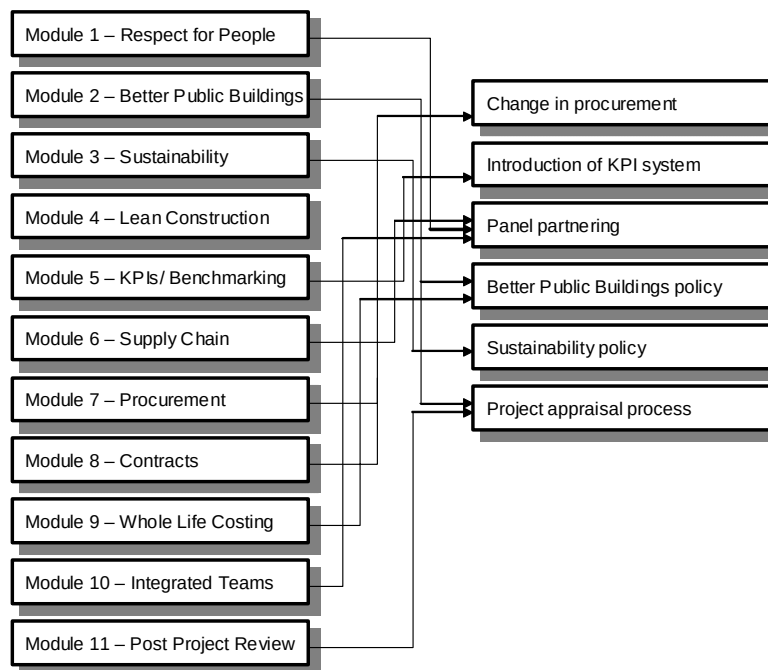
Table 2 – Organisations/ Functional Boundaries

Organisations	Functions
NWDA	Project Managers
North West Local Authorities	Designers
Special Development Organisations	Cost Consultants/ Managers
Contractors	Grant Appraisers
Consultants	Grant Holders
Supply Chain Members	
Other Organisations	

A feedback process has been put in place to allow the delivery teams to assess if any changes are required to the modules. Generally, this model leads to minor changes in the programme to take account of the variable experiences within the audience.

3. IMPLEMENTING CHANGE

The NWDA is not seeking a training programme as such, rather it is seeking the adoption of new practices that increase productivity and produce better quality buildings. A change management approach was therefore adopted from the outset. This started with the championing of the project at the highest levels of the agency to provide the drive to ensure that changes are implemented. As already stated, Initial awareness raising sessions were held with agency staff to ensure that they were all aware of the aims and benefits of the programme. The participation of the Chief Executive of the Agency in this awareness raising was key to establishing the credibility of the programme amongst staff. A project Implementation Team meets monthly to discuss the programme and to ensure that its lessons are being adopted in everyday practice. Within the NWDA the training has so far led changes in procurement practices as well as associated changes to process this has impacted. Each of the modules was designed to be tied to an internal activity to change the NWDA to a Constructing Excellence organisation. Module deliverers are also tasked with producing internal guidance to be included in the NWDA's project manuals. The diagram below shows how the training modules are designed to directly lead to change in NWDA activity.



It is also important to realise that the training modules as such are only one part of the overall change programme for the NWDA. As these lessons are adopted the programme also includes active facilitation for the adoption of these principles on two of the NWDA's flagship strategic sites, auditing of agency projects and assisting in up-dating the approved suppliers' selection criteria. These are key activities that go far beyond the normal approach of training delivery with no follow on support. It requires CCI staff to work in partnership with the agency and to fully understand the day to day working of the agency. The anticipation is that initially the support required from CCI on these projects would be high but as the training takes root the support required will reduce.

3.1 OUTCOMES AND FEEDBACK

The programme of training began in November 2003 with the Respect for People module. This suffered from low attendance both internally and externally meaning targets were not met by some 50%. 'No shows' were common at these events and so measures were introduced to ensure that both internal and external partners attended after having booked. For the next module, Better Public Buildings in January 2004, 70% of the targets were hit, while Sustainability in February 2004 met expectations. By the end of the third module over 250 people had received some form of training.. A policy of overbooking was adopted based on the numbers of individuals who cancelled or did not attend the event, despite previously booking.

Initially, a pre and post-assessment model was used in order to assess the modules. However, it was felt that the level of training and its associated complexities, did not lend itself well to a simple assessment model. To this end, more reliance was placed on the level of interactivity of the workshop and the use of feedback from the participants. As with all Continuous Professional Development (CPD) events, attendance was determined as sufficient to merit an award. The level of attendance for both the awareness sessions and the workshop sessions was closely monitored and fed back into the training database. This data was used as the basis for the issue of CPD certificates.

4. CONCLUSIONS

It is still early days in the training programme, which at the time of writing is 30% complete, with 4 of the 11 modules delivered. The wider implications of the project have yet to be felt, but the high level of the commitment from the NWDA has demonstrated their intention to change.

At the process level, procurement routes are already changing as is the performance measurement regime. These changes are closely tied into the delivery of the modules. The impact that this has on the wider construction community in the NW is that increasingly procurement is being done on the basis of quality not cost. This is a radical change for the industry in the region. Currently, the performance measurement regime is being developed alongside the KPI and Benchmarking Module for delivery. This will be the next major change in agency practice.

The programme is, in some respects to be viewed as a two-way process. Often, in the discussion and consideration of issues within the mixed NWDA and external partner groupings, it becomes apparent that there is a gap of understanding between the two groups. This creates an opportunity for dialogue around the issues. This process has informed the further development of both Better Public Buildings and Sustainability policies.

At this early stage the measurement of the impact of the project has yet to be fully undertaken. The implementation of a performance measurement regime against Constructing Excellence Key Performance Indicators will give an excellent picture of the impact of the training. It is envisaged that the KPIs will allow teams to discuss the impact of the training directly on their own projects, while giving the NWDA a broad picture of the portfolio of activity that they are currently engaged with. These performance measures will look at project management issues, such as time and

cost as well as more complex issues of sustainability, design and community involvement.

There is evidence that the training is meeting not just the requirements of the NWDA, but also the wider client base. The programme has been an excellent opportunity for NWDA staff to engage with their partners in a non-project environment. This has helped them assess the gap between reality and perception in terms of their partners understanding of expectations, especially in the workshop context. A large number of attendees are from client organisations such as local authorities, who have a wider remit to bring their construction projects under the Constructing Excellence Agenda and are initiating a change process in their organisation as a result of the training programme.

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VISUALISATION AND INFORMATION

Full Paper

VALUE ADDING IN 3D CAD MODELS FOR ENVIRONMENTAL ASSESSMENT OF BUILDINGS

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ABSTRACT

Environmental assessment of buildings at an early stage of design development rather than after the design has been established is an essential requirement for achieving a building with the lowest impact. One of the sources of design information is the CAD drawings or models, particularly 3D CAD models, which contain much of the dimensional information and some properties of products to be used in construction of a building. Combining such information with databases of the environmental properties of materials and performance evaluation of alternative designs can provide measures of expected performance to satisfy clients' demand for decision-making information as early, and as efficiently, as possible.

The reported experiences of what clients (users) want from a computer application are reviewed and considered in relation to the ability to acquire a great amount of detail from 3D CAD models which has to be presented in the simplest of ways for the user to quickly grasp the implications of a proposed design. Practical aspects are discussed using examples drawn from recent experiences in creating LCADesign, a system which integrates the assessment of the eco-efficiency of commercial buildings into the design process.

Keywords: 3D CAD, life cycle assessment, commercial buildings

1. INTRODUCTION

Typically environmental impacts of buildings are long-term impacts with building design lifetimes of many decades and therefore minimising impact at the design stage is essential. A tool to automatically generate assessment of environmental impacts from 3D CAD models requires fully integrated procedures capable of delivering:

- repeatable evidence based calculations from absolute values of individual building components aggregated upwards from individual components,
- users selections of a variety of performance measures, and
- comparative ratings of buildings and components based on evaluation of detailed environmental impacts for identifiable trade-offs.

Successful implementation of a tool capable of performing the above tasks involves not only the development of computer software and related databases but paying considerable attention to the needs of the potential users. The technological advances made in producing a unique and versatile tool potentially form a paradigm shift in assessing the environmental impacts of buildings but only if the implementation addresses the problems faced by those who currently assess the environmental impacts of building and their materials.

This paper outlines the limitations of existing tools and summarises user needs and comments about utilising a new approach to assessing the environmental impact of buildings.

2. LIMITATIONS OF EXISTING TOOLS

Tools such as LEED of US Green Building Council in 2000 (US Green Building Council, 2002), BREEAM and ENVEST of the UK Building Research Establishment in the 1990s (Baldwin et al, 1998 and Building Research Establishment, 2003), and GBTool of National Resource Canada in 1995 (Cole and Larsson, 1999) have been adopted widely to assess various measures of environmental impact of buildings. Recently, similar rating tools such as NABERS (Vale et al, 2001) and GreenStar (Green Building Council of Australia, 2003) have been launched in Australia. These tools can be used to assess environmental impacts over a buildings' life cycle, from materials used to a whole of life cycle approach. Furthermore, each of the individual assessment tools and rating schemes address different aspects of a building's environmental impacts. Their coverage also varies from building components to whole of building construction as illustrated in Figure 1, as an example, for some of the Australian tools and rating schemes (see environmental design guide by Foliente et al. (2004) for more tools comparison world-widely used).

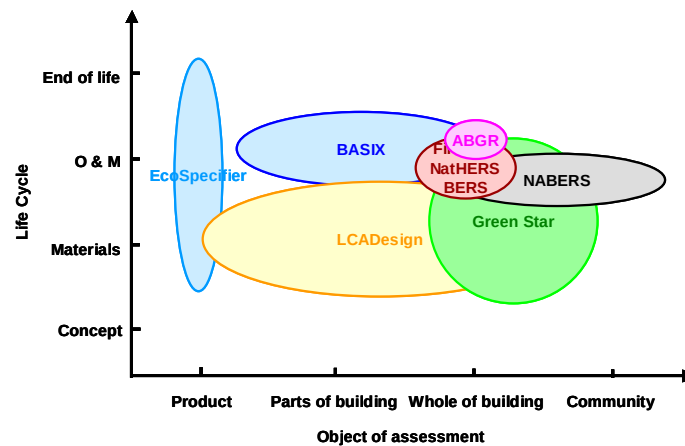


Figure 1 Classification of Australian tools and rating schemes for environmental assessment of buildings and related components

Most of the tools have limitations and weaknesses and in a recent review of such tools many common problem areas have been identified (Seo, 2002). They included having a narrow focus, lacking in-depth assessment, needing professional assessors, requiring time-consuming data input, considering minimal economic criteria and lacking transparency in weighting environmental indicators (Todd et al, 2001). No one model available in Australia completely satisfied all criteria considered in the study or is ever likely to cover all aspects.

The approaches vary greatly. For example, the limitations of the GBTool include it being a framework which is more time consuming than others as it requires users to use other tools to simulate energy performance, estimate embodied energy and emissions, thermal comfort and air quality, etc. It is used to assess pre-occupancy performance as well as occupied building performance. Cole and Larsson (1997) pointed out limitations of the LEED and BREEAM models include the difficulties in simplifying as they are not structured to handle different levels of assessment. Also they were not explicitly designed to handle regional-specific issues, i.e. national or regional variations.

Although some models included criteria such as commuting transport (GBTool, GreenStar and NABERS), almost all tools concentrated on assessment of a building. The exceptions were BEES and Eco-quantum which focused on building products. Seo (2002) suggested that it was important to extend models such as GBTool and LEED to cover community level assessments, as in GreenStar and NABERS, where broad coverage was a goal.

While all real-world design/assessment decisions consider economic aspects alongside other objective criteria, only BEES and LCAid address economic topics. Most models emphasise environmental loadings such as global warming, indoor air quality, energy consumption and resource depletion. As expected of rating tools, the checklists in these models are fixed so they cannot be modified by regional differences or users' concerns.

Most models give all criteria inherently predetermined weightings partly because of the difficulty in assignment as in LEED or a transparent fixed weight that avoids assigning relative importance because of regional differences as in BREEAM and Ecoprofile. On the other hand, both GBTool and BEES employ flexible weighting methods so users can give due weight to criteria considering regional sensitivities or conditions (which may cause controversial problems as well).

All tools reviewed provided for environmental assessment over the building life cycle to some degree to assist users to become more familiar with such concepts. However the tools could be improved by addressing the following general shortcomings:

- Lack of clarity in what the tool can be used for (e.g. buildings, community, products, energy, eco-indicator, greenhouse gas emissions etc),
- Inability to assess comparisons of alternatives directly to inform choices,
- Need for especially educated assessor even for preliminary assessments,
- Time-consuming effort to obtain and input data,
- Lack of simple parameter settings to apply to Australia as a whole or regions,
- Non-availability of essential economic aspects, and
- Not showing weightings that can mislead for some applications.

3. AUTOMATED ENVIRONMENTAL ASSESSMENT

An automated environmental assessment system for commercial buildings has been developed to integrate a CAD-based tool with associated material-performance databases into an assessment system called *LCADesign* in an attempt to provide a system which is simple to operate despite its very detailed calculations. This unique combination of 3D CAD model, use of IFC export files and rules for estimating the quantities of materials in ill-defined 3D CAD objects, building material quantity estimation, drawing on a life cycle inventory of resource usage and environmental emissions for environmental indicators provides a facility to analyse in real time the environmental impacts of alternative commercial building designs. The system has been created with input from potential users who have a growing need for quick appraisal of the environmental design performance of constructed assets.

The key to being able to assess a proposed design is the modern 3D, object-oriented CAD files which contain a wealth of building information which is not commonly utilised to any great extent. *LCADesign* is a fully integrated approach to automatic eco-efficiency assessment of commercial buildings from the completion of the 3D CAD drawing of a building to viewing of the environmental impacts resulting from the construction of the building. *LCADesign* accesses the 3D CAD detail through Industry Foundation Classes (IFCs) (Wix and Liebich, 1997) - the international standard file format for defining architectural and constructional CAD graphic data as 3D real-world objects - to permit construction professionals to interrogate these intelligent drawing objects for analysis of the performance of a design.

The automated take-off provides quantities of all building components whose specific materials, where necessary, are identified to calculate a complete list of the quantities of all materials such as concrete, steel, timber, plastic etc. This information is combined with the life cycle inventory database to estimate key internationally recognised environmental indicators such as Eco-indicator 99 and a range of additional readily understandable indicators such as greenhouse gas emissions, embodied energy and water and carbon (for considering the impact of any future carbon tax).

The building model database is populated from the CAD model via IFC files. An EXPRESS Data Manager (EDM) (Express Data Manager, 2002) system that was chosen to store and manage the specific building (or project) data provided facilities to import the IFC schema and IFC formatted data. The Australian Cost Management Manual (ACMM) (Australian Institute of Quantity Surveyors, 2001) was used to provide a building element classification - a descriptive hierarchical nomenclature

that was familiar to many potential users of *LCADesign*. It also enabled a “drill down” capability by location to any single element assigned as a 3D CAD object in the model building.

The environmental data for all required building products was created in a Boustead (Boustead Consulting, 2002) Life Cycle Inventory model of resource use and emissions mainly per kilogram of building product. This Life Cycle Inventory database was refined to reflect Australian industry practice to related domestic and imported products and logistics, raw materials consumption and emissions generation and consequently to associated environmental impacts. Environmental results calculated in the Australian Life Cycle Inventory Model database to an international standard (ISO, 1998) are used to estimate impacts according to environmental indicator methodology of Eco-indicator 99.

4. ANALYSIS OF ENVIRONMENTAL IMPACTS

There are essentially two stages of an assessment:

- Creation of a 3D CAD model and tagging of each object, and
- Analysis of the environmental impacts of the model and variations.

The tagging is done by the 3D CAD modeller and is straight forward as many of the tags are the same (e.g windows, walls, doors etc) and are added simultaneously. In one building there were about 1500 3D CAD drawing objects which for initial analysis only required about 25 different tags to clearly define all the objects at material level. A typical view of a building model of a small commercial office building as drawn in ArchiCAD is shown in Figure 2.

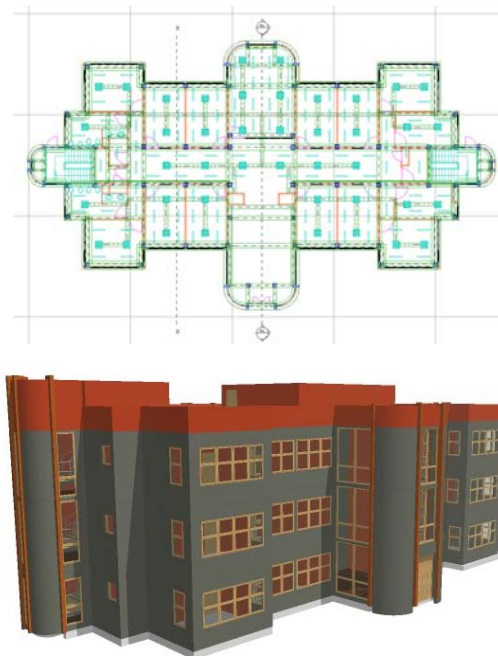


Figure 2 Views of the example building in ArchiCAD

With guidance from a Life Cycle Inventory expert the modeller could perform initial analyses, particularly if targets are given for a particular indicator or architecturally different models are required for comparing alternatives. *LCADesign* is most

effectively used as a tool for the environmental analyst to consider the impact of alternatives from a basic design or significantly different designs.

LCADesign provides the environmental assessors with the capability to test variations (alternatives) on all the objects drawn in the 3D CAD model and investigate, in as much detail as required, the specific impacts or indicators of these variations. This is a role for an environmental expert who does not need any 3D CAD experience.

The most significant value-adding capability of an automatic assessment procedure is the ability to consider a wide range of alternatives while a design is being formulated rather than post-design as is almost always the case. There is a gap between macro level design intentions and the practical delivery of micro level specifications at a builder level. This is where *LCADesign* is designed to excel in that it can continually provide environmental indicators at both extremes of the design from whole building and life cycle views to individual components to compare the selected choices with other alternatives.

Typical output analysis charts are shown in is shown in Figure 3 and Figure 4. The first shows a radar chart for five measures: greenhouse gas emissions, carbon dioxide emissions, embodied energy, embodied water and cost for one alternative compared to another – the outer symmetrical pentagon is the original performance (at 100% of the benchmark) and the inner pentagon the improved measures resulting from an alternative. Similarly, in Figure 4, one alternative is compared with a benchmark building for four measures with the contributions from the major components of building being identified.

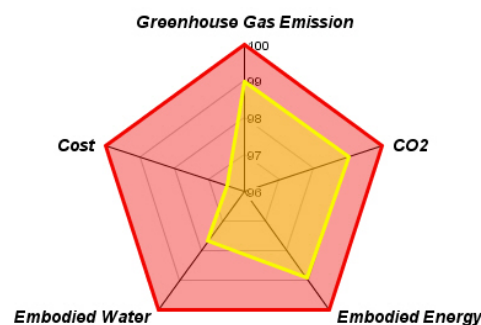


Figure 3 Chart of comparative environmental assessment of one design option against a base option

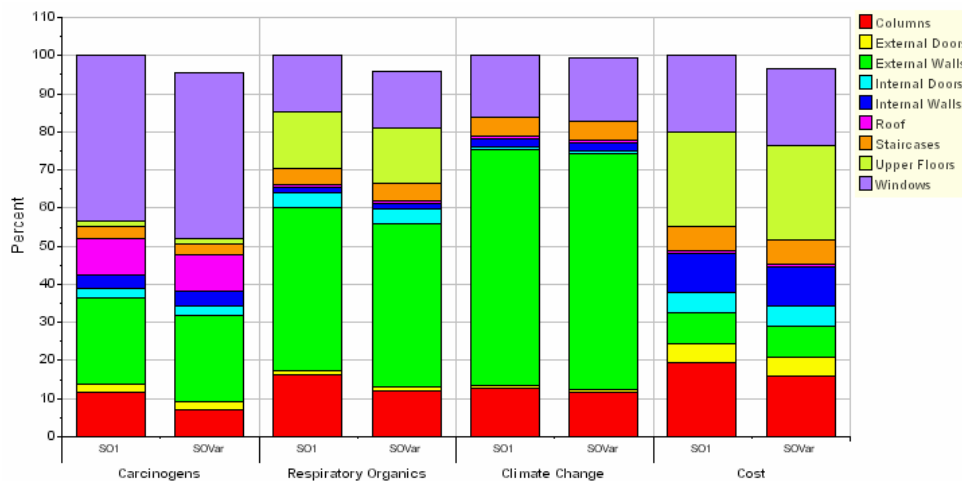


Figure 4 Chart of comparative environmental assessment of four design options measured in impacts per gross floor area showing breakdown by building element

From the perspective of the general user, *LCADesign* is the front end to the environmental analysis of commercial buildings. The “Analysis” is the basic “unit of work” of the system and provides the user interface into the results of the environmental analysis of one or more commercial building designs.

Benefits of an automated environmental assessment system Include:

- Environmental assessment direct from 3D CAD drawings,
- Choice of environmental impact and performance measures,
- Detailed design evaluation to assist in making choices, particularly on materials,
- Comparative ratings of environmental impacts of alternatives at all levels of design analysis, and
- Comprehensive graphical and tabular outputs specifically designed to convey to the user quantitative and comparative information on alternatives.

5. INDUSTRY NEEDS

A market survey in 2004 (CRC CI, 2004) indicated that the attitude to environmental assessment of buildings was changing in that most in the building design industry consider that recent years have seen a significant increase in amount of environmental issues in industry talk and exposure to the industry at large. This is also substantiated by regular comments on the expanding number of emerging rating schemes for buildings, the increasing number of seminars and conferences on environmental impacts of buildings and the beginnings of a formal group of rating specialists.

There is a lot of action with knowledge growing with positive attitudes to seeking improvements in the environmental impacts of buildings, but behaviour is slow to change. Implementation of environmental assessment appears to be very client-dependent and most building practices do not innovate until they are forced to (by clients and/or regulators) so even environmental tools such as *LCADesign* for decision making rather than ratings have only limited opportunities for application.

Comments on the integrated assessment approach were solicited from industry partners with the Cooperative Research Centre for Construction Innovation. While

the number of industry partners are few, they are amongst the largest and most innovative of the players in the construction industry in Australia.

5.1 General

The lack of environmental tools and agreed procedures is often repeated with comments such as “Current analysis can be very crude but is the best available for reporting and often based on limited experience” indicating a demand exists but the tools to assist the required/ expected analysis are not available. Similarly, “A quantitative agreed procedure would provide more acceptable information for guidance on selection of materials quickly and in a standard form” implies speedy and credible information on which to make decisions relating to environmental impacts of selected building materials is in demand but not yet accessible. “LCADesign addresses the type of reporting which we are currently commonly asked to do” also suggests that the information being sought for reporting to those who make the final decisions can be provided by such a tool.

Questions about whether the constructed building is as intended raised the possibility of comparing “as built” with “as designed” with the former being a variation to audit post-construction. With comprehensive analysis being able to be done quickly, auditing procedures become feasible and are readily performed as long as the original computer files, materials database and rules are available at a later date.

As with the introduction of any new tool whose capabilities are substantial and a paradigm shift in relation to current practice, there is a strong need for education on the actual capabilities of a tool integrating 3D CAD models with a materials database so that users would know what to expect, e.g. which products or level of products can be analysed, the boundaries of application and outcomes, choice of generic building and construction products currently in the model, and any limitations.

5.2 Applications

The tasks and decision making to which Life Cycle Assessment of building materials can be applied in design stages of building and construction include the following:

- Identifying building materials which produce the minimum environmental impact,
- Comparisons of environmental impacts of products direct from the LCI database,
- Assessment of environmental impacts of building materials to make informed decisions on material selection as part of the design process,
- Very detailed analysis of materials used in standard designs (including a wide range of alternatives) which are constructed many times for institutional buildings e.g. schools,
- Suggesting which building materials might be improved from an environmental impact or specific emission point of view,
- Impact of materials (particularly finishes) on Indoor Air Quality which has become an important consideration in sustainability assessment,
- Cost effectiveness (indicative costs) to estimate payback times and judge which alternatives produce the best improvements per dollar spent, and
- Comparisons of alternative designs of components and/or sub-systems.

5.3 Useful features of LCADesign

LCADesign is intended to assess various environmental impacts from micro to macro level of building (e.g. building product comparison to whole building assessment). Some useful features of *LCADesign* include:

- Environmental assessment direct from 3D CAD,
- Assessing the environmental impacts of a whole building design in one step,
- Assessing the impact of different materials used in buildings,

- Assessing the impact of alternative designs and being able to compare the impacts using selected indicators from a comprehensive range,
- Drilling down on building components to identify source of differences between alternative designs, and
- Providing a unit rate of the indicator, e.g. per unit Gross Floor Area, because eco-indicator values do not mean anything by themselves and should be extended to other areas (e.g. net floor area) but must differentiate between office and car parking.

5.4 Stakeholder needs

Stakeholder needs for built environment analysis extend beyond the capabilities of *LCADesign*. Built environment analysis tool applications, attributes, features and functionality cover assessment and reporting over the building life cycle to support asset, project, design, product, construction and building processes. Gap analysis of previous/new reviews showed the extent that needs were being met over the building life cycle and found deficiencies in current tools and applications and found many lacked:

- Support for stakeholder decision making,
- Whole of life considerations integrated from investment /planning,
- Consideration of policy development and pre/post-occupancy assessment, and
- Functionality focussing on service delivery measures rather than physical dimensions.

Design performance appraisal requires consideration of environmental performance criteria and best practice performance benchmarks/end points, communication of environmental principals/policy for strategic decision-making as well as interactivity with supporting frameworks, guidelines and checklists. *LCADesign* has been depicted as a forerunner and significant contributor to stakeholder needs in that it provides:

- Objective detailed and comparative assessment rather than subjective assessments,
- Real time detailed design appraisals and evaluations with tool automatic take-off CAD,
- Generation of meaningful comprehensive graphics, tables and reports,
- Comparing alternatives at all level of design analysis, and
- Environmental assessment of building's development from cradle to construction.

5.5 Future developments

Future developments suggested by the first users, and based on demand from clients, included:

- An indoor air quality model to address an urgent common problem as much of the emissions occur from the materials chosen for the construction and fittings of the building but there is currently no usable prediction model,
- A whole life cycle assessment, not only for materials repair and replacement but also for estimating operating consumptions such as energy and water using detailed models,
- Estimation of recycled content as some rating schemes include recycled content of materials and identification reused proportion of renovation (if applicable),
- There is a development opportunity to enhance integrated packaging of *LCADesign* to provide user-friendly comprehensive flexible tools and appropriate features for:

- Communication in planning and strategic decision-making towards better environmental outcomes of buildings,
- Documentation and interactivity with frameworks, guidelines and checklists, and
- Plug ins to facilitate future deliverables/attributes in a development timeline.

6. SUMMARY

It is recognized that *LCADesign* is a huge step forward in environmental assessment of buildings and its real potential is yet to be ascertained. As a quantitative agreed procedure it provides more acceptable information for guidance on selection of materials quickly and in a standard form than has previously been available. *LCADesign* does give an ability to provide quantitative results using agreed indicators (e.g. Eco-indicator 99, greenhouse gas emissions) to substantiate decisions which are currently either tediously done poorly or based on experience.

Almost all of the comments were of a constructive nature to provide feedback on what should be done or expected of an environmental assessment tool with the suggestions on future developments implying that *LCADesign* has a future with other capabilities added as and when they can be implemented.

7. ACKNOWLEDGEMENT

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INNOVATIVE ASSET MANAGEMENT

Full Paper

OWNER INITIATED MODERNIZATION OF BRIDGE SAFETY INSPECTIONS

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ABSTRACT

This paper reports on an “asset management” research program that is applicable to both the private and public sectors. This work presents the strategies and endeavors initiated and driven by a public sector owner in an effort to modernize their current asset management practices. The Commonwealth of Virginia’s Department of Transportation (VDOT) is attempting to modernize a bridge safety inspection processes that requires over 14,000 bridges be inspected at least once every two years. The research effort involved investigating the capability to transform and replace paper-based inspection practices with advanced mobile computing practices. A series of owner-agency initiated research proposals are discussed and the impacts each would have on the procedural processes directed at transforming current work processes with newer mobile handheld computing processes. Ultimately the DOT selected a phased proposal and activated the first phase. This first phase research approach is presented, as are the results. The research determined that field inspections are readily transformable from one that relies on field marking paper reports and then returning to the office for semi-manual reporting to one that is electronically assisted in the field by using handheld computers. Identifiable areas of assistance are field data capture, automated asset inventory updates, and semi-automated report production. From this analysis a series of strategies and recommendations were identified. The owner-agency’s decision to abandon a controlled phased study in favor of an ad-hoc in-house development process is then presented and discussed.

Keywords: Asset Management, Mobile Computing Inspections, Process Mapping, Bridge Inspection

1. BRIDGE INVENTORY MANAGEMENT APPROACH AND PHILOSOPHY

The annual cost for maintenance and improvements to the world's transportation infrastructure is billions of dollars. Much of this cost is associated with bridge maintenance, rehabilitation and replacement (MR&R). Within the United States, an individual state department of transportation (DOT) is eligible for federal highway support funds through the Federal Highway Administration (FHWA). Eligibility is contingent on each state establishing its own methodology to inspect and report bridge deterioration in compliance with National Bridge Inspection (NBI) Standards. All states report their inspection results in a standard format for inclusion within the NBI inventory (NBIS 23, 2002). State and federal laws and associated policies mandate the frequency of inspections. These inspections range from a monthly cycle to once every four years with a routine bridge inspection usually required once every two years. Within the state of Virginia alone, there are approximately 22,000 structures (bridge and culverts,) requiring between 7,000 – 10,000 inspections annually.

The primary objective of any bridge management system (BMS) is to make the best use of available funds in an overall bridge MR&R program while maintaining an infrastructure that's safe for public usage. Without regular maintenance, the overall conditions of any infrastructure element including a bridge will deteriorate over time. Therefore, a BMS must utilize accurate and accessible inspection information to predict a bridge's structural conditions over time.

A fully functioning enterprise wide BMS, or any other infrastructure management system, involves four major informational processes. These processes span the entire structure's life cycle. First, among these processes is the maintenance of an accurate inventory of structure information. This information must be retrievable, updatable, and reflective of the actual inventory item. Second an enterprise wide BMS needs to maintain a consistent and timely inspection and reporting process. Third, a needs assessment process that is coupled to a strategic MR&R optimization program is necessary to meet the goals of a safe and effectively administered infrastructure. Fourth, an MR&R projects development program allows for timely and cost effective budget allocations consistent with infrastructure management goals. At the state level each of these processes is handled internally across several different operational departments, including information technology (IT.)

1.1. INFORMATIONAL FRAGMENTATION OF THE INSPECTION PROCESS

At present, the VDOT bridge management enterprise has coherence in intent although throughput is slowed by the fragmentation of informational support tools. This system wide fragmentation has both technical hindrances and cultural bottlenecks that must be overcome if an effective and integrated BMS is to be achieved. Research to modernize the BMS can be extensive and cumbersome crossing many DOT operational domains.

Bridge information in Virginia, like many other states has a combination of IT tools that assist in managing its inventory. Virginia in particular combines this information within two distinct database applications, 1) Highway Traffic Records Information System (HTRIS), a coded inventory only database that exists within a Disc Operating System (DOS), and 2) Pontis, a well developed software application that operates within a Windows Operating System environment and maintains significant amounts of condition state data. The

HTRIS inventory application is a relic of the 1980's, yet does all that is asked of it which is little more than maintaining inventory data. As currently used by the owner/agency Pontis data is typically restricted to coded entries although it has capabilities for modeling and simulating "what-if" scenarios within an MR&R project decision making environment. A third component of Virginia's overall BMS is a non-indexed structural inspection report (SIR) that is the only visual and verbally description of a bridge's condition. The two databases (HTRIS and Pontis) help the state meet its obligation for compliance with federal laws and NBIS. The SIR is composed of written commentary, deterioration quantities, graphical data, and photographs compiled from inspector observations and allows for a non-codified assessment of a structure's condition. Collectively these three applications form the backbone of informational support and inspection data for Virginia's BMS.

The "bridge management databases" themselves are diverse and have low interoperability and fragment the inspection process. There is limited throughput within these three databases as they cross the four BMS domains of inventory, inspection, needs assessment, and project/program development. With the advent of wearable and handheld computing the opportunity for transforming an inherently fragmented paper based asset management process into one that is seamlessly integrated has become achievable by any large asset owner, public or private.

2. OWNER INITIATED TRANSFORMATION OPPORTUNITY

It was this awareness of a fragmented process that precipitated the VDOT Bridge and Structures Division (BSD) to embark upon an initial investigation to minimize or eliminate all inspection process fragmentation within the inspection domain by advocating the use of personal digital assistants (PDA's). Previously the owner/agency had implemented a process whereby laptop computers were issued to all field inspection teams, with the express purpose to allow field based reporting for later uploading to the agency database.

This previous effort failed for a variety of reasons, one being that basic inspection workflow process was neither investigated, nor documented as a necessary aid to overall process improvements. It was discovered after deployment, that even though new computer capabilities were added, work processes never changed. Therefore, a charge for this investigation was to not repeat this mistake.

It has become evident upon completion of the initial research that specific process improvements can still be derailed through organization structures that fragment improvement processes. The charge of not repeating a past mistake is proving easier said, than done. This was apparent during the research proposal stage and was later reinforced by the Bridge Inspection Division's decision to implement a "hardware first" direction.

2.1. VIRGINIA TRANSPORTATION RESEARCH COUNCIL (VTRC)

To further improve transportation research the state maintains the Virginia Transportation Research Council (VTRC) as a state-sponsored center for innovation in advanced transportation-related engineering technology and for improvements in state agency management and operational practices. These objectives are intended to be met by conducting a broad-based program of applied and basic research, including support for technology transfer to the VDOT. In this capacity as innovator the VTRC is a coordinating agency that assists in interfacing between agency needs and university researchers to address innovative research issues (VTRC, 2004).

Although the VTRC acts as a catalyst, many of the research activities are internally linked back to a specific VDOT organizational unit. In the instance of inspection improvements the direction and focus is being provided by the BSD. This mechanism of yielding major research direction to an operational arm of the agency adds to process fragmentation, yet allows for a broader user led and initiated research. This fragmentation was, to a certain extent, obvious in the initial research proposals and further reinforced by the BSD post research decisions and the VTRC's weakness in redirecting these decisions.

2.2. FRAGMENTED RESEARCH STRATEGIES

The VTRC had previously discussed strategies with researchers to improve the inspection processes it took the BSD to make the initial call through the VTRC for process improvement proposals. Upon receipt of the call an initial proposal was prepared that addressed only inspection process improvements through; 1) research on work processes, 2) defining optimum user needs; 3) developing process improvement strategies, 4) proposals for specific hardware/software solutions, 5) the implementation of prototype trials, 6) development of implementation procedures, and 7) measuring and assessing improvements. Upon proposal review the BSD countered that only hardware/software solutions are proposed with a particular desire to target a specific hardware solution set.

This "hardware first" solution was indicative of the previously mentioned laptop implementation failure. Preconceived notions without process understanding are doomed to failure. A second proposal was prepared to address this owner-driven approach. Fortunately, the VTRC recommended otherwise. The VTRC recommended that agency work processes must be researched and understood before any hardware solution could be proposed. This led to a third proposal that addressed a simple work processes investigation within a transformation strategy of incorporating wearable/handheld computers into the inspection process.

3. RESEARCH APPROACH

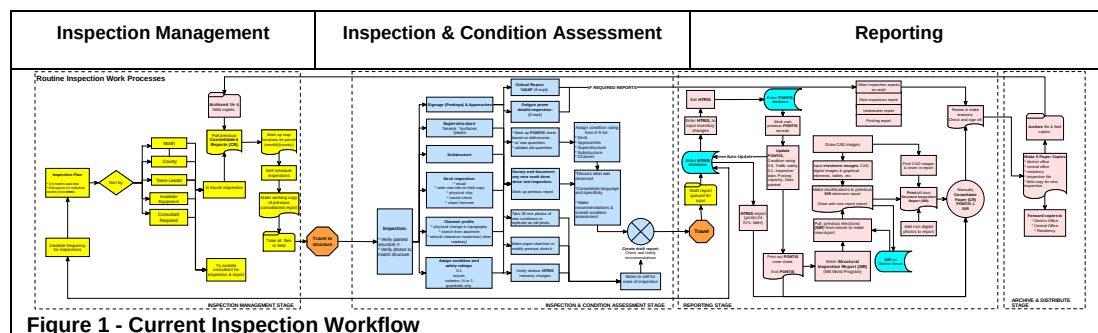
The strategy for this research was to map the work flows as described and then observe how field personnel actually proceeded with their work tasks. To quote Anjard (1996), "A processes map prompts new thinking about how work is done." Additionally as Symonds and Jacobs (1997) have shown in their work, multi-level process maps can produce higher levels of detail and hence higher levels of understanding and opportunity for innovative process improvements. Thus the use of simple mappings to understand and analyze workflow can be quite successful in identifying change opportunities.

Due to the uniqueness, diversity, and locations of the states asset inventory it was determined that several bridge inspection teams or districts operational processes would be observed and mapped. To find out how different people and different teams approached and conducted similar inspections, and to get reliable and transportable mappings, bridge inspectors from four different districts were interviewed and then physically observed in the field and office as they implemented the inspection process. Not unexpectedly the observations of the different inspection teams identified a common work process. Although the processes had commonality in accomplishment and outputs the actual procedures were sequenced and implemented differently by each of the different teams. This validated the need for a modernization strategy that could incorporate mobile computing technology into standard operating procedures but also allow different teams to work in self-defined sequences.

4. RESULTS

Most if not all states, including Virginia provides its inspectors with standardized training through comprehensive courses based on the FHWA's "Bridge Inspector's Training Manual" and NBIS. This commonality in training is intended to standardize the process by minimizing the variability in inspection observations and reports. Although inspector training and reporting requirements are standardized to comply with FHWA requirements, each state is free to develop its own inspection and reporting methodologies. Therefore, each state has a unique inspection, collection, internal reporting, and archiving methodology.

In general, the different inspection teams accomplished their basic inspection tasks using similar but not identical procedures. From the research, see Figure 1, it was determined that the inspection process operates within three distinct and sequential functions, 1) Inspection Management, 2) Inspection, and 3) Reporting.



In all instances data collection by field inspectors was done by marking up, in red, the previous paper reports with any new data. Later the inspectors would return to the office and manually input the newly recorded data into three separate electronic applications and print out a paper archival report. The data collection and reporting systems used to complete an inspection was characteristically paper based with the results being manually transferred and archived into three separate and distinct software applications, 1) HTRIS, an older DOS-based asset inventory database; 2) Pontis, a Windows-based proprietary database application; and 3) a word processing document that contained text, graphics, and images. These three applications have limited interoperability and required a manually composed report combining paper outputs from all three applications to produce a final archival report.

4.1. WORK PROCESSES IDENTIFY INFORMATION FRAGMENTATION

It was determined that at the inspection level information was compiled, stored, and archived within three functionally independent information interfaces. Although these interfaces exist independently and have limited interoperability they are collectively used to record bridge/structure inspection data and to manage the state's bridge/structure assets. The three independent information archives having been previously described are; 1) HTRIS (DOS-based), 2) Pontis (Windows-based), and 3) SIR (text with graphics and images).

Table 1 is an example of the level of fragmentation in information accessibility that exists within the state's bridge/structure inspection process. Access to each of these information types is necessary to fully comprehend the condition of a bridge and to develop any MR&R strategy (Mills and Wakefield, 2004). As can be observed in Table 1 no single software application provides an

assessment of the structure's condition that is usable and adequate for competent asset management.

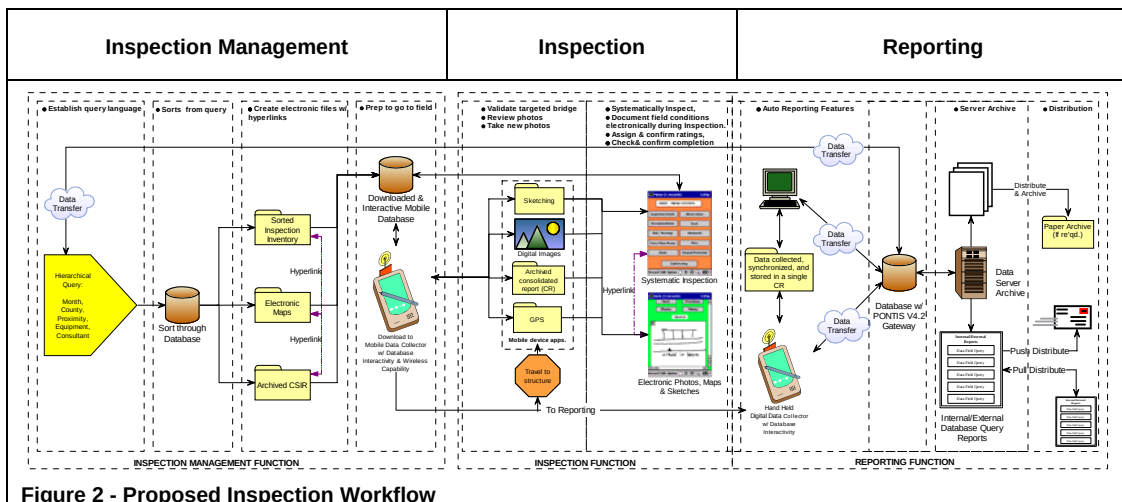
Table 1 – Bridge/Structure Condition Data Fragmentation

Information Type	HTRIS	Pontis	SIR
Text commentary			√
Graphical data (sketches)			√
Photographs			√
Geometrical data	√		
Condition ratings	√	√	
Inspection frequencies	√	√	
Element conditions		√	
Maintenance & improvement cost		√	

From an analysis of the research data, it was determined that a modernizing of the inspection processes through the implementation of mobile computing devices could improve the processes within the inspection management, inspection, and reporting functions.

4.2. MODERNIZATION RECOMMENDATIONS

A series of recommendations were offered to the agency that described a deliberated and phased approach to the agency's goals of modernizing the inspection process by incorporating mobile computing devices and current information transfer mechanisms. Figure 2 is a workflow redefinition of the current work practices with an attempt to address redefinition by incorporating mobile computing technology. The recommendations proposed a tiered strategy for modernization that attempts to incrementally modernize the process by defining varying levels of internal improvements prior to any revolutionary hardware/software transformation.



Tier One improvements are intended to foster an achievable level of internal agency action. This was to be accomplished by; 1) simple procedural adjustments that eliminated agency redundancies and minimized internal inefficiencies without any new hardware/software additions, and 2) adopting agency procedures that would aid in the standardization of upstream and downstream information transfers to improve the chances of a more successful transformation when mobile inspection tools were added to the process (Mills and Wakefield, 2004).

Tier Two work proposed an implementation sequence that mimicked the first research proposal and offered three alternative mobile computing solutions to the agency and the VTRC. Essentially the work proposed that the BSD; 1) establish its inspection modernization priorities through a facilitator led workshop, 2) that three proposed solutions be investigated, 3) that VTRC/BSD create a mobile field application pilot program with solution supplier support, and 4) that VTRC/BSD pilot the solutions and present the findings to the agency.

Upon a complete assessment of the pilot program a prototypical mobile inspection assistant could be compiled for actual field testing and benchmarking. Once this phase was completed a hardware/software solution could be established, followed by a procurement, implementation and adoption procedure. This last phase of the work was to implement a field monitoring assessment to monitor productivity improvement (Mills and Wakefield, 2004).

5. A FRAGMENTED STRATEGY FOR MODERNIZATION

Prior to completion of the Phase I work, the BSD was desirous of a quick solution and proceeded to initiate a “hardware first” solution. This effort was consistent with the BSD’s initial strategy to ignore the work processes and focus on a solution before understanding the existing work processes and how they could be modernized. Thus the BSD proceeded in designating an “affordable” Palm OS device as the pre-designated solution to integrating mobile computer assistance for modernizing the inspection process.

5.1. RAMIFICATIONS AND THE RETURN TO FRAGMENTATION

It is being discovered that the BSD “hardware first” solution is not meeting with much success. During this attempt to implement the solution before determining the problems, researchers of Phase I were not contacted nor consulted. The researchers are aware that the results of Phase I have been read by BSD and there has been discussion of continuing the research. What becomes apparent is that without a studied and careful effort to understand the problems, any solution is primed for failure. A research focused facility such as the VTRC has the vision to foresee this problem and as such initiated the Phase I research that yielded a reasonable strategy and excellent opportunity to modernize the processes much as proposed.

What is also evident is that by observing BSD’s desire for a quicker solution and VTRC’s mediated phase one proposal the fragmentation that exists reinforces an action versus research dilemma in transforming an organization’s operational processes. The acceptance of a reasonable proposal that staged the progression of deliverables and allowed research findings to be incorporated into action prior to report completion would have allowed fast-tracking and a quicker solution.

5.2. CONCLUDING LESSONS LEARNED

History has a unique way of repeating itself. The innovative VDOT laptop deployment that failed earlier has the opportunity to repeat itself during VDOT’s current efforts to modernize their antiquated inspection processes. Successful innovation requires an adequate understanding of the problem and the issues that make innovation possible and successful. Innovative solutions take understanding and understanding requires time. To be a successful innovator, an owner/agency must gather buy-in from all users and allow time for the process to develop. VTRC and VDOT dedicated research approach fosters buy-in through the very elements aid fragmentation. Any fragmentation within

an organization hinders the organizations ability to quickly foster innovation and modernization.

When an organization is unclear on its internal roles and responsibilities, action or research, it will encounter difficulty in driving innovation. VDOT's efforts to modernize their inspection processes are resulting in multiple starts, stops, and redundancies that characterize the process with internal delays and failed successes. With regards to VTRC/BSD effort to modernize their inspection processes, the end users' (BSD) needs should drive the research and the research group should drive the investigative process.

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PROCUREMENT & RISK SHARING

Full Paper

INNOVATIVE BENCHMARKS FOR BUILT ASSET PERFORMANCE – THE TRIPLE BOTTOM LINE APPROACH

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ABSTRACT

The utility of enclosed space is the basic performance measure for built assets. Historically these assets have been assessed on the ability of the occupier to pay for the space, resulting in an expression of the financial return from the investment. However, astute investors are beginning to expand this concept today, particularly with respect to the sustained optimal utility of space.

This paper is concerned with the development of triple bottom line performance benchmarks for operational built assets. Specifically it maps out the conceptual changes taking place from short-term financial agendas to longer-term economic, environmental and social considerations. It also identifies the innovative work currently being undertaken internationally on environmental standards by the Green Building Council of Australia and others.

While reasonable progress has been made developing environmental rating systems for building design and operation, significantly less work has been done identifying and measuring the social factors relating to built assets. With this in mind, particular emphasis is placed on the identification and measurement of important social issues relating to building performance. The case study research of the CRC-Construction Innovation project on 'The Evaluation of the Functional Performance of Commercial Buildings' is outlined, and the complementary work of other leading researchers in this field is reviewed. Finally, avenues for further research are suggested.

This paper is highly relevant to the property asset management sector because it advances the development of the triple bottom line performance measures that are being keenly sought by forward-looking property owners.

The research described in this paper was carried out by the Australian Cooperative Research Centre for Construction Innovation within Project 2001 – 11 – C.

1. INTRODUCTION

The recent favourable economic climate in Australia has helped to fuel significant growth in the property and construction sectors. Construction costs have risen at an exponential rate and property values have escalated as investors increasingly view property as a desirable security. Moreover, the technological aspects of construction have advanced strongly, meaning that the market is now being supplied with products that continue to improve in various ways. This is delivering better value for money, increasing productivity and enhancing well-being for users and occupants, and is providing scope for more environmentally friendly products.¹ Some of these improvements are reflected in the financial returns of the asset, and can be measured accordingly. However this reflection is somewhat indirect and hence, sole reliance upon financial evaluation methods are sub-optimal for determining built asset performance. Indeed, this traditional evaluation approach privileges financial concerns and fails to keep abreast of technological change, environmental demands, and new expectations in social responsibility reporting.

Technological change is impacting the property industry by creating more durable and flexible built assets that allow for longer investment horizons, and is helping occupants to better utilise space. What remains unclear though is the relationship between standard costs and the additional cost to investors of incorporating technology above market expectations, particularly innovation geared toward sustainability. Basically, the question is whether the advancement in technology is, or will, result in improved returns from property assets?

Another aspect of change relates to the impact of social values on the built environment. There is a demand for users of built space to have an improved living and working environment and social aspects feature among their requirements. Many of the social aspects of buildings have more to do with design and management than technology directed at energy savings. Social sustainability of built assets are measured in terms of user friendliness, compatibility, the free flow of information, and the impacts the building itself may have on the wider social environment. These criteria are more difficult to measure than technological or environmental features, which helps explain why there has been comparatively less research undertaken attempting to understand and evaluate the social side of built assets. However, it makes little sense to talk of performance in the built environment if property is not measured against human satisfaction. Appropriate benchmarks arguably need to be developed, tested and applied.

The development of social benchmarks will complete the triple bottom line performance assessment approach to the evaluation of operational built assets. Some astute property investors are likely to embrace such an approach, and it

¹ There is a growing literature encouraging improved building performance. Probe (Post-Occupancy Review of Buildings and their Engineering) has been very influential in the UK. It was a research project that ran from 1995-2002 under the Partners in Innovation scheme carried out by Energy for Sustainable Development, William Bordass Associates, Building Use Studies and Target Energy Services. The Sustainable Building Task Force (California) and the Rocky Mountain Institute are at the forefront of this research in the US, while the CRC CI projects such as 2001-005-B Indoor Environments: Design, Productivity and Health, and 2002-043-B Smart Building for Healthy and Sustainable Workplaces are also making a significant contribution.

can reasonably be expected that the entire industry will, over time, be either coerced by regulation or encouraged by competition and internal pressure, to provide triple bottom line performance data. The benchmarks used will vary depending on a number of variables, such as asset type, utility and locality, and will change over time according to market demands, social attitudes and political and economic conditions. What must be remembered though is that the data delivered by measuring the benchmarks “has to be available in an accessible format that allows meaningful comparison of one building with another...[and]... it has to be capable of being fed into a standard appraisal tool, such as a DCF, by a valuer, or similar, without specialist environmental or engineering training.”²

This paper will explain the emerging trends in building performance evaluation with particular reference to the current research into the setting of benchmarks for the environmental and social measures that should feature as part of the evaluation basis. The paper will conclude with proposed standards and measures for the Triple Bottom Line (TBL) evaluation of investment-type buildings.

EMERGING EVALUATION TRENDS

Traditionally, the property valuation approach for investment-type buildings calculates the market value using financial analysis – the bottom line. In a market that has been dominated by ‘profit-only’ goals, this method has been capable of simulating the market activity provided the limitations of subjectively assessed variables are understood.³

However, in recent years advanced economies have increasingly entered into a climate of heightened public scrutiny with respect to corporate and public administration practices. This new environment is characterised by the proliferation of independent watchdogs driving expectations of greater self-regulation, accountability and transparency. All this means that there has been a shift in the institutional landscape that legitimises the property industry. And this has implications for the market in terms of the socio-political backdrop forging the demand for built assets of a specific calibre.⁴

Meanwhile, much of the property industry has been trying to carry on with business as usual, largely ignoring subtle, yet fundamental differences in the way the market is responding to changing attitudes and value systems. Major companies are becoming aware of the changing business environment, evidenced by the enthusiastic embrace of non-economic performance self-reporting. These broadened ‘profit-plus’ objectives have come to be known as the triple bottom line. Although outcomes from this new accountability are mixed, research indicates that for a number of reasons, businesses that

² S. Sayce and L. Ellison (2003) ‘Integrating sustainability into the appraisal of property worth: identifying appropriate indicators of sustainability’, paper presented at the ARE and UEA conference, August 21-3, Skye, Scotland, p.8.

³ The impact of key variables in cash flow studies is demonstrated in T. Boyd (2003)

⁴ For a discussion on this see P. Kimmet and T. Boyd (2004) ‘An Institutional Understanding of Triple Bottom Line Evaluations and the use of Social and Environmental Metrics’, paper presented at the PRRES conference, Bangkok, January 25-8.

endorse triple bottom line principles were making changes in the way they carried out, or at least thought about, what they did.⁵ Yet there is new evidence indicating that such changes have slowed, and perhaps even stalled.⁶ What this demonstrates is that corporate performance needs to be closely, independently and objectively monitored, to ensure business is paying more than lip service to the environment. This is especially the case in regard to the seldom reported yet highly visible, physical and procedural changes relating to built assets that businesses occupy and sometimes own.⁷

To portray triple bottom line as an altogether new phenomenon is not entirely correct. It clearly has its roots in shareholder activism commencing in the 1960s. Shareholders with vested interests progressively called company executives to account, and have in this way become influential in generating community values that have sponsored 'new' corporate values that reach beyond narrow economic constructs.⁸ While ultimately important from a business point of view, profit taking now competes for elbowroom at the board table along with a raft of priorities that relate to continuity, efficiency, legitimacy, goodwill, reputation and morality. Indeed, there is now clear evidence that these ostensibly non-tangible elements of business are having significant impacts on economic assessments in terms of demand and supply factors – the major determinants of market value.⁹ This has implications for market transactions, and prompts suggestions that both shareholders and investors are informing the market in a way that reflects the advancement of institutional economics. And from a valuation perspective, this 'institutional' process is clouding various input variables.

The fuzziness that is now obscuring what was once a relatively straightforward, essentially numeric exercise is the very reason for the research summarised in this paper. It is about providing a way forward for valuers, owners, managers and investors to adequately assess built assets from a total life-cycle and performance perspective relative to the market. To successfully navigate through the thickening institutional fog, it is argued both here and elsewhere that an agreed set of social and environmental benchmarks will need to be developed.¹⁰ How to apply such benchmarks in practice is open to speculation,

⁵ C. Deegan, M. Rankin and P. Voght (2000) 'Disclosure Reactions to Major Social Incidents: Australian Evidence', *Accounting Forum*, 24:1, pp.101-30.

⁶ An Australian Conservation Foundation corporate report has recently concluded that Australia's top 50 companies failed to improve their environmental performance in 2003. See ACF (2004) *Corp Rate: An Assessment of Australia's Top 50 Listed Companies in 2003*.

⁷ The Upstream group have reported that companies in the property sector are beginning to move away from a narrow concern with environmental issues towards a broader agenda of corporate responsibility and socially responsible investment. *Upstream* (2003) 'Sustainability and the built environment - an agenda for action', June, London, p.15.

⁸ The efforts of Ralph Nader were inspirational for the shareholder movement. See T. Whiteside (1972) *The Investigation of Ralph Nader: General Motors vs. One Determined Man*, Pocket Books, New York.

⁹ Kimmet and Boyd (2004) 'An Institutional Understanding of Triple Bottom Line Evaluations...'.
¹⁰ See P. Kimmet (2003) 'Socially Responsible Public Administration and the CBD', paper presented at the Vision 2020 IPAA conference, Griffith University, Brisbane, November 26, available at

http://www.gu.edu.au/school/gbs/ppp/ipaa/ipaa_papers.htm; P. Kimmet (2003) 'Socially Responsible Commercial Property Entities and the Allocation of Cultural Space', paper presented at paper presented at the International Association for the Study of Common Property 2nd Pacific Regional Meeting, Brisbane, September 7-9. To become available at <http://www.iascp.org>; Sayce and Ellison (2003)

and will largely be configured through use over time, and according to individual asset specifications and data collection purposes.

3. IMPACT OF TECHNOLOGY AND SUSTAINABILITY ON BUILDING ASSETS

This paper questions the impact of advances in technology and the current focus on sustainability in buildings, in terms of the performance of the building assets. In the introduction the following question was posed: “whether the advancement in technology is, or will, result in improved returns from the property assets?” In short, the answer to this question is inconclusive at present. Some experts are predicting that with an increasing number of ethical investment funds emerging, it is inevitable that investors will begin to look more seriously at property over the next 5 to 10 years, and that this increased demand for environmentally and socially sustainable buildings is likely to result in premium values.¹¹ Even now, a good energy rating (e.g. a 4 to 5 star ABGRS rating)¹² on a building that otherwise conforms more or less to standard gives it a market edge. And there is some evidence that for public sector tenants at least, a fall in the rating during tenancy can actually trigger a diminution in rent.¹³ This suggests that a premium rent can be achieved based on an expectation of lower occupancy costs or a better working environment. And these higher rents influence the capitalised value and the calculations generated by DCFs.

Sustainable building features have more distinct benefits in the long term. As Deutsche Asset Management’s Tony Gulliver explains, “unless you make the decisions now that are standard expectations in the future, you’re really going to be behind the eight-ball”. For many though, making investment decisions based on future market expectations is an enormous commercial risk. Most developers depend on selling their recently completed buildings to institutional investors who primarily look at specification in relation to industry standards, tenant quality and rental level. On the other hand, long term property owners, such as funds, companies, trusts and public bodies are more interested in future building performance, and seek to optimise both the short-term and long-term performance of property assets under their management.

Many of the cost effective technological advances relate to environmentally friendly ‘green construction’. Some green building features are not obvious or might not be appreciated by occupants, particularly in the short-term. This emphasises the need for ongoing management support and building feature instruction to ensure green components are understood and used to their

‘Integrating sustainability into the appraisal of property worth’; and G. Newell and P. Acheampong (2002) ‘The Role of Property in Ethical Managed Funds’, paper presented at the ERES Conference, Glasgow, June 4-7.

¹¹ Howard Brenchley of APN Funds Management is quoted by Terry Ryder to this effect, (2003/4) ‘Facing up to the Future’, *Property Australia*, Vol 18, No.4, p.50.

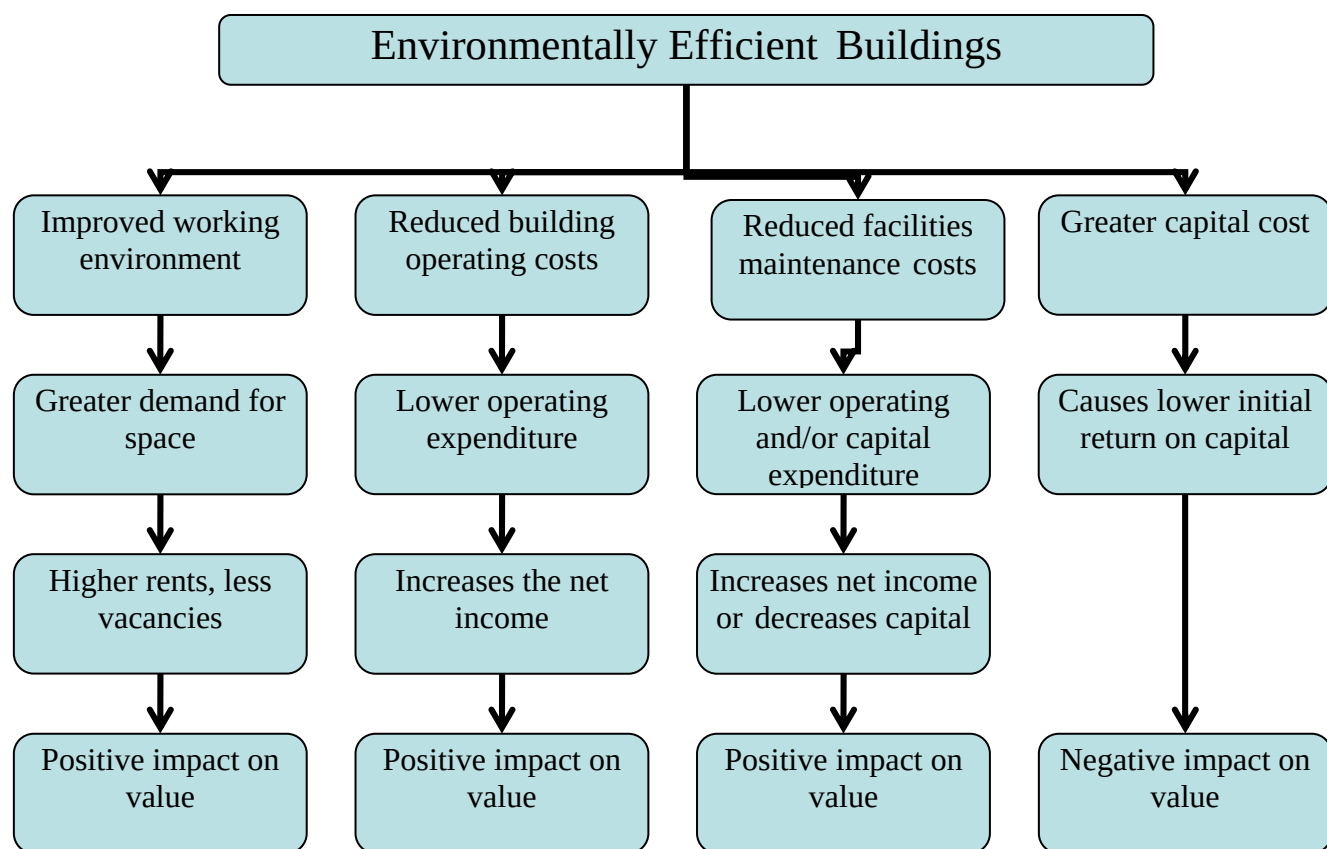
¹² The Sustainable Energy Development Authority (SEDA) ABGRS - Australian Building Greenhouse Rating Scheme, or alternatively a favourable Green Star rating.

¹³ New South Wales Police Services have signed a lease with Multiplex for the Parramatta Headquarters declaring that the rent is to be reduced if its 4½ star rating falls. See Michael Dorfling (2004) ‘Buildings put to the greenhouse test’, *the Australian*, May 6, p.40.

optimal potential. It is in the medium-term however, when the benefits of operating cost savings, and the even less obvious employee satisfaction, are factored in to the equation. It may only be then that advantages of green buildings are fully realised by tenants, resulting in a willingness to pay rental premiums. Even if rental premiums on new green buildings are not factored in until the first rent review process when outgoing savings and tenancy satisfaction is more fully understood, the leasing up period is still speeded up by green credentials.¹⁴

The overall impact of enhanced environmental characteristics on investment-type buildings is illustrated in Figure 1 below:

FIGURE 1: Value Impact of Environmentally Efficient Buildings



The diagram in Figure 1 indicates that there are four expected results from greater environmental efficiency and that three of the four impacts should have a positive effect on the capital value of the building. However the degree and timing of the impact is complicated and will differ according to the type of environmental improvement. It is too simplistic to conclude that the change will always, or even frequently, have a positive impact on the capital value. What

¹⁴ This is confirmed in by Chris Kinder of FPD Savills, managing agent of Brisbane's 4½ star William Buck Building (120 Edward St.), which was leased in 12 months to high quality tenants, with energy savings likely to be factored into the first round of rent reviews.

is important is that environmental factors have the potential to provide a better return from a building asset.

4. ENVIRONMENTAL BENCHMARK RESEARCH

Valuable work identifying appropriate environmental indicators for built assets has already been undertaken both in Australia and overseas. The Green Building Council of Australia has been very active in this area. The Council's office rating tool was particularly instructive for developing indicators to measure the CRC-CI's Evaluation of the Functional Performance of Commercial Buildings project's case study commercial high-rise office buildings that this paper has emerged from. The tool focuses on strategies to enhance efficiency and reduce greenhouse gas emissions, and it should also be part of the performance assessment. However, environmental rating schemes on the whole tend to focus on the design, construction and management rather than looking at buildings as operating entities within a broader market framework in the manner that property valuers do. A few studies that approach environmental benchmarking from a valuation perspective are worth closely reviewing here.

The Royal Institute of Chartered Surveyors (RICS) Foundation funded a report by the Upstream group, which lists energy use, water use, waste management, transport; pollution; and materials use and selection, as the most prominent environmental criteria for valuers.¹⁵ There is little dispute over the validity of their criteria, although others have further expanded the list. For instance, a project underway at Kingston University in the UK and supported by government and business partners, also includes management, or as they call it – occupier criteria, within their categories. Known as The Sustainable Property Appraisal Project, this project prefers to label water consumption and waste management – ecology, while materials use and selection is subsumed by building flexibility, and design categories. What Kingston's Sarah Sayce and Louise Ellison also identify is that indicators in each criterion vary in their impact with respect to environmental, social and economic components. For instance they argue that the indicator 'build quality' has environmental and social impacts only, while 'reuse of building', 'quality of management', and some transport and energy efficiency indicators are exclusively environmental and economic in nature.¹⁶

Sayce and Ellison list reuse of building; operational CO2 emissions; embodied CO2 emissions; CFC emissions; methane emissions; nitrous oxide emissions; hydro fluorocarbon emissions; perfluorocarbon emissions; efficient use of equipment; distance from local public transport nodes; provision of facilities for non-drivers; policies to encourage alternatives to single occupancy car journeys to work; use of brown field sites; quality of management; water consumption; and waste management as distinctly environmental indicators. Let's look at these indicators in a bit more detail.

According to Sayce and Ellison, the more a building is reused in a variety of ways by its occupants, the more flexible it proves to be, and the more resources

¹⁵ *Upstream* (2003) 'Sustainability and the built environment'.

¹⁶ Sayce and Ellison (2003) 'Integrating sustainability into the appraisal of property worth', p.11.

and energy invariably spent in total redevelopments is conserved.¹⁷ While office high-rise is seldom used for any other purpose, there is no reason why less desirable and aging offices cannot be converted to apartments or a variety of other uses, or even upgraded to exemplary environmentally sensitive space.¹⁸ And there is no reason why the original materials cannot be re-used in refurbishments, and if the façade is retained, this may also add to heritage values.

Operational and embodied CO₂ emissions (greenhouse gases) are chosen by Sayce and Ellison to measure the energy efficiency of a building because carbon tax and climate change levies in the UK fails to allow for the use of energy generated from renewable resources such as wind power and photovoltaics. This complicates reporting, reduces energy use to an economic basis, and fails to adequately reward the use of renewable energy supplies. In the Australian context, a more accurate picture of responsible energy use can be ascertained by recording and comparing the net fossil fuel energy use on an intra-building (sub-metering) and market comparison basis. Energy efficiency is clearly a very important environmental indicator, and features prominently in the calculations of the various environmental building rating schemes such as *Green Star*. As far as embodied energy is concerned though, Sayce and Ellison admit that this indicator “is so far considered to be of very limited or no significance to property worth within the existing building stock.”¹⁹

CFC emissions largely relate to the age and condition of air-conditioning equipment, and the desirable use of ODP, and to a lesser extent, GWP refrigerants.²⁰ To be adequately reported, maintenance records must be made available to the valuer. The various other emissions specified by Sayce and Ellison are generally not released in high enough quantities from office high-rise to warrant individual reporting at this stage. It is perhaps more manageable for the valuer to follow the example of the GBCA and include them under the greenhouse gas reduction criterion.

Efficient use of equipment is closely related to the social indicator recommended in this paper – “level of awareness and training on building/socially responsible facilities” except that it takes an environmental perspective. And as pointed out with the social equivalent, unless there is widespread awareness of the environmentally sensitive design features of the building, optimal benefits will fail to accrue.

From an environmental perspective, transport indicators focus on the availability and efficiency of public transport. The inference is that if public transport is not close by, is irregular, or fails to service a wide area, then occupants will opt to commute using private means, which may result in further reductions in environmental quality. Public transport is of course not the only solution to regular worker commuting. A raft of strategies should be in place to

¹⁷ Sayce and Ellison (2003) ‘Integrating sustainability into the appraisal of property worth’. p.13; S. Brand (1997) *How Buildings Learn* 2nd Ed (London: UK Phoenix Illustrated), www.bre.org.uk

¹⁸ See for example Melbourne’s 60L project (60L stands for 60% less energy). Go to: www.60lgreenbuilding.com/

¹⁹ Sayce and Ellison (2003) ‘Integrating sustainability into the appraisal of property worth’. p.16.

²⁰ GBCA (2003) *Green Star...*, p.19.

discourage single occupancy vehicle journeys, and there is no reason why these cannot all be reported under a single indicator.²¹

As high-rise office buildings are nearly always located in highly developed centres, they are seldom erected on green field sites. This indicator may be relevant to new developments and the history of the land prior to development. Like the efficient use of equipment, an environmental indicator covering this criterion has a very similar social equivalent. In this case it is – “facilities and recognition appropriate to the cultural requirements of indigenous people and the preservation of heritage values where applicable”.

There are at least three major elements of ‘quality of management’ – managing risk, facilitating the optimal environmental potential of the building, and ensuring good corporate governance, particularly disclosure. The first two elements are reported elsewhere – risk is distributed throughout all the indicators, and maximizing environmental capabilities has its own indicator. Governance on the other hand is such a major component of both the social and environmental dimensions of buildings that it should be divided into sub-categories. It is suggested that transparency of environmental data, any non-compliance with regulations, the winning of awards, and environmental expenditure of any type should be reported as a governance metric. What cannot be emphasised enough though is the centrality of disclosure with respect to governance. Without quality disclosure an accurate triple bottom line assessment cannot be made.²²

Water consumption and waste management are issues that are likely to increase in importance over time. While there may be some equipment installed for these purposes, particularly in more modern buildings²³, these measures rely largely on good policy and implementation of conscientious practices. Specifically, these indicators reflect recycling, water capture measures, and the disclosure and relative performance of wastewater discharge that reduces flow to the sewer. They also question the nature and impact associated with any hazardous and non-hazardous waste and effluents, and recycling or removal strategies.

The 5 indicators that Sayce and Ellison attribute to both environmental and social dimensions are briefly considered here from the environmental viewpoint. Building age may have environmental significance depending on the materials used, condition, and the technology incorporated in the design features. It is clearly less important than build quality, however it may indicate the possible extent of obsolescence and depreciation in terms of environmental appeal. And location from centres assumes greater importance when vehicles are used to traverse the distance between them and the building.

Finally, corporate environmental engagement should reflect the overall performance of the building against environmental benchmarks. This includes internal quality in terms of worker satisfaction, a crucial environmental measure that arguably deserves individual attention. Indeed, the GBCA tool offer credits

²¹ Next to public transport, the *GBCA* offer the second highest transport credits for the provision of cyclist facilities, p.18.

²² Kimmet, P. (forthcoming) ‘Benefiting from Disclosure: Reporting the social responsibility of built assets’, to be presented at the CRC CI conference, Gold Coast, Oct., 2004.

²³ Particularly in regard to cooling tower water consumption.

for several indoor quality features ranging from ventilation to natural lighting, views, individual thermal control, noise abatement and particularly the absence of indoor air pollutants.²⁴ And external quality should also be addressed specifically in terms of aesthetics and visual blending. This involves a building's celebration, utilization, connection, contribution and appropriation of its street frontage and local precinct.

5. PROPOSED ENVIRONMENTAL BENCHMARKS

Taking account of the GBCA measures and the substantial work of Sayce and Ellison (referred to above), we recommend the environmental indicators listed below for existing investment-type buildings (Refer Figure 2). They do not appear in any particular order for weighting purposes, but they are organised into 3 distinct fields.

Figure 2: Recommended Environmental Benchmarks – Existing Buildings

1.Resource consumption 1.1 Energy	• Net fossil fuel energy use (assessed on an intra-building and market comparison basis) • Effective action to reduce greenhouse gas emissions (particularly from energy use) • Office lighting power density and peak energy demand reduction strategies • Evidence of alternative energy supplies from renewable sources or from cogeneration
1.2 Air conditioning	• Condition of air-conditioning plant • Use of ODP or GWP refrigerants
1.3 Water	• Water consumption (potable, hygiene and cooling towers) • Recycling and water capture measures • Wastewater reduction • Hazardous and non-hazardous waste and effluents recycling or removal strategies
2.Design and Use 2.1 Transport	• public transport availability and standard of service • strategies to discourage single occupancy vehicle journeys, including cyclist facilities
2.2 Building fabric	• Age of building (obsolescence or depreciation of materials) • Re-use or upgrade history or potential • Suitability of original materials for refurbishment and façade retention • Ecological impacts of materials used (can be ascertained by using LCA Design²⁵ or similar software package)
2.3 Interior	• Indoor quality measured by ventilation, natural lighting, individual thermal control, noise abatement • Absence of indoor air pollutants
2.4 Environment	• Quality of overall built environment and site use in relation to aesthetics, visual blending, connection, contribution and appropriation of its street frontage and wider precinct
3.Governance 3.1 Awareness	• Maximisation by management of the potential of the environmental design features through awareness

²⁴ GBCA (2003) *Green Star*, p.18.

²⁵ This is developed by a project in the CRC for Construction Innovation.

	programs
3.2 Disclosure	• Disclosure and transparency of environmental data, regulation compliance, awards, and environmental expenditure of any type

It is accepted that there are many more useful environmental indicators. The table above is one attempt to identify the major characteristics that relate to operational issues with particular reference to the utility of the building. And it is emphasised that the selection of benchmark indicators should be evaluated against the market's perception of value of the individual measures. Once the appropriate indicators and their component characteristics have been selected, the next challenge is to determine a grading or weighting for the indicators. The GBCA's Green Star rating system is a well reasoned grading approach and consequently it is recommended provided it is applied with the usefulness of the building asset to the occupiers in mind.

6. DEVELOPMENT OF SOCIAL BENCHMARKING

While environmental benchmarking is well advanced, a corresponding effort with respect to social benchmarking needs to be made to provide for meaningful triple bottom line assessments of built assets.²⁶ Upstream list important social issues in the appraisal process as: investment in the community; local employment; stimulating local economic activity; community engagement; accessibility; health and safety; crime prevention; occupier productivity; and employee/ supplier relations. This list is partially endorsed here, with crime prevention the only issue called into question as a legitimate social criterion for benchmarking. Local impacts and cultural issues should also be added to this list of highly significant measures of social sustainability in the built environment. Moreover, local employment and economic activity, investment, and employee/ supplier relations are arguably more conveniently reported within stakeholder relations and community engagement criteria. Each of these observations will be discussed in this section.

Crime prevention is an interesting issue. At this stage though, the profile of crime in the context of Australian high-rise office stocks is not significant, nor is it clear how a prospective benchmark should be measured and what the responsibilities of a commercial property are in this regard. It is felt that this area requires further exploration before it could be recommended as an appropriate appraisal indicator.

Investment in the community is possible as either cash injections or in-kind contributions. It is easily measured, as long as records are kept, and disclosure is made to the valuer. However, 'investment' takes a rather a narrow, material view of community interest, precluding a wide range of building management policies that can benefit the community. It also fails to recognize that the broader community is a legitimate stakeholder in commercial property, which after all relies on social capital infusions for commercial success.

²⁶ J. Fiksel, (2001) 'Measuring sustainability in ecodesign', chapter 9 in M. Charter & U. Tischner eds., *Sustainable Solutions: Developing Products and Services for the Future*, Sheffield: Greenleaf Publishing, p.168.

It is important to consider what is actually meant by the level of community engagement of a particular property. The first observation to make is that certain properties, by design and purpose, 'engage' the community much better than others. It is therefore important not to compare dissimilar properties. A second point is the difficulty of distinguishing between properties that actually share many characteristics. Arguably the important distinction to make here is with respect to management.

Accessibility is an important social indicator, however it needs to be more clearly defined. Specifically, access for whom, by what, and by which standard? Transport should be a separate indicator, so we can assume accessibility refers to walking and wheelchair access for occupants and visitors, in both the internal (ease of access to public and leased space) and external (proximity to desirable spaces from the building) senses.

Health and safety is also clearly important. This not only refers to adequate provisioning and maintenance of the building and plant, but should also include generous insurance and public liability cover in case of injury from accident or the contraction of illnesses such as legionnaires disease (legionella). This indicator relies heavily on disclosure by management.

Occupier productivity is undoubtedly a leading social indicator for the assessment of commercial buildings. This encompasses the quality of the indoor environment, which is beginning to be researched quite extensively as we have pointed out earlier. It also involves building age and condition, occupant satisfaction, functionality and psychological and physical well-being.

Perhaps more than any other indicator, stakeholder relations relies heavily on disclosure and transparency from management. Objectivity can be brought to the assessment process by interviewing occupants and visitors. An important element here is the quality and content of negotiations with agents, tenants, contractors and staff. It is a strong indicator of management in general, or as it is increasingly referred to in the modern corporate environment, it is the measure of 'good governance'. This will be qualified by the contextual capacity in which the building operates, including the prevailing regulative environment and the level of accountability expected of the individual premises.

Sayce and Ellison identify 6 indicators that impact on the social dimension of the triple bottom line, and find that a further 5 have both social and environmental implications. The 6 social indicators they suggest are: protection of heritage buildings; access to local green space; local economic impact; occupier satisfaction; functionality; and impact.²⁷ Obviously heritage buildings' protection only applies to certain, usually older building stock. However, it is unclear how this might impact on market value. Some properties actually decrease in value if redevelopment potential is restricted. On the other hand, ownership and preservation of a heritage property contributes to the 'national estate', and may accrue significance in terms of reputation and social responsibility. More research will need to be undertaken in this area to ascertain the implications for triple bottom line assessment. In the meantime, age of building and renovation requirements can be considered under productivity and satisfaction.

²⁷ Sayce and Ellison (2003) 'Integrating sustainability into the appraisal of property worth'.

What is of increasing significance in Australia, given the ongoing public debate about reconciliation and native title, is the appropriate recognition of original indigenous owners. This indicator alone occupies the entire focus of a separate paper produced by this project.²⁸ And a further cultural indicator that surfaced when the social indicators discussed here were recently tested was the art on display, measured as a percentage of total fit out cost.

Sayce and Ellison's final social indicator is more difficult to measure. They explain that:

"a building's physical presence will inevitably illicit a response from the local stakeholder community...[pointing out that]...what *is* important is public perception of design.... The difficulty with this measure is that issues of taste and perception change over time and it is almost impossible to predict what aesthetic design quality will be valued in the future. Nonetheless, as the assessment will be done on a recurrent basis, it can be kept under review."²⁹

The rest of their discussion concerning this indicator is well worth citing as well.

"The importance of design is also dependent upon the impact a building has within its location. This requires consideration of the extent to which a building is appropriate to its environment, reflective of local architectural style, a landmark, denoting an important gateway or entrance for example. Does it create a wind tunnel effect for local pedestrians? A building that blends in with the surrounding area will not be unsustainable; neither will it create any positive local impact from which the investor and/or occupier can benefit. A building that has a strong and negative local impact will be a liability to both occupier and investor, in terms of sustainability."

And:

"the fabric of the local environment uniquely effects the local community and, an occupier and/or investor that shows scant regard for these stakeholders is simply not demonstrating good CSR" (corporate social responsibility).³⁰

Sayce and Ellison's 5 indicators that have social and environmental significance are: building age; distance from town centre; distance from local centre; corporate environmental engagement; and build quality. Once again, when approaching the appraisal from a social point of view, building age mostly relates to occupant productivity and satisfaction, and how the age of the building influences maintenance and refurbishment strategies. Meanwhile, distance from town and local centres are a mix of locational and transport factors. From a social perspective, accessibility, which has already been flagged, is generally more significant than the largely economic implications of positioning in the most prestigious and central locations. Transport on the other hand clearly also has environmental significance and in this case in particular it is important not to duplicate the reporting process.

²⁸ Kimmet (2003) 'Socially Responsible Commercial Property Entities and the Allocation of Cultural Space'.

²⁹ Sayce and Ellison (2003) 'Integrating sustainability into the appraisal of property worth', p.23.

³⁰ Ibid.

Sayce and Ellison point out there is a danger of also duplicating reporting by making build quality a distinct indicator on its own, when it clearly influences many of the other benchmarks.³¹ And they also warn that low quality buildings are likely to impact on the corporate image of owners and occupiers. They explain that:

“whilst it may not be reasonable to suggest that the very existence of a low quality building within a portfolio will increase investor risk, an absence of evidence of efforts to improve the quality, particularly over the long term, may well have a negative impact. Thus it is not so much the existence of the building but the approach taken by the investor (and occupier) to that building.”³²

Corporate environmental engagement is about the acquisition of socially responsible capital (meaning goodwill and reputation) by embracing environmental criteria. This is an important indicator for social impact studies, but in a triple bottom line framework it is arguably best left to environmental indicators.

Other social indicators that neither *Upstream* or Sayce and Ellison discuss are largely informed by the extensive and widely acclaimed work of the *Global Reporting Initiative*.³³ Admittedly, their approach focuses on business reporting, but some of the indicators they have developed also make sense in the performance context. For instance, credible indicators include: level of awareness and training on building/socially responsible facilities; and provision and monitoring of facilities/amenities (emphasis on equal opportunity), and lobby space from the public’s perspective. And indicators that can be identified as broader society impacts include the nature of tenant businesses and naming rights, and appropriate training for security personnel.

It is one thing to have a socially productive building and even advanced social policies, but these things of themselves do not ensure a high level of awareness of the socially optimum use of the premises. Training and regular updating needs to be provided for the occupants to facilitate it. This is fairly straightforward to report (assuming adequate disclosure), and can be accurately checked by brief interviews or a survey. And reporting on facilities and amenities provision need not be bound by regulations. This is a very important aspect of social responsibility, so it follows that generous common area allocations are highly desirable.

A simple perusal of the nature of businesses housed within a building will help us gauge the level of social support and services provided by tenants, strongly influencing community impressions of the building’s social responsibility. For instance, tobacco and alcohol companies and other unethical businesses will detract from a building’s public image, particularly if naming rights are acquired. It is envisaged that as triple bottom line assessments are progressively

³¹ Ibid.

³² Ibid.

³³ Go to their website at www.gri.org

accepted within the industry and this indicator is specifically embraced, then socially irresponsible businesses will begin to expect to have to pay a premium for rental space to compensate for the negative impact of their business on the premises.

And finally, in some instances certain business and executive government may require an overt security presence. In such cases it is important that security personnel are adequately trained in public relations.

7. PROPOSED SOCIAL BENCHMARKS

In order to select the relevant social benchmarks, the CRC CI project examined not only the sources discussed above but also interviewed major users of office space and property managers, while testing helped to determine the relevance and practicality of the indicators. This helped to identify forward-looking issues for space users. In compiling the benchmarks, we selected seven social criteria and thereafter chose components of these indicators that were both indicative of the criteria and measurable. The table below (Figure 3) sets out the indicators and the measures.

Figure 3: Recommended Social Benchmarks – Existing Buildings

1. Health and Safety	• compliance with H & S regulations and appropriate signage • adequate public liability and service provider insurance • awareness and training of emergency evacuation and accident first aid procedures for all floor wardens • a first aid station accessible to all building users
2. Stakeholder Relations	• monitoring of stakeholder concerns, views and provisions • transparency and disclosure of landlord/tenant contracts and marketing agreements • supportive use and occupation guidelines for tenants • appropriate training for security and public relations personnel
3. Community Engagement	• encouragement of employment of local residents within the building • provision of accessible public facilities (seating, toilets) • promotion of and linkage to local service providers • accessible communication channels with building stakeholders
4. Accessibility	• connections to designated green spaces • proximity to urban spaces (town centres, malls, etc) • availability and efficiency of public transport • wheelchair access • proximity to childminding facilities
5. Occupier Satisfaction and Productivity	• quality of communal service areas e.g. toilets, kitchen facilities • complementary usage of building (compatible tenants) • occupant productivity in terms of satisfaction and physical wellbeing • smart technology design provisions

6. Cultural Issues	• recognition of indigenous people through allocation of cultural space (for display or performance) and communication of site or community history • consideration of gender equity and minority group requirements • preservation of heritage values • value of artwork as % of fit out
7. Local Impacts	• aesthetic implications (compliance with precinct theme, building scale, etc.) • practical implications (traffic generation, off-street emergency parking and pedestrian management) • nature of tenant businesses and naming rights • community linkages and sponsorship of local neighbourhood activities

Yet even with the availability of data in this developmental stage, it was decided that given the current unrefined nature of the research it would be premature to report any more than 3 basic findings:

1. not socially responsible
2. social responsibility required of a private corporation
3. social responsibility required of a public body.

8. CONCLUSIONS

The CRC-Construction Innovation project on *The Evaluation of the Functional Performance in Commercial Buildings* found that a significant part of assessing functionality performance of built assets involved determining the measure of achievable sustainability relative to the market. Technological advancement has the potential to produce high sustainability outcomes for buildings, but the cost of much of this innovation is difficult to justify to 'rational economic' investors. An examination of market activity showed that property investors were essentially demand driven. They were concerned about the ability to generate increased rental from environmental and social improvements. The project also found though that significant sustainability gains could be achieved largely through management strategies designed to satisfy TBL benchmarks.

A key lesson derived from testing the project's benchmarks on case study buildings is the need for uninhibited stakeholder input. In the case of commercial buildings, stakeholders not only include owners, managers and occupants, but the wider public also has a stake in their operation. By this it is meant that management decisions need to be informed by society norms, habits and values, as well as by the economic and utility objectives of the parties directly involved. A major plank of this normative agenda is environmental ethics, but it is by no means the only emerging issue to consider.

The research project has advanced the benchmarks required for the performance evaluation of commercial buildings. In particular there has been keen interest from property investors and managers on the benchmarks for TBL evaluation. They accept the inevitability of the changing concepts of

performance evaluation but are uncertain about the timing of the market forces that will demand these changes.

What CRC CI project 2001-011-C confirmed is that a triple bottom line assessment approach to built asset performance can be grounded on the development of innovative benchmarks. Moreover, the benchmarks developed in the project were found to be measurable and appropriate for high-rise office buildings. This finding supports the claim that the sooner complete and objective triple bottom line built asset guidelines are adopted, the sooner the property industry is likely to recognise that the provision of a safe, harmonious and productive built environment for people is not negotiable.

It is broadly agreed that rating systems are a powerful driver of environmentally sustainable built asset performance. There is very useful research emerging detailing the costs and financial benefits of improving the sustainability of buildings.³⁴ However, much more research needs to be undertaken to help determine the market implications of these innovations, and particularly the economic implications of efforts to satisfy the environmentally and socially sustainable benchmarks like those advanced in this paper. It is only when it can be emphatically demonstrated to property investors and managers that such efforts are not just affordable but have significant performance benefits and actually contribute to higher returns and premium values that the triple bottom line will be expressed by more than just lip-service. Assuming this occurs soon, which appears highly likely, triple bottom line frameworks are set to become an integral part of the valuation approach for investment-type buildings.

³⁴ See for eg. Greg Kats et. al. (2003) 'The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force,' unpublished.

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STAKEHOLDERS

Full paper

INDUSTRY CULTURE: CHALLENGES TO THE SUCCESSFUL IMPLEMENTATION OF INNOVATIVE CHANGE

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ABSTRACT

Research indicates, one of the last available 'mechanisms' left for organisations to improve their competitive position within an industry, is by considering its people (culture) along with its technology (Schein E. H. 1997). In other words, if one wants to make Architectural, Engineering, and Contractor (AEC) industry organisations, groups and project teams more efficient and effective, then one must better understand the role that culture plays within them. Furthermore, culture inevitably is difficult to change and manage, as it essentially represents the accumulative beliefs, attitudes and values that individuals within an organisation, group or team possess, which must ultimately be changed if the overall culture is to be changed. Leaders of a change process need to realise that most changes within an organisation will usually cause and expect some change in its existing culture and sub-cultures – i.e. change in certain values, attitudes, assumptions, and behaviours, etc. Therefore, having a better understanding of the effects change has on the sub-cultures of an organisation, group or team, will in turn help leaders of a change process better understand the resistance towards the change itself, and provide a more realistic approach on how to manage it.

Future development in determining new and improved ways for AEC industry participants to do business through information and communication technology (ICT) tools and systems is dependent on the innovation of the user, not only the technology itself – i.e. the successful implementation of ICT requires careful consideration to the 'human touch'. The success of technological developments, in terms of uptake and usage, can be improved if the conditions of innovation diffusion within project organisations, parent organisations, and the broader AEC industry are better understood and brought into play. This includes the matching of technological innovation with the perceived needs and preparedness for change on the part of the industry.

Supporting its aims and objectives, and as a major deliverable of the recently completed two year industry and government supported CRC for Construction Innovation (CRC CI) 2001-008-C Research Project, this paper provides:

- A summary of one of its recently completed literature investigation into the unique and 'deeply embedded' cultures of today's AEC and other industry sectors - in an attempt to better understand the inherent resistance to change; and
- 24 'Guiding Principles' on how today's AEC industry can achieve and benefit from both a cultural and technological driven change.

This paper is not intended as a comprehensive statement of the AEC industry's need or ability to change its existing culture. Rather, it provides an overview based on a comprehensive literature review of 'general' industry organisation experiences, characteristics and cultural attributes towards implementing a cultural and technological driven change. It is also part of an ongoing PhD investigation – identifying and analysing AEC industry organisation and project team member values, attitudes and beliefs, etc. towards change - to help develop an AEC industry specific 'Culture Change Framework' which addresses the key cultural issues that challenge the adoption of innovative ICT solutions within project teams.

Key words: Technology; Culture; Change; AEC Industry.

INTRODUCTION

Over the past decade, the word 'culture' has dominated the thinking of many managers and become an integral part of their everyday language. That is to say, today's global competitive business environment has made the culture of an organisation a critical aspect of its success (Sadri G. and Lees B. 2001). Every organisation has its own unique culture, sub-culture, character, nature, and identity. It has its own history of success and failures, which reinforces or challenges the organisation's 'way of doing things'. Older and more successful organisations, for example, are said to have stronger cultures, natures, and identity (Meudell K. and Gadd K. 1994; Schneider W.E. 2000). Yet, despite the growing awareness of various cultural issues, little attention is paid to the practical, day-to-day process involved in creating, managing and changing culture (Williams A., Dobson P. et al. 1993).

Research indicates, one of the last available 'mechanisms' left for organisations to improve their competitive position within an industry, is by considering its people (culture) along with its technology (Schein E. H. 1997). In other words, if one wants to make construction industry organisations, groups and project teams more efficient and effective, then one must better understand the role that culture plays within them. By employing a dedicated, highly skilled, flexible, co-ordinated, committed and productive workforce, coupled with a leaner, flatter and more responsive organisation, will ensure a more effective and successful implementation of innovative ICTs (Morley M. and Heraty N. 1995). Current 'secretive' organisational cultures, for example, who see information as a source of power, influence, and importance, and made available only on a 'need-to-know' basis, are to 'transform' themselves into more 'open cultures' where, whilst a degree of control is maintained, there is an atmosphere of mutual trust and respect within and between organisations (Baines A. 1998). Unfortunately, this transformation of personalities (culture) and traditional processes is not easy (Michel H.L. 1998), characteristically hindered by the industry's unique and determined way of 'doing things' the way it always has, and by its deeply embedded and resistive nature to change.

RESEARCH BACKGROUND

Four decades of international construction industry reports reinforce poor communication, information transmission; coordination; and teamwork issues are the cause of countless performance problems in the construction industry. Failure to achieve significant improvements in what are well-identified issues can be linked to the hitherto limited capacity to conceptualise and manage the very complex dynamics in project processes throughout the project's life cycle.

Debatably, today's industries, businesses and personal worlds are dominated by a wide range of technologies and e-activities, including: computers, email, Internet, Web sites, etc., finding it more and more difficult to function without them. Yet, the success of any profession is described as going beyond simply exchanging electronic information. Successful implementation of innovative information and communication technology (ICT) requires careful consideration to meet industry needs - where future research and developments (R&D) in determining new and improved ways of doing business through innovative ICTs, is dependent on the innovation of the industry (and end user), not only the technology itself – i.e.: matching technological innovation with the perceived needs and preparedness for change on the part of the industry. Consequently, there is an urgent need to address those key issues that will most significantly influence the construction industry and

the way in which it contributes to our society and the economy as a whole in the future.

In an attempt to demonstrate leadership in implementing a cultural and technological driven change within the Architectural, Engineering, and Contractor (AEC) industry, the main objectives for the two year industry and government supported CRC for Construction Innovation (CRC CI) 2001-008-C Research Project included:

- Identifying, examining and better understanding the 'deeply embedded' culture of today's AEC industry, its organisations, teams and participants - by focusing on human and cultural factors, limitations, barriers, and drivers as they arise from this investigation.
- Developing a set of research and industry recommended Culture Change Guiding Principles that will foster the expansion of an ICT adaptive culture - thereby stimulating stakeholder efficiencies and encouraging the wider adoption of innovative ICTs in the building and civil construction sectors.

CULTURE

Being "one of the last mechanisms" for organisations to enhance themselves within an industry (Schein E. H. 1997), the study of an organisation, group or team's culture is important:

- Culture focuses on communication at all levels of a hierarchy, where individuals identify who they are in relation to one another and their environment, and where shared understandings form identifiable subgroups / sub-cultures.
- By focusing on culture, one inevitably focuses on the daily routine and 'sense-making' that is the process of building identities and shared reality among members.
- A cultural approach focuses on largely ignored issues such as assumptions and brings underlying values and motives to the surface.
- The understanding of culture offers a better insight to the managers and leaders – not in order for them to better shape the culture, but to better understand and participate in the 'sense-making' activities of members.
- Undertaking a cultural approach will help identify novel approaches and understandings of future organisations, groups and teams.
- Finally, culture is pervasive, not simply a variable that affects the organisation, group or team, but indistinguishable from it (Pepper G. L. 1995).

Culture is also identified as one of the most difficult and complex approaches to understand. This is mainly due to culture being defined in so many different and sometimes conflicting ways (Pepper G. L. 1995):

- *"Begins to form wherever a group has enough common experience" which in turn becomes the "property of that group"* (Schein E. H. 1999) p13.
- *"Is influenced by traditions, myths, history and heritage...it is the sum of how we do things around here"* (Hensey M. 2001) p49.
- *"Pervades the decision-making and problem-solving process of the organisation, influencing the goals, means and manner of action...a source of motivation and de-motivation, of satisfaction and dissatisfaction, thereby underlining much of the human activity in an organisation"* (Williams A., Dobson P. et al. 1993) p15
- *"Is a pattern of shared basic assumptions that has been learnt whilst solving problems, that has worked well enough to be considered valid and, therefore, to*

be taught to new members as the correct way to perceive, think, and feel in relation to those problems” (Schein E. H. 1997) p12

When it comes to people, culture is identified as “a set of mores, values, attitudes, beliefs, and meanings that are shared by the members of a group or organisation” (Williams A., Dobson P. et al. 1993; Duarte D. L. and Snyder N. T. 2001), and is often the primary way in which one ‘group’ (organisation, team, etc) differentiates itself from others. Further described as influencing and influenced by various issues, ranging from major strategic decisions down to the layout of the offices or the way members of an organisation, group or team address one another.

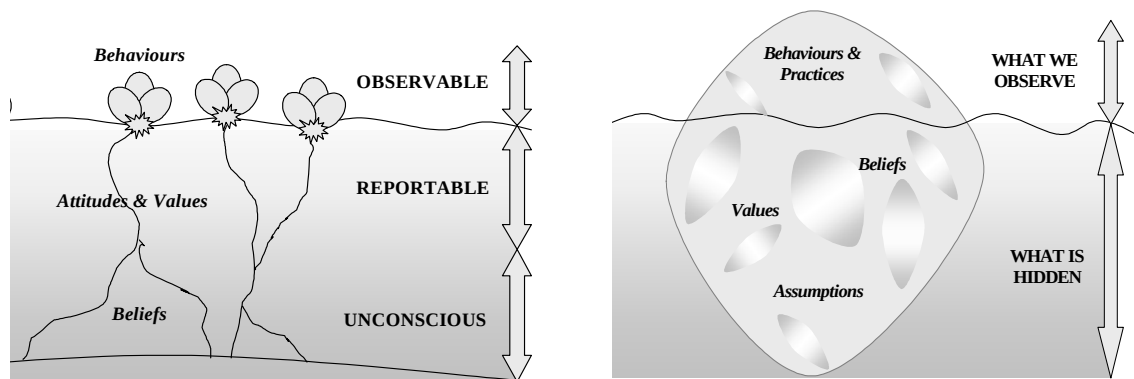
CHARACTERISTICS

The characteristic patterns of a group’s behaviour and the elements of its culture can be portrayed via two diagrams (Figure 1):

- **Lilly pond:** where over time, behaviours and elements become ‘invisible’ and ‘second nature’ - serving as ‘shortcuts’ for guiding actions and making decisions.
- **Iceberg:** similarly exposing a partially ‘hidden’ culture created by repeated interactions between members of a group, which in turn, guides their behaviours.

In short, the two diagrams illustrate the behaviour, attitudes, and values, etc. of people, which in turn are dependent upon both their ‘conscious’ and ‘unconscious’ sets of beliefs, and seen as a ‘key element’ of organisational culture.

Figure 1: The ‘Lilly Pond’ and ‘Iceberg’ of Culture and Behaviour

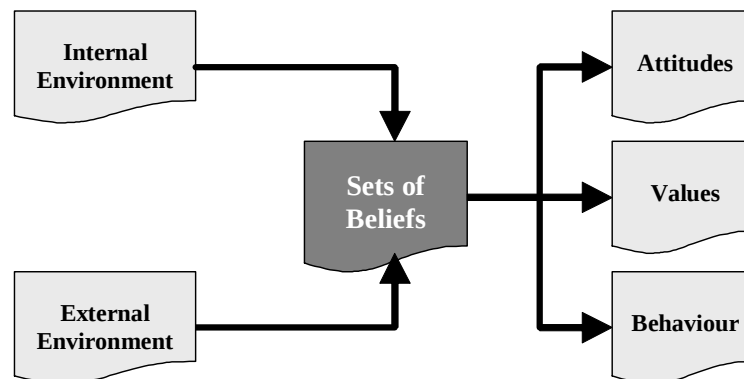


(Williams A., Dobson P. et al. 1993) and (Duarte D. L. and Snyder N. T. 2001)

The ‘relationship’ between these beliefs, attitudes, behaviours and values of people is summarised in

Figure 2. Here culture is portrayed as '*defined needs related to behaviour*', and consequently related to that of organisational behaviour. Further illustrating that the attitudes, values and behaviours of members of an organisation or team are dependent on the level of internal and external 'influences' on the '*sets of beliefs*' they possess, which in turn underlie individual attitudes, values and behaviours relating to a specific person, action (change) or object.

Figure 2: Relationship between Belief, Attitude, Values and Behaviour



(Williams A., Dobson P. et al. 1993)

CULTURE 'BRANDING'

Industry organisations should also take care not to simply 'brand' a group or team as having either a 'strong' or 'weak' culture, and rather ask themselves, for example: "is it a strong culture..."

- Because its central beliefs and attitudes are strongly held?; or
- Because they are common to all groups (homogeneous)?; or
- Because it promotes overall effectiveness?

The 'non-branding' of culture is also supported in (Bate P. 1996), describing a 'strong' culture as having employees with increased authority and responsibility, who can be relied on to set their own standards and discipline, and where this 'freedom' is conditional upon the ability to 'deliver'. In addition, (Williams A., Dobson P. et al. 1993) defines the strength of an organisation's culture as the extent to which members have 'internalised' the beliefs, attitudes and values that exist within the organisation – i.e.: whereby individuals undergo a 'reasoning process' to mutually accept, agree with, own and value the beliefs, attitudes and values of other members. Further stating strong cultures are characterised by "*dedication, spontaneity and cooperation in the service of common values*" that can operate in direct conflict with the goals of senior management and other sub-cultures. That a strong culture is unlikely to be 'imposed', but rather 'fashioned' through the availability of valid information, openness, trust and free choice. Therefore the internalised beliefs, attitudes and behaviours of a 'strong' culture is less likely to change, where as in the case of a 'weak' culture, changes in policies, rewards, tasks and structures are likely to "*modify organisational behaviour and cause a cultural shift*".

CHANGE

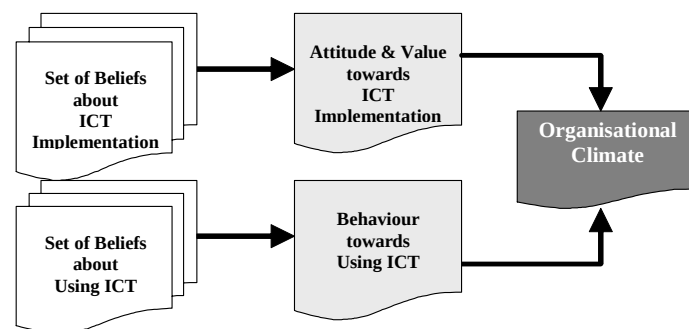
*"When we know what culture is, we know what needs to be changed for culture to change.
Only once we appreciate its nature can we understand how it might be changed.
When we know its role, we can comprehend its importance"*

(Williams A., Dobson P. et al. 1993) p11.

IMPLEMENTING CHANGE

When implementing change – e.g. a new ICT system or process - the 'climate' of an organisation, team or group is also influenced by the relationship between how members would like or ought to behave and what the work environment dictates that they do, in relation to that implementation (Figure 3). Of course, employees or team members can be forced to comply to *'the new way of doing thing around here'*, but usually at a price. On the other hand, if employee and employer (or change agent) attitudes, values and behaviour are in harmony, then a stronger and more effective culture is likely to result, where members are committed to the overall change, goals and methods of the organisation, group or team (Williams A., Dobson P. et al. 1993).

Figure 3: Change vs. Organisational Climate



Adapted from (Williams A., Dobson P. et al. 1993)

NEED FOR CHANGE

*"If you do not see a truck racing towards you, you are unlikely to jump out of the way...
...likewise, if you do not realise that you are standing on a treasure of gold...
...you are unlikely to bend down and pick it up"*
(Black J. S. and Gregersen H. B. 2002) p20

The above extract reinforces the importance for organisations, groups and teams to realise the 'need' for change, before the act of change can take place. Unfortunately, to be convinced of the need for change is easier said than done, because people tend not to see even the most obvious threats and opportunities because they are 'blinded' by the *'way we have always done things around here'*. Many organisations decide to change their existing culture based on the need to implement a strategically driven change, due to a certain 'crises' or 'opportunity' being identified – i.e.: many organisations are driven to change due to business demands, not necessarily by the need to change culture. Yet, this change strategy requires a change in organisational objectives, work methods, habits, systems, structures, training, and the way people *'think or do things around here'* (i.e. culture). The successful realisation of the need for a change in culture can therefore promote a strategic change, but if not properly implemented and managed, both existing and 'enforced' culture groups may constrain a new business strategy (Williams A., Dobson P. et al. 1993; Bate P. 1996; Schein E. H. 1999).

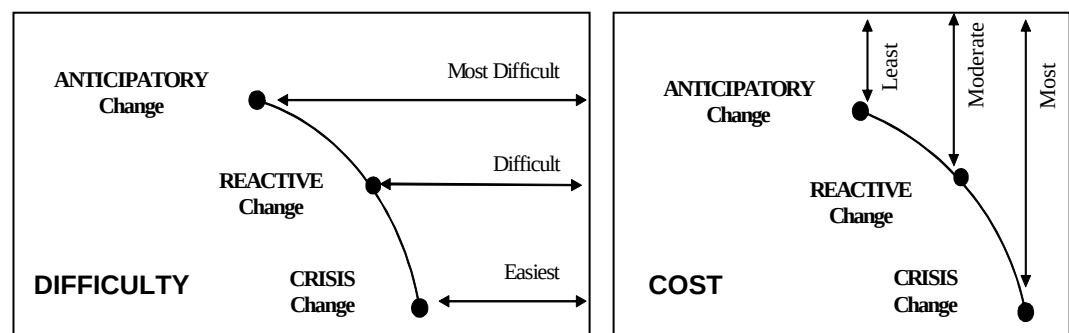
"If people fail to see the need for change (whether threat or opportunity drives it), they will not change"
(Black J. S. and Gregersen H. B. 2002) p20.

TIME VS. COST

Research also shows the timing and cost effectiveness of implementing the following three types of change process or method could determine the success or failure of a change (Figure 4):

- **Anticipatory:** *When organisations look ahead and predict change in advance – i.e.: anticipating the need for change.* This is the most difficult of the three approaches to start and finish due to difficulty in sensing future threats and opportunities or what unpredictable course they may take. Unknown return on investments is also a major reason why organisations avoid this process. However, if executed correctly, this change tactic can present the greatest potential benefits and lowest cost to a firm, and when change involves steep and ongoing learning, then the sooner a firm starts changing, the greater will be the firm's advantage over the 'slower-to-change' competitors.
- **Reactive:** *When organisations react to the obvious signs and signals that change is needed – i.e.: by observing customers, competitors, shareholders, employees, etc.* This seems to be the most common approach. It is slightly easier to get underway than the 'Anticipatory' change and less costly than the 'Crisis' change (below), due to a more certain change opportunity being identified before the organisation's 'survival' is a critical factor in decision-making. Organisations with a reasonable 'agility' to change at short notice can benefit greatly by responding to change as a 'quick second mover' rather than a 'slow first mover'.
- **Crisis:** *When signs and signals to change have multiplied and intensified to the point where the organisation no longer can deny them – i.e.: where the need or opportunity for change has been ignored for too long, and where competitors have already begun to change.* The longer an organisation ignores this need or opportunity for change, the less chance of survival and competitive edge. Although this type of change is the easiest, it usually costs money, shareholder value, customer value, and jobs.

Figure 4: Difficulty vs. Cost of Change



Adapted from (Black J. S. and Gregersen H. B. 2002)

CHANGE METHODS

Changing the culture of an organisation and its members takes time. That is because it is a slow process for people in existing or newly established 'social systems' to develop a new set of common held beliefs, attitudes and values (Williams A., Dobson P. et al. 1993). Today's industry organisations are using a wide variety of mechanisms in an attempt to change their culture. The identification of the aforementioned 'crisis' and 'opportunity' factors, for example, are echoed in (Whyte J.

2002), stating there are two major methods to create the need for change – i.e.: motivating people to change:

- When they are confronted with real or perceived **threats** (e.g. job security, increasing competition, etc), which in turn motivate short-term behaviours.
- Through real or perceived **opportunities** (e.g. improved profitability, greater productivity, increased employee development, etc), which in turn motivate long-term behaviour within an organisation.

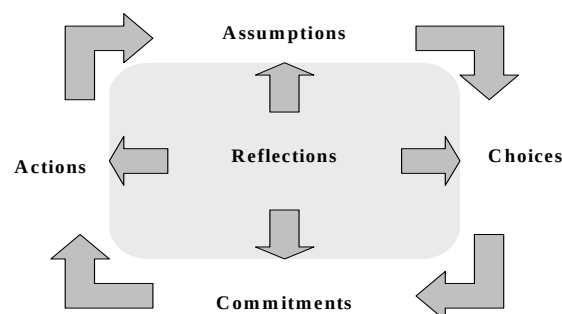
Importantly, the real or perceived threats and opportunities will vary from organisation to organisation, where certain key threats and opportunities are better or worse for one but not the other. Further investigations identified a number of alternate key approaches of changing the culture of an organisation (see Guiding Principles).

CHANGE PROCESSES

Investigations identified a number of analytical frameworks used to describe the process of culture change, including:

- **Change Process Model:** enabling organisations to facilitate substantial change and improved implementation via five critical activities, which in turn help ensure long-term effects:
 - Identifying Assumptions: Assumptions can be considered as the '*taken for granted*' beliefs that individuals have about reality, which guide their actions and are to be isolated and fully understood before an organisation will advance and accept any change.
 - Analysing Choices: This includes examining how decisions are made, who participates in the decision-making process, what criteria are used, and what consequences follow the choices made.
 - Making Commitments: Requires choosing between two or more desirable outcomes. Leaders and their employees must then determine which of the positive outcomes they desire most and which they are willing to allocate financial and human resources over a lengthy period.
 - Selecting Appropriate Action: Where organisations take definite actions to help satisfy their assumptions, choices and commitments.
 - Engaging Critical Reflection: Where organisations attempt to understand why they made certain decisions, but perhaps more importantly, how to improve upon that action (Figure 5).

Figure 5: Change Process Model

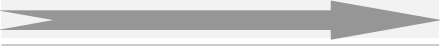
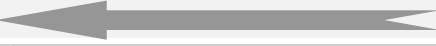


(Gilley J. W. and Maycunich A. 2000)

- **Force Field Model:** Based on early 1950's research into changing behaviours of individuals and social systems, (Williams A., Dobson P. et al. 1993) elaborated on

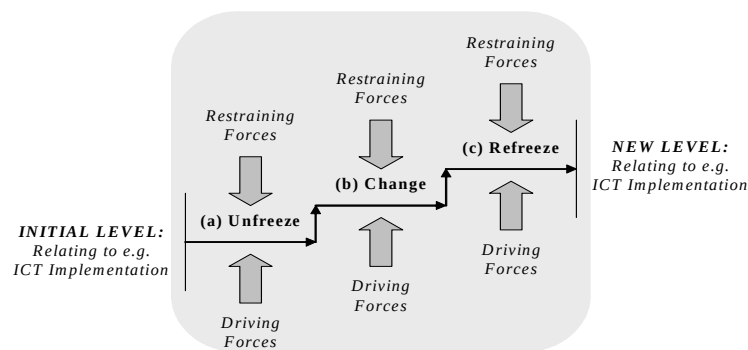
a model portraying two sets of forces (driving and restraining) to help bring about change. Firstly, one is encouraged to identify the various forces impeding on the change 'target' (e.g.: implementing an innovative ICT solution or process); secondly, one is encouraged to consider the relative strengths of these forces, and finally it helps one explore alternate strategies to 'modify' these forces (Table 1).

Table 1: Forces of Change

DRIVING FORCES (eg)	RESTRAINING FORCES (eg)
	
Change at the top	Career-based organisation
Powerful external influence	Low turnover
Powerful leader	Stable environment
Crisis or opportunity	Lack of clear authority
Acceptance of need to change	Blindness to the need to change

- **Three-Stage Model:** Again based on early 1950's research and elaborated on by (Williams A., Dobson P. et al. 1993) and (Schein E. H. 1997), is yet another useful and 'revolutionary' mechanism in bringing about change in culture. Achieved by firstly, 'unfreezing' existing forces, secondly, introduce change (geared to re-establishing the 'equilibrium of forces') and finally, to 'refreeze' the new situation (Figure 6).

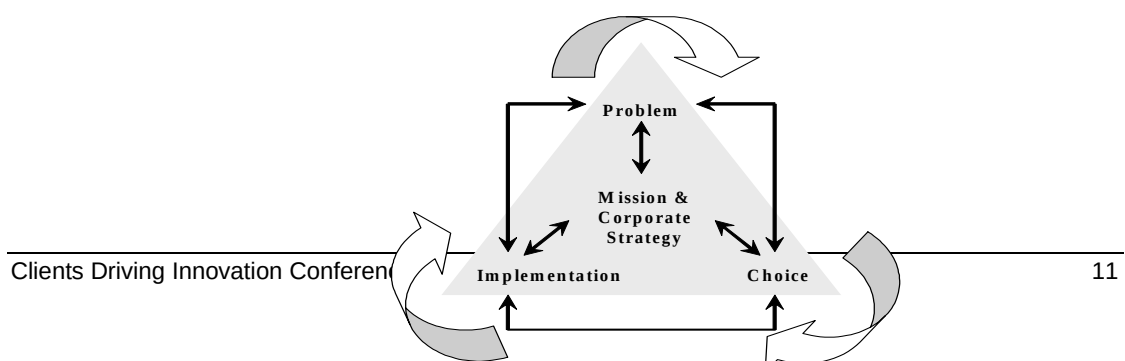
Figure 6: Three-Stage Model



Adapted from (Williams A., Dobson P. et al. 1993) and (Schein E. H. 1997)

- **Decision Making Model:** Described as a common and rational tool used to encapsulate the various stages management teams go through in solving organisational problems or in developing new opportunities in a change process (Figure 7) (Williams A., Dobson P. et al. 1993).

Figure 7: Decision Making Model



(Williams A., Dobson P. et al. 1993)

Due to their very simplicity, the above change models / processes can be applied to a wide range of applications, whether at a group, team, individual or organisational level, and highlight the importance of a number of considerations in managing change.

GUIDING PRINCIPLES

Supporting the research aims and objectives, and as a major deliverable for the Construction Innovation 2001-008-C Research Project, the research team identified - via an extensive literature investigation – 24 'general' 'Culture Change Guiding Principles'. These principles are meant to introduce stakeholders and change leaders to the underlying need to transform the AEC industry's deeply embedded culture and resistive nature to technologically driven change, as well as provide a 'preliminary guide' on how to adopt a more technology and culture driven change 'philosophy' (Table 2).

Table 2: Culture Change Guiding Principles

24 GENERAL CULTURE CHANGE GUIDING PRINCIPLES		
#	OUTLINE	RECOMMENDATION
CC1	Harmonise Attitudes, Values and Behaviour	If member attitudes, values and behaviour are in harmony, then a stronger and effective culture is likely to result, where members are committed to the overall change, goals and methods of the organisation, group or team (Williams A., Dobson P. et al. 1993).
CC2	Understand the 'Role' of Culture	To make industry organisations, groups and project teams more efficient and effective, one must better understand the role that culture plays within them (Williams A., Dobson P. et al. 1993) (Schein E. H. 1997).
CC3	'Culture' is Never 'Singular' Always 'Plural'	Attempts to change the 'whole' culture of an organisation must be abandoned, because every culture is made up of a whole range of mentalities and sub-cultures, all of them different, and at different stages of development (Bate P. 1996).
CC4	Identify the Need for Change	It is import for organisations, groups and teams to realise and create a 'need' for change, before the act of change can take place (Black J. S. and Gregersen H. B. 2002).
CC5	Motivate People	People are 'motivated' to change when they are confronted with

		real or perceived 'threats' and/or 'opportunities' (Whyte J. 2002).
CC6	Suitable Change Strategy	To ensure successful change in culture, a suitable change strategy needs to be identified and properly implemented and managed, which in turn can promote a new business strategy (Williams A., Dobson P. et al. 1993; Bate P. 1996; Schein E. H. 1999).
CC7	People and Places	People in key positions may need to be changed, moved or rotated to ensure successful change in culture within an organisation (Williams A., Dobson P. et al. 1993).
CC8	People's Beliefs, Attitudes and Values	To ensure successful change in culture, individual beliefs, attitudes and values may need to be altered by applying one or more suitable change methods (Williams A., Dobson P. et al. 1993).
CC9	Structures, Systems and Technology	An organisation's existing communication network may entail restructuring, and require the implementation of an improved reward, appraisal, monitoring, budgeting and/or control systems to ensure successful change in culture (Williams A., Dobson P. et al. 1993).
CC10	Corporate Image	Promote an improved corporate image to help develop positive attitudes between both customers and staff, which in turn will enhance overall commitment towards the organisation (Williams A., Dobson P. et al. 1993).
CC11	Invest in People	To ensure successful change in culture, organisations need to improve their attitude and performance towards respecting and recruiting their people in order to retain their best talent (Rethinking Construction 2000) (Linowes J.G. 1999).
CC12	Create a Feeling of 'Shared Ownership'	Employee participation is essential to ensure increased commitment and 'feeling of ownership' towards the implementation of a culture change process (Baines A. 1998).
CC13	Suitable Culture Change Process	To ensure successful change in culture within an organisation, a suitable change process needs to be identified, properly implemented and managed (Lewis P. and Thornhill A. 1994).
CC14	Timing of Change	Timing and cost effectiveness of implementing a change process or method in an organisation determines the success or failure of change (Black J. S. and Gregersen H. B. 2002).
CC15	'Align' technology with people	Understanding the 'interconnections' between technology and people (culture) is essential during the implementation of a technologically driven culture change process. This can be achieved by: (a) designing the technology to fit the organisation's current structure and culture, or by (b) reshaping the organisational structure (processes) and its culture (people) to fit the demands of the new technology (Cabrera A., Cabrera E.F. et al. 2001).
CC16	Promoting an 'Electronic' Culture	Organisations need to investigate and implement a suitable 'transition strategy' to help ensure a technological driven culture change – i.e.: assisting an organisation in its transition from existing / traditional business operations and processes, to industry required (electronic) operations and processes (Grenier R. and Metes G. 1995).

CC17	ICT Champion	An organisation pursuing technological driven advancement or change requires strong support from an ICT champion (preferably senior management within the organisation) to undertake and lead the difficult task of managing its impact upon organisation structures and cultures (<i>Tantoush T. and Clegg S. 2001</i>).
CC18	'Three Cornerstones' of Successfully Implementing Innovative ICT	Industry organisations are to consider three success factors when implementing ICT: (a) Vision: A durable vision of the change process is required to ensure progress - shared with top management, construction managers, developers and ICT staff. (b) Commitment: Obtain overall commitment from top management, construction and ICT managers (re allocation of financial and human resources). (c) Possibilities: apply a 'migration strategy' that enables ICT staff to balance the ICT strategy with the companies business needs, thereby underwriting the success of the change process (<i>Myllymaki R. 1997</i>).
CC19	ICT Implementation Strategies	Construction industry executives and management need to consider various ICT implementation strategies, and select the one that best serves the needs of the application and its users (<i>Paulson B.C. 1995</i>).
CC20	Overcome Fear	The construction industry is to lesson and ultimately remove the fear of 'exploitation' of technology-led innovation (<i>CRISP 2000</i>).
CC21	'Camouflaging' Change	It is important for implementers of an innovative ICT tool or system, not to 'camouflage' the true nature of a change prior to its implementation – i.e.: not to portray the change as less dramatic and positively beneficial to the employees and the company (<i>Hughes T., Williams T. et al. 2000</i>) (<i>Kaerst-Brown M.L. and Robey D. 1999</i>).
CC22	Promote ICT Adoption Benefits	The construction industry will increase and strengthen the rate of technological adoption by promoting its benefits, developing and running short courses, establishing industry-wide awards for ICT best practice, and taking relevant action (<i>Fujitsu Centre 1998</i>).
CC23	Continued Training and Education - A Must	Construction industry organisations need to become learning organisations - attuned to absorbing and using knowledge and providing for lifelong learning (<i>Foresight 2000</i>) (<i>Kajewski S.L., Weippert A. et al. 2002</i>).
CC24	Enhanced Tertiary Training and Education	Tertiary education (both undergraduate and postgraduate) is to further develop and support the understanding of how to evaluate and implement technological and cultural change and innovation within construction industry organisations (<i>CRISP 2000</i>) (<i>Kilby T. 2001</i>).

FUTURE RESEARCH

This report provides an overall snapshot of 'general' industry organisation experiences, characteristics and attributes towards implementing a cultural and

technological driven change. It is also part of an in-depth PhD investigation into AEC industry specific organisation and project team member values, attitudes and beliefs, etc. towards a technology driven culture change. This on-going PhD research investigation will further identify and analyse various AEC industry team culture (a) driving and restraining forces; (b) threats and opportunities; whilst (c) considering various proven and innovative change methods / processes (similar to those highlighted in this paper) in order to develop, test, trial and evaluate an effective, easy to use, but more important, AEC industry specific 'Culture Change Framework' that team leaders can strategically implement to help address key cultural issues that challenge the adoption of innovative ICT solutions within project teams. This in turn will help ensure the successful adoption of technologically driven change, and significantly influence and enhance a project team's ability to meet its objectives.

CONCLUSION

Based on the literature provided, initial investigations concur, AEC industry organisations and teams will change only as far and as fast as its collective individuals are willing to change. This is because people are and always will be 'instinctively programmed' to resist any form of change. To change any organisation or team strategically and successfully, one must first attempt to change individual beliefs, attitudes and values (i.e.: culture) before the organisation or team as a whole can benefit (Black J. S. and Gregersen H. B. 2002). Yet, culture is identified as not a sure or stand-alone remedy to achieve, for example, improved organisational performance - described as being '*complex*', '*multi-levelled*' and '*deeply rooted*' – and a concept that must be observed and analysed at its every level before it can be fully understood or successfully changed and managed (Williams A., Dobson P. et al. 1993; Schein E. H. 1999). Therefore, when examining or attempting to change an existing culture, industry organisations are to keep in mind that 'culture' is never 'singular' and always 'plural'; that every culture is made up of a whole range of mentalities and sub-cultures; all of them different and at different stages of development (Bate P. 1996).

The development of an adaptive and innovative culture is characterised in this paper as one of several critical and mutually reinforcing variables and activities which organisations must implement and manage effectively. In order to achieve this, industry organisations need to define their objectives; decide on how best to achieve them; develop effective tools to evaluate the progress; and finally, learn how to do this against a background of constant change (Williams A., Dobson P. et al. 1993). Further suggesting AEC industry organisations not only manage change, but also develop their collective capabilities in order to turn continuous change into competitive advantage. This, according to (Grenier R. and Metes G. 1995), can be accomplished by letting go of current 'managing change beliefs', and by building an innovative and adaptive culture that can work within a continual change environment. Many organisations decide to change their existing culture based on the need to implement a strategic driven change, due to a certain 'crises' or 'opportunity' being identified – i.e.: many organisations are driven to change due to business demands, not necessarily by the need to change culture. Yet, this change strategy requires a change in organisational objectives, work methods, habits, systems, structures, training, and the way people '*think or do things around here*' (i.e. culture). The successful change in culture can therefore promote a strategic change. However, if not properly implemented and managed, both existing and 'enforced' culture groups may constrain the new change strategy (Williams A., Dobson P. et al. 1993; Bate P. 1996; Schein E. H. 1999).

This paper recognises an increase in the relevance and importance of culture and the need for it to be changed, in turn reinforcing the need for continued efforts in identifying ways for the AEC industry to cope with, and eventually overcome, its resistance to change. The 24 general 'Culture Change Guiding Principles' identified during this investigation is the first of many stages in developing a set of AEC Industry Specific Best Practice Guidelines that will assist industry stakeholders in transforming their deeply embedded and resistive nature to technologically driven change, into a more 'technology adoptive', flexible, and continuously evolving culture.

Finally, by encouraging the use of innovative ICT solutions; identifying practical and effective ways in which people can improve their performance; and by determining improved and strategically driven ways of aligning technology and people (culture) - will undoubtedly help increase the overall knowledge, awareness and skills, of all industry stakeholders in bringing about a much needed change.

*"If you are serious about managing culture...
...the biggest danger you face is that you not fully appreciate its depth and power."
(Schein E. H. 1999) p185*

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CONFERENCE THEME: VISUALISATION AND INFORMATION

Full paper

SUPPORTING COLLABORATION AND MULTIPLE VIEWS OF BUILDING MODELS IN VIRTUAL WORLDS

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ABSTRACT

Collaboration in virtual environments has the potential to support communication and collaboration in multi-disciplinary teams. Current software for documenting and developing models of buildings focuses on supporting a single user who is a specialist in the specific software used within their own discipline. In this paper we report on the research, and a proposed approach, in supporting multiple disciplines in virtual worlds. We emphasise that the views and models are founded on the functional concerns of designers and the concerns are discipline specific. An agent-based approach to representing multiple views is described, along with a virtual world environment that supports communication and collaboration. In order to prototype and develop a collaborative environment, we consider simple models in an inherently multi-user virtual world.

Keywords: Collaboration, Multiple Views, Virtual Worlds, Agents

1. INTRODUCTION

Current software tools for documenting and developing models of buildings focus on supporting a single user who is a specialist in the specific software used within their own discipline. Such tools tend not to be multidisciplinary and not foster collaboration. Collaboration in distributed virtual environments has the potential to support communication and collaboration in multidisciplinary teams if a suitable design infrastructure could be added. Collaborative Virtual Environments (CVE) provide one kind of infrastructure to support communication and collaboration.

A Collaborative Virtual Environment (CVE) is a computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents or with virtual objects. CVEs might vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, text-based environments, to combinations of these (Li and Maier, 2000). Figure 1 shows, by way of example, the prototype CVE that we are developing. To facilitate distributed collaborative designing, a number of features are required. These can broadly be classified as either facilitating artefact modelling or as facilitating communication and collaboration.

CVEs, such as the Active Worlds¹ one shown in Figure 1, facilitate communication and collaboration by providing mechanisms for shared context, awareness of others, visual and textual communication, immersive manipulation of constructed artefacts, and a fostering of community design. What current CVEs do not provide are mechanisms for reasoning about artefacts and the representation of different views or properties by practitioners from different disciplines. This paper reports on the research, and a proposed approach, in supporting reasoning about, and representation of, different views in virtual environments.

¹ <http://www.activeworlds.com>

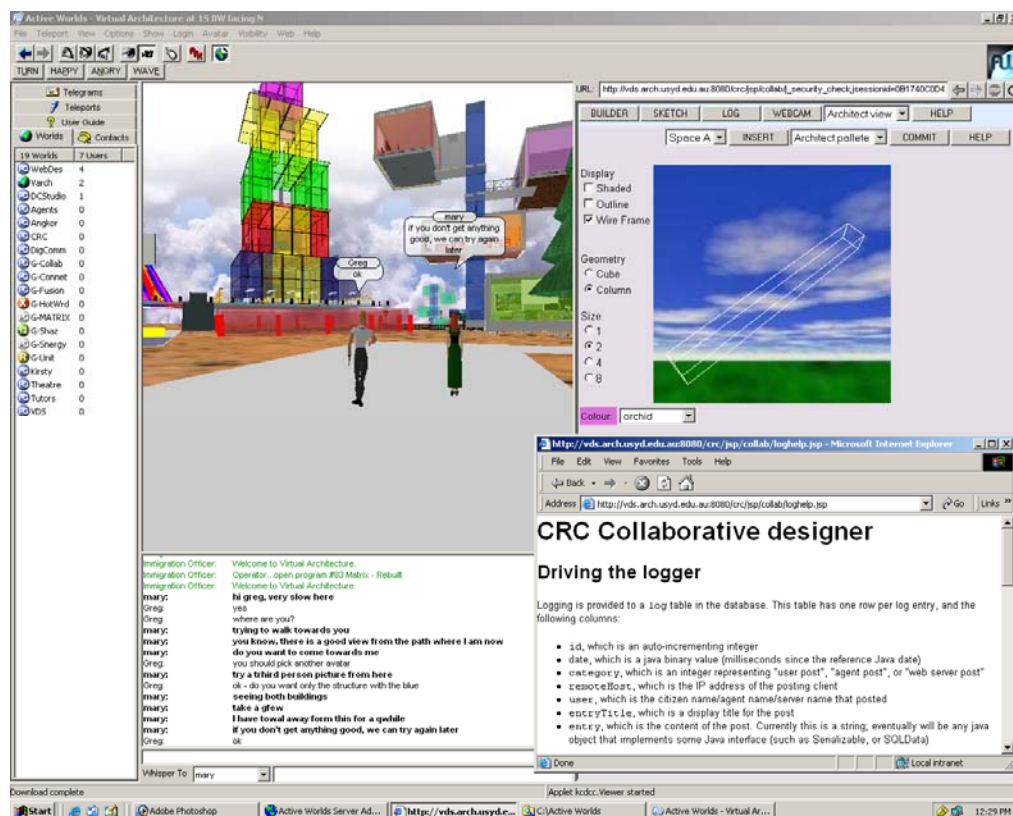


Figure 1. Virtual Worlds and the prototype CRC Collaborative Designer

In this paper, Section 2 considers representing the multiple views of a single design artefact that may be held by practitioners from different disciplines involved in a project. Discipline models allow each discipline to work according to its own concepts and representations, with a common model providing for the integration required between models. Section 3 describes an approach where role-based agents provide the reasoning mechanism that connects the visualization of the objects in the virtual world with the discipline and common artefact models in a database. Section 4 introduces a scenario to illustrate these ideas using simple conceptual design artefacts.

2. REPRESENTING MULTIPLE MODELS

A model of an object is a representation of that object resulting from a particular view taken. Given a design object, such as a building, there are many views that may be taken, leading to different conceptual interpretations. For example, a building may be viewed as a set of activities that take place in it; as a set of spaces; as sculptural form; as an environment modifier or shelter provider; as a set of force resisting elements; as a configuration of physical elements; etc. A building is all of these, and more. For each different view of a building there will be a corresponding model, as illustrated in Figure 2.

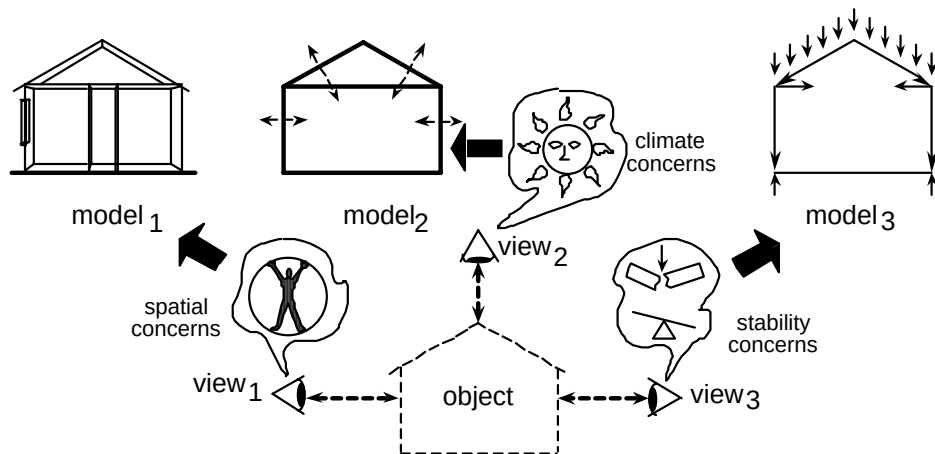


Figure 2. Multiple views and models.

Depending on the view taken, certain properties and descriptions of the object become relevant. The sound insulating properties of a wall are not relevant to a structural engineer's description of that wall. In fact, many walls may not be relevant at all to a structural engineer if they do not either contribute directly to the stability of a building or indirectly by providing a substantial load. The architects will model certain elements such as floors, walls, doors and windows. For the architects, these elements are associated with the spatial and environmental qualities with which they are concerned. Structural engineers, however, see the walls and floors as elements capable of bearing loads and resisting forces and moments. Both models must coexist since the two designers will have different uses for their models. For example, the structural engineers will need to carry out calculations based on their model while the architects may need to ascribe different properties to their separate wall elements. According to Bucciarelli (2003) "There is one object of design, but different object worlds." And "No participant has at any stage in the process, a comprehensive, all-encompassing understanding of the design. No participant has a 'god's eye view' of the design." The engineers may modify some of the properties assigned to elements by the architect and may add some new elements, such as beams and columns. The addition of such new elements may affect the architect's model (and vice versa). Any such decisions taken by the engineer must be conveyed to the architect by making changes in the architect's model as appropriate. It will be shown that such changes in another discipline's model can be done when the change affects a function which is the concern of that discipline.

There exists considerable work using a single model approach based on the construction of a model from 'primitive' elements from which multiple interpretations are derived (Howard et al., 1992; Amor and Hosking, 1993; Clayton et al., 1994; MacKellar and Peckham, 1994). This approach is analogous to the formation of views in database management systems. However, it is argued that this approach is insufficient, since the 'primitive' elements themselves are subject to the views taken by the different viewers and hence different primitive models are constructed by each such viewer (Rosenman et al. 1993; Rosenman and Gero, 1996). Since the basic description of an object differs from viewer to viewer, each viewer may represent an object with different elements and different composition hierarchies. For example, while architects may model walls on different floors as separate elements, bounding various rooms, the structural engineers may model only a single shear wall. So that, not only is the interpretation of the meaning of a design object different from one viewer to

another but, also the description of the structure of the object differs. There exists no single unified model or even a single set of unique elements but rather different descriptions of the same elements and different subsets of these descriptions in different models. The disciplines have their own discipline models and there exist a number of core models which contain the common concepts between disciplines. We refer to this approach as the “common model” approach. It is similar to that taken by Nederveen (Nederveen, 1993; Nederveen and Tolman, 1992) and also Pierra in his work on PLIB (Pierra, 1993; Sardet et al, 1998).

Although each discipline creates and maintains its model, the various models refer to the same object and, therefore, must be consistent. Using the common model approach, this is achieved through the common models using the a_view_of relationship (Pierra,1993; Sardet et al., 1998), as illustrated in Figure 3.

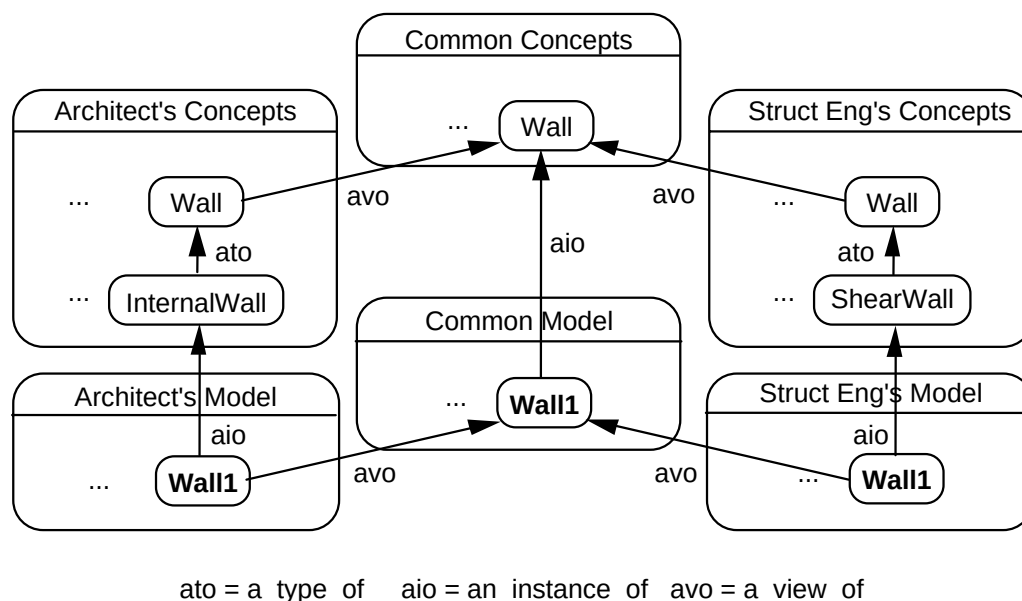


Figure3. Communicating across models through the a_view_of relationship

The discipline concepts (classes) hold those properties specific to the discipline. For example, the Wall (architect) concept may have a function that is to bound a space, while the Wall (structural engineer) concept may have optional functions of supporting elements and/or transferring lateral loads. The Wall (common) concept will have the structure properties, such as the material, shape, dimensions and location. Since both the architect and engineers Wall are a_view_of the common Wall, they will inherit properties from the common Wall. When either the architect or engineer creates a wall object (such as Wall1) in their model, a corresponding instance of the common class is created and the discipline object is related to the common object through the a_view_of relationship. Wall1 may be an instance of a Wall class either directly or as an instance of a Wall subclass such as InternalWall.

3. SUPPORTING COLLABORATION AND MULTIPLE VIEWS

Our approach to supporting collaboration and multiple views augments the inherently multi-user platform provided by the Active Worlds platform with additional collaboration tools (such as webcam, sketching whiteboard, etc); an object database; and an agent system to facilitate multiple views functions. The components are shown distributed across a network but need not be. Figure 4 shows a system architecture depicting our approach. The major components are:

- A client browser to a virtual environment provides the CVE experience to the designers with real time rendering to reflect changes immediately.
- A virtual world server provides the interactive 3D world to the CVE, as well as interactive chat.
- A 2D HTTP server enables server-side scripting of the web pages that provides information from the database, access to tools like a webcam, iphone, and sketching board.
- A database that holds the discipline models, the common model, mappings between these models and virtual world objects, and other data to facilitate collaboration as well as provide the basis for translating to and from specific CAD models.
- A multi-agent system to monitor and maintain the information in the servers and the database, providing a unified experience to designers.

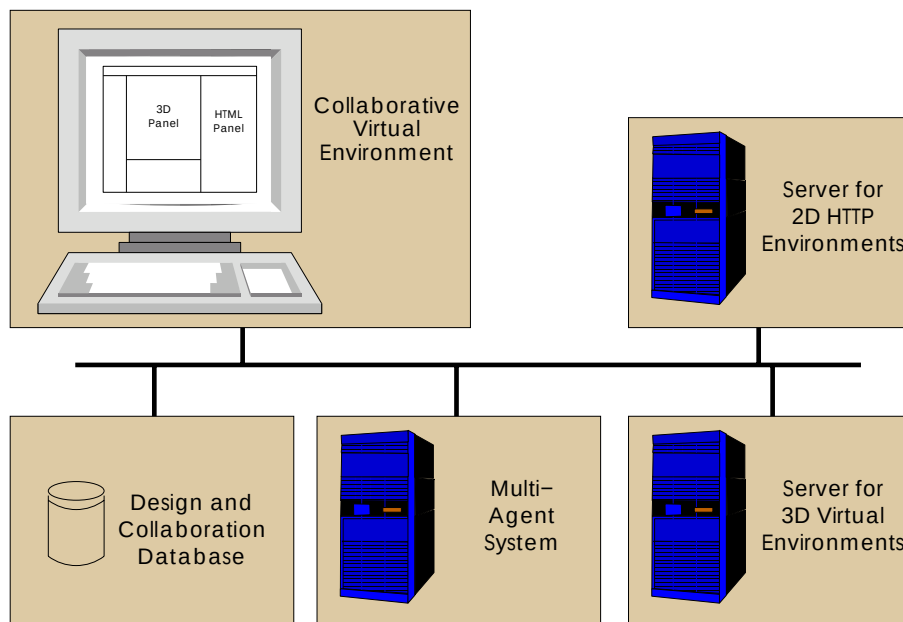


Figure4. System architecture

The primary role of the agents is to construct and maintain multiple views, both abstractly of the design artefact, and concretely of 3D objects instantiated in a virtual world. Haymaker et al. (2000) describe how agents that play roles as filters, constructors or mediators interpret semantic database entities. Our agents play similarly classified roles except that the

database entities that our filter agents interpret and update are the discipline and common models of Section 2.

Filter agents filter the view of the discipline and common models. The filtered view presented to constructor agents changes according to the disciplines of the designers that are currently collaborating and their current interest. Filter agents also provide the interface between the 3D objects from which the 3D virtual worlds are constructed and the database objects that comprise the discipline and common models.

Constructor agents build design artefacts in a 3D world. They insert 3D objects to build artefacts, as well as moving and deleting 3D objects to reconstruct the space of the design artefact. Mediator agents associate 3D objects with designers and their 3D world avatars, handle text chat from designers to agents, handle remote method invocations from the HTTP server, control the work flow between filter and constructor agents, and enable session data to be logged. Data collector agents provide for logging and data collection for later cognitive and data mining analysis or simply as a record of important collaborative sessions.

Figures 5 and 6 show two typical interactions of the agents. Figure 5 shows an architect adding a new wall to an existing building. The architect sets parameters on the 2D build panel and clicks an insert button. This results in a message being sent via the HTTP server to the mediator agent. The mediator decides that construction is required and adds a new 3D object to the world, with selection of the object and its location being parametric. If successful, an identifier of the new object is returned by the virtual world server, which the mediator passes to the filter agents along with the other parametric details. The filter agents use these to update the models in the database. The virtual world server also sends update messages to each client browser to update their 3D views.

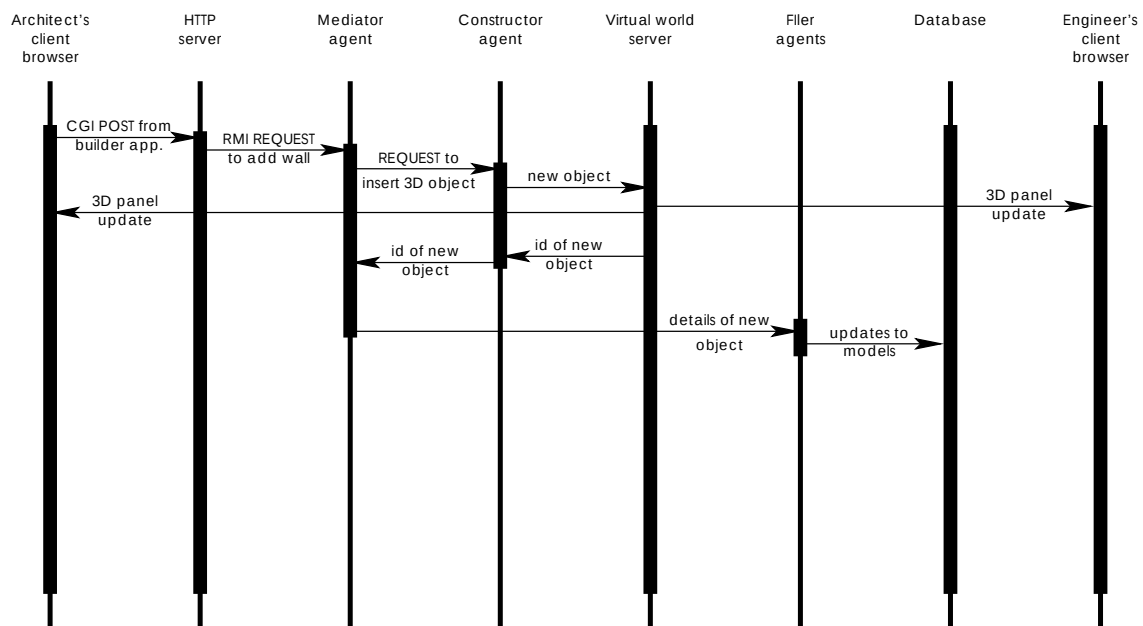


Figure 5. Interaction diagram illustrating an architect adding a new wall to the design artefact.

Figure 6 shows the interaction diagram for an engineer entering the world and changing the view of the building presented from that of an architect's view to that of an engineer's view. At any time the 3D view of the design artefact will be that of one of the disciplines. When a designer requests a change of view the mediator requests that the constructor change each object accordingly. What each change is will depend on the view and the object. For a change from an architects view to an engineers view, some spatial objects may be re-rendered such that they are invisible as spatial concepts are generally not of concern to a structural engineer. Similarly, some other objects may become visible. Other objects that are of interest to both disciplines, but to different degrees, may change visual properties such as by changing colour, texture or transparency.

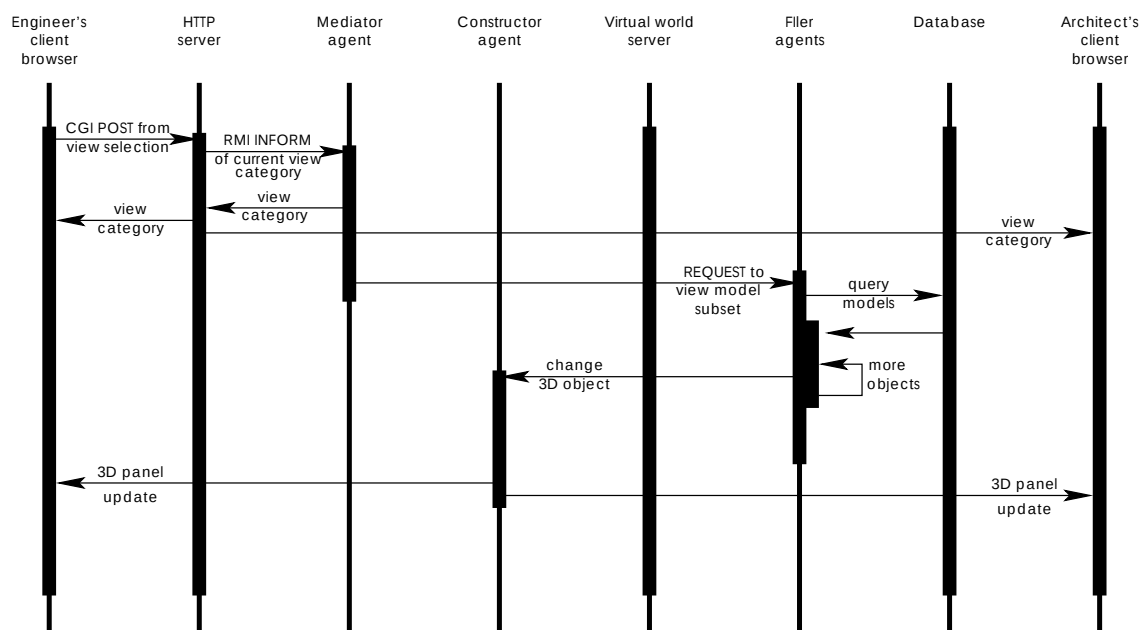


Figure 6. Interaction diagram illustrating an engineer changing the current view from that of the architects.

4. PROTOTYPE IMPLEMENTATION AND SCENARIO

Figure 1 shows one view of the client browser on our prototype implementation. In this implementation, Active Worlds is used as the 3D virtual world server and their browser is the basis for the CVE. The long vertical panel on the left of the client browser shows the 3D worlds known to the 3D world server. Each designer is represented in their current world by an avatar, as seen in the large panel to the right of the worlds panel. This shows a 3D view from the viewpoint of the avatar of the person logged in on this browser. It is this panel, along with sound and chat, that provides the 3D immersive experience. The panel below the 3D view panel facilitates chat. To the right of the 3D view panel is a panel that shows dynamically served web pages that provide more information about the design or run interactive applications.

The right panel window shown in Figure 1 contains row of buttons at the top, each of which launches one application. Currently these applications include

a builder, a distributed sketchpad, an interface to the data logger, a web cam with audio, and help pages. Figure 1 is showing the builder application. Help pages launch as separate overlay windows, as shown in Figure 1.

The sketchpad is an applet that provides for freehand sketching over a background image. The background image may be uploaded and so designers in different locations can sketch over a 3D view of the design artefact. The current sketch and background image are saved in the database such that designers can work on the same sketch.

The web cam page shows live images of the online collaborating designers, plus will provide for audio after the manner of Voice-over-IP (VoIP). This is to facilitate collaboration over a distance using materials not otherwise catered for in a virtual environment, such as showing books, magazines, real world models, and so on.

The agents are programmed in Java and C, and communicate with the HTTP server using Java remote method invocation (RMI). Agents interact with the Active Worlds server using the AW software development kit (SDK) using a java native interface (JNI). The mediator agent connects itself to the system as an RMI server with which to receive messages from the HTTP server. It also registers itself as a callback with which to receive textual chat from designers and avatar events from the virtual world. The mediator interprets these messages and forwards them to the filter and constructor agents. The constructor agents also register themselves as a callback with which to receive 3D object add, change and delete events. Filter agents communicate with the database. Currently queries are in SQL via Java database connectivity (JDBC); future versions may instead use XQuery on a native XML database. Previous research (Maher et al. 2003) has demonstrated how IFCs can be used to populate a database from an ArchiCAD model, and how this database can be used by agents to construct views in Active Worlds. Following from this, our database will hold the discipline models, the common model, mappings between these models and the virtual world objects, and other that facilitates collaboration.

In order to prototype this collaborative environment we consider only simple 3D models, although the database is being constructed with translation to and from existing CAD tools in mind. We illustrate the prototype with a scenario in which an architect and a structural engineer insert simple models to communicate their conceptual design ideas to each other. The architect inserts two zone objects, showing how the two major spaces of the building are connected. These objects are shown in Figure 7 (a). The engineer inserts two wall objects, showing where the major load bearing systems will be located with respect to the spatial elements. The engineer's objects are shown in Figure 7(b). Figure 7(c) shows a view that display both the architect's and the engineer's models.

In this scenario we show the visual interface using different colours and types of objects that indicate models from the different disciplines. The database represents each of these objects and includes properties that record the discipline that is associated with the object, the location of the object and the basic geometric properties of the object. The agents' roles include filtering the objects to be displayed, recording the changes to the database to create new

objects or modify existing objects, and to manage the insertion of new objects into the AW server.

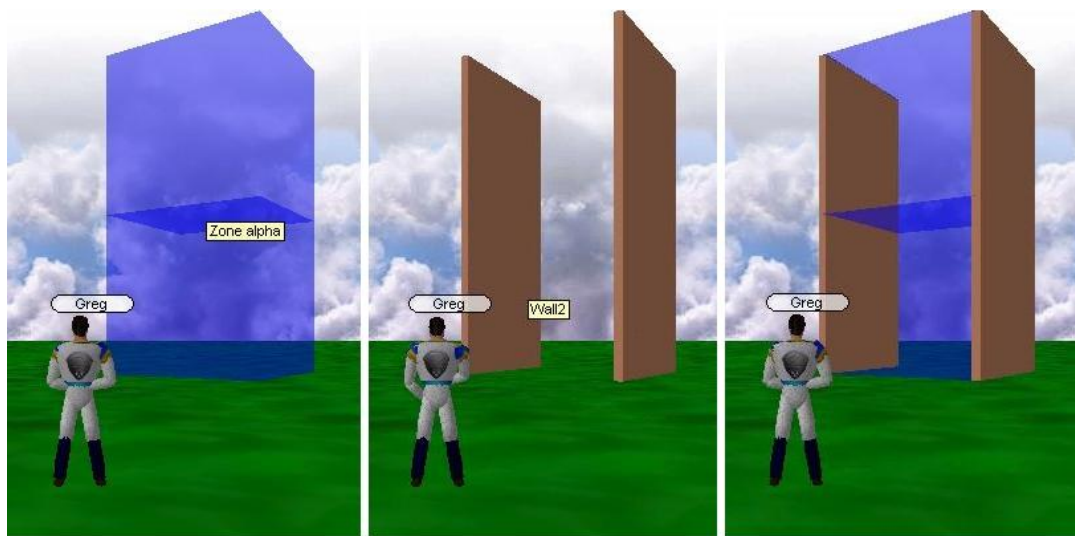


Figure 7. Collaboration between an architect and an engineer. (a) The architect inserts a zone denoted "alpha". (b) The engineer inserts wall objects denoted "Wall1" and "Wall2" (c) Combined view.

5. CONCLUSION

This paper has described research on augmenting existing virtual world platforms to support collaborative multidisciplinary design, with an emphasis on developing a representation and scenario that facilitates communication of function through simple forms. We take advantage of the distributed immersive 3D environment to facilitate communication, enhancing it with a distributed sketchpad, web cam and audio. Supporting multiple disciplines is handled by a multi-agent system that maps between a database of discipline and common models and a 3D view being presented in a virtual world. We describe here a prototype implementation that is the basis for ongoing development and cognitive studies of designers.

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CAPTURING AND MAINTAINING THE CLIENT'S REQUIREMENTS

Full Paper

NECESSARY SKILLS AND PRACTICES REQUIRED FOR EFFECTIVE PARTICIPATION IN HIGH BANDWIDTH DESIGN TEAM ACTIVITIES

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ABSTRACT

Technology is continually changing, and evolving, throughout the entire construction industry; and particularly in the design process. One of the principal manifestations of this is a move away from team working in a shared work space to team working in a virtual space, using increasingly sophisticated electronic media. Due to the significant operating differences when working in shared and virtual spaces adjustments to generic skills utilised by members is a necessity when moving between the two conditions. This paper reports an aspect of a CRC-CI research project based on research of 'generic skills' used by individuals and teams when engaging with high bandwidth information and communication technologies (ICT). It aligns with the project's other two aspects of collaboration in virtual environments: 'processes' and 'models'. The entire project focuses on the early stages of a project (i.e. design) in which models for the project are being developed and revised. The paper summarises the first stage of the research project which reviews literature to identify factors of virtual teaming which may affect team member skills. It concludes that design team participants require 'appropriate skills' to function efficiently and effectively, and that the introduction of high band-width technologies reinforces the need for skills mapping and measurement.

Keywords: virtual teams, generic skills, design teams.

INTRODUCTION

Environmental and technological changes have impacted on the way in which construction teams function. An historical trend in the construction industry has been that each time a project team is formed the make up of it's members (both at an individual and organizational level) changes, ensuring that there is little or no consistency in membership (Emmitt and Gorse, 2003). A major driver of environmental change has been a move towards more collaborative contractual arrangements, such as alliancing and partnering (Love et al., 2002), which, in turn, promotes technological change. Longer term relationships between project team participants act as drivers for the uptake of new technologies. Investing time and money in new computer hardware and software is more attractive if such technologies can be used on many projects, with the same people.

With regard to the nature of teams, technology (i.e. cost of technology, speed of information transfer and the associated costs) promotes moves from co-located to more virtual team activities. However, the challenge of such a move is to incorporate aspects of co-location, for example, seeing people whilst interacting with them, and the ability to collaborate on issues such as developing an aspect of a design, within a virtual environment. This paper reviews literature on the issues of teamwork, virtual teaming, generic skills involved with teamwork and virtual teams. These issues are examined in the environment of early design from a broad range of industries, and conclusions to date are presented.

COMPOSITION AND NATURE OF TEAMS

As time and technology move forward, and design projects become more complex, relationships, roles, and responsibilities have become more varied. It is through the sharing of ideas that superior products are created and delays and miscommunication are avoided (Maher et al., 2000). Teams are a cluster of two or more people usually of differing roles and skill levels who interact '*...adaptively, interdependently, and dynamically towards a common and valued goal.*' (Salas et al., 2000). They are the vehicle for the process of collaboration (Beyerlein et al., 2003). In a majority of organisations there exists a wide variety of challenges and issues.

Collaboration or partnering may be achieved through many forms of interaction. A succinct summary is provided by McDonough III et al (2001) who distinguish between various teams:

- **Co-located** - comprised of individuals who work together in the same physical location and are culturally similar.
- **Virtual** - comprised of individuals who have a moderate level of physical proximity and are culturally similar. One example of virtual team is when team members are in the same building but on different floors.
- **Global** - comprised of individuals who work and live in different countries and are culturally diverse.

Co-location is the principle way that teams operated before technology gave team members an ability to communicate with others in different physical locations. Co-located teams, are those whose members operate in the same physical and cultural space (McDonough III et al., 2001). Collocated teams interactions are synchronous, occur in a similar place, and their members may be culturally different in terms of

different organisations. However, with increasing globalisation of projects it is becoming harder to collocate these national and global team members (McDonough III et al., 2001).

Virtual teams exist when the members of a team are culturally similar but operate, for the majority, in different physical spaces such as different cities within the same country (Lurey and Raisinghani, 2001; McDonough III et al., 2001). As clients of construction and design companies demand more efficient and higher quality services, use of diversely located team members on the one project may increase (Kimble et al., 2000). This need for efficiency (Kayworth and Leidner, 2000) and group interaction has led to increased partnering between companies of differing fields (Love et al., 2002). Due to difference in location, team members now increasingly use electronic media to communicate ideas and designs (Jaafari and Tooher, 2002).

A global virtual team exists when virtual team members are also culturally displaced, such as in international collaboration (Kayworth and Leidner, 2000). A majority of definitions of global virtual teams suggest that they are temporary in nature with a lifespan related to a specific project (Jarvenpaa and Liedner, 1998).

ISSUES OF GENERIC SKILLS ARISING IN A VIRTUAL CONTEXT

When attempting to change the context of a team from co-located to virtual it is important to factor in skills possessed by team members and how these may be affected. Generic skills are defined by Salas et al (2000) as, *“...the knowledge, skills and attitudes that a team member possesses when completing a task or communicating with fellow members, whether in a co-located or virtual environment”*. Generic skills influence both individuals and teams; they are skills which are *“...transportable and applicable across teams.”* (Salas et al., 2000).

CORE GENERIC SKILLS IN A VIRTUAL CONTEXT

Problems exist in the transfer of information, and the ability to utilise these skills, in a virtual team context, and are generally centred on team members' abilities to communicate using these skills. For example, when someone attempts to give feedback in a virtual team they can be limited by the level of communication dictated by the virtual technologies available to them. The main area for concern for virtual teams is the ability to communicate, especially non-verbal communication which is more difficult in the majority of virtual communication. The impact of this limitation of skills is most prevalent in relation to team management, feedback and trust. Relevant skills, derived from the literature, are shown in Table 1.

Literature has illustrated that attempts to transfer the skills outlined in Table ,1 from a co-located environment to a virtual one, have met substantial resistance. It becomes clear that need or use of these skills would differ between co-located and virtual teams.

Table 1. Integrated skills (as adapted from Cannon-Bowers et al 1995 [Salas et al., 2000]).

Core Generic Skills	Definition	Sub skills
Adaptability	The use of compensatory behaviour and reallocation of resources to adjust strategies based on feedback	• Flexibility • Compensatory behaviour • Dynamic reallocation of functions
Shared situational awareness	When team members have compatible mental models of the environment within and outside of the team.	• Orientation • Team awareness • System awareness
Performance monitoring and feedback	Ability of team members to give, seek, and receive task clarifying feedback.	• Performance feedback • Acceptance • Mutual performance monitoring • Procedure maintenance
Team management: Project management/leadership	Ability to direct and co-ordinate the activities of other team members particularly pertaining to performance, tasks, motivation, and creation of a positive environment.	• Task structuring • Motivation of others • Goal setting • Goal orientation
Interpersonal relations	Ability to optimise the quality of team members' interactions.	• Conflict resolution • Assertiveness • Moral building
Co-ordination	Process, by which team resources, activities and responses are organized to ensure that tasks are integrated, synchronized and completed within established temporal constraints.	• Task organisation • Task interaction • Timing
Communication	Information exchange between members using the prescribed manner and terminology.	• Information exchange • Consulting with others
Decision making	Ability to gather and integrate information, use sound judgment, identify alternatives, select the best solution, and evaluate the consequences.	• Problem assessment • Problem solving • Planning • Implementation

Below are descriptions of these generic skills, and major issues relating to them.

- **Adaptability** – increase in use as team members need to adopt changes associated with the virtual environment i.e. communication methods, such as electronic whiteboards, as opposed to face-to-face (Baldwin, 2004).
- **Shared Situational Awareness** – increase in the need for skills in creating a 'shared situational awareness', due to distance and the sometimes fragmented communication channels between team members. An increase in these skills can be seen in creation of a shared (i.e. the web) bulletin board which assists in uniting team member's cognitions (Lipnack and Stamps, 2000).
- **Performance Monitoring and Feedback** – skills in delivering feedback may be impeded in a virtual team due, again, to the restrictive nature of communication (most significantly non-verbal communication). These limitations may be combated by increasing the number of communication channels used. While not allowing tactile communication it will enhance the experience for receivers (Emmitt and Gorse, 2003).
- **Team Management** – skills in team management including project management and leadership are again disabled because of difficulties in establishing free and clear communication (i.e. like face-to-face conversation); for example to control conflict using only email, between two team members. However, operating in a virtual team allows for management to be based on up-to-date information and instant data transfer, in this respect creating an ability to use management skills efficiently.
- **Interpersonal Relations** – sub-skills of this skill such as assertiveness (Alonzo and Aiken, 2004) and conflict resolution (Furst et al., 1999) may be difficult to use in a virtual environment. The virtual environment creates an atmosphere of 'ambiguous' communication, where it may be difficult to interpret whether a person's communication, is promoting unhealthy conflict, or simply assertive (Furst et al., 1999).
- **Co-ordination** – Co-ordination for the construction industry refers to the ability to deliver 'accurate and timely information (Emmitt and Gorse, 2003) for decision making and problem solving'. Virtual technologies could aid co-ordination significantly. Effective co-ordination may reduce conflict and assist in archiving and decision making (Emmitt and Gorse, 2003).
- **Communication** – The most significant challenge to virtual teams is the ability of team members to communicate non-verbally. In a team situation it is often non-verbal cues which convey most meaning; a wink, a raised eye brow, or an ear tug (Hoyt, 2000). These cues, whether created on purpose or accidentally, can give secret or subtle information about project or team dynamics (Cleland and Ireland, 2002). Because of the lack of actual physical face-to-face team interaction these non-verbal cues may be lost.
- **Decision Making** - Decisions in the construction industry are often needed immediately and rarely allow adequate time for all data and perspectives to be considered (Emmitt and Gorse, 2003). As a consequence decision-making by virtual teams is more difficult than when teams are co-located. This is because of the need to clarify positions from a variety of different locations. Industry case

studies have shown that for decision making in a virtual team, there needs to be on going virtual training (Kirkman et al., 2002).

TEAM SKILLS IN A VIRTUAL CONTEXT

Team skills are those which are held by team members that affect the performance of a team in which an individual is currently working (Salas et al., 2000). The dominant issues in team skills are summarised in Table 2 below and then discussed.

Table 2. Generic team skills and definitions

Generic Team Skill	Definition
Dealing with Issues of Trust	Ability to foster trust between team members. Especially in early stages of team development.
Dealing with Cultural Issues	Culture may be defined as the values, beliefs and ideals held by a group of individuals. Skills are needed to ensure that team members do not conflict on this cultural level.
Archiving	An ability to archive is important for collaboration as it allows members to revisit conversations and decisions made during past team interactions.

Computer mediated communication does not have the infrastructure to support all interactions and cues that convey trust between members of a team (Jarvenpaa and Liedner, 1998; Riedlinger et al., 2004). Because of the highly complex nature of virtual teams and networked organisations trust is a necessity (Lipnack and Stamps, 2000; Mohamed, 2003).

Team members may differ significantly in terms of cultural (i.e. values, beliefs and ideals) alliances, especially if the team members operate in different countries, or organisations. Possible solutions to these issues were identified in Kayworth and Leidner's (2000) study which highlighted strategies for dealing with cultural issues including attempts to: build skills in cultural awareness in virtual team members, and form virtual teams with members from complementary cultures.

An ability to archive is important for collaboration as it allows members to revisit conversations and decisions made during past team interactions. Records of construction meetings frequently take the form of minutes. These often result in lost data because of inaccurate recording methods or individual agendas. This can result in a need to go over 'old ground' in future meetings (Emmitt and Gorse, 2003).

DESIGN TEAM ACTIVITY

Research by Lawson (1997) identified collaboration as a large component of designer's working time and there has been a move toward applying research methods to gain a better appreciation of this activity and the skills required to effectively participate in collaborative design processes. In the process of gaining an understanding of design team activities Muir (1995) defined collaboration as, "...an activity of communication between parties involved on a project".

Stempfle and Badke-Schaub (2002), and Gay and Lentini (1995) have both proposed models of design team activities. These models are similar to the early design process defined in Thorpe's (2004) Construction Process Protocol. All three models are now summarised in Table 3. They allow us to understand that design and more importantly collaborative design, is a segmented process, punctuated by 4-5 stages that define design processes. A link between these models would suggest that there is a possibility of establishing protocols for design team collaboration.

Table 3. Table of design activities and processes as adapted from Stempfle and Badke-Schaub (2002), Gay and Lentini (1995), and Thorpe (2004).

Design Process (Stempfle and Badke-Schaub, 2002)	Design Activities (Gay and Lentini, 1995)	Construction Process Protocols (Thorpe, 2004)
Planning	Orientating	Demonstrating the need (Phase zero)
	Subdividing the problem	Conception of need (Phase one)
	Establishing roles	Outline feasibility (Phase two)
Analysis	Information seeking	Substantive feasibility study and outline financial authority (Phase three)
	Information sharing	Outline conceptual design (Phase four)
Evaluation	Monitoring	Full conceptual design (Phase five)
Decision	Negotiating/ understanding	Coordinate design, procurement, and full financial authority (Phase six)
	Designing	Production information (Phase seven)
Control	Building	Construction (Phase eight)
	Evaluating	Operation and maintenance (Phase nine)

There is a difference between types of problems in design, well-structured (defined and understood) versus ill-structured (less understood, larger ramifications) (Perry and Sanderson, 1998). Ill-structured problems require longer periods of communication and the use of a range of artefacts (Perry and Sanderson, 1998). The early design process is an iterative form of problem solving, whereas solutions are formed and constantly revised or redefined to bring to light a satisfactory product (Lahti et al., 2004).

To be effective design team participants and designers, in virtual environments, designers will require a skill set that extends beyond specific design skills. The skills required to manage teams working in virtual environments will also need reconsideration if they are to be contextualized in virtual environments. There currently exists a need to better understand the core skills which will be required by virtual design teams.

Literature describes differences in the skills used by team members between co-located and virtual teams in the early design stage, including:

- **Leadership** – Leadership decides the balance of relevant skills and contributions from members to a project (Baird et al., 2000). The leader or leaders need to be able to create teams which identify the important 'social links' between virtual team members (Baird et al., 2000).
- **Co-ordination** - To obtain optimal results when designing collaboratively through a virtual medium, co-ordination and structuring skills need to be active in the early design period (Lahti et al., 2004). Lahti et al's (2004) study also highlighted the ability of the team members to discuss design in a virtual context. The ability to communicate ideas by making changes to others designs online was not available to their participants; essentially the communication was through a web chat system and email. They felt that not having this virtual aspect somewhat hindered the ability of the design students to communicate ideas.
- **Feedback** - Due to the ill-structured nature of early design processes, an ability to provide feedback is an important skill for team members to possess, particularly vertical communication channels between junior team members and senior decision makers (Baird et al., 2000). An ability to give feedback is crucial at this point because large amounts of information must be validated before progressing the design (Baird et al., 2000).
- **Communication** - Within Baird et al's (2000) study of collaborative engineering design some interesting communication processes were identified. An ability to build interpersonal relationships in an engineering team can be a slow process in terms of when a junior engineer has the privilege to interrupt a senior, termed 'permissions'. However, in the distributed team this process is yet again more slow (Baird et al., 2000). Depending on the relationship, a design engineer may need to contact another engineer regarding a necessary task but may delay this communication until the task is "...urgent and unavoidable." (Baird et al., 2000). In Baird et al's (2000) findings it was suggested that the virtual environment may not foster skills such as feedback to enable necessary communication between members. If an intranet is used within a design organisation the links between members should be mixed so as to strengthen weak social connections to provide more clear communication channels.
- **Non-verbal communication** - In Baird et al's (2000) engineering examples, senior engineers are referred to as 'consultant engineers'. Skills in communication, particularly non-verbal, were important for consulting engineers providing feedback to juniors on their suggestions including smiles, nods and frowns (Baird et al., 2000). An ability to utilise these non-verbal cues would be severely impaired in the virtual environment. As yet it is unclear whether video media or use of extremely rich and detailed language could convey these cues in a virtual environment.
- **Interpersonal relationships** - The way in which team members collaborate during the early stages of design can impact on a team's ability to form a satisfactory product. Social collaboration appears to play an important part in the design process especially when researching and determining limitations in the early design processes.
- **Team skills** - Trust is not easily created in a computer mediated environment, especially when team members have had no prior experience with other members (Jarvenpaa and Liedner, 1998). What is suggested is that the early

stages of a design project are conducted in a co-located setting until trust is formed. Virtual teaming may then begin (Jarvenpaa and Liedner, 1998).

CONCLUSIONS

In order to function efficiently and effectively in a team environment, irrespective of whether it is a traditional or virtual team, team participants require 'appropriate skills' (i.e. awareness, understanding, abilities to apply). One cannot 'assume' that all team members automatically possess all necessary skills. Previous research, as discussed in this paper, has identified that the introduction of new technologies can impact, both positively and negatively, upon the performance of teams. Therefore the ability to map and measure skills of individuals and teams, leading to training in any deficient areas identified, is seen as critical. Skills development and training should be viewed by management as an investment in creating more valuable and skilled employees. Development of skills mapping and measurement tools will be the major outcome of this aspect of the research project. Having identified key issues and critical skills, from the literature reviewed to date, the next phase of the project will take the first of a series of steps by developing a framework for analysis of design team activity, categorising activities and skills.

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CAPTURING AND MAINTAINING THE CLIENT'S REQUIREMENTS

Full Paper

THE DEVELOPMENT OF 'SOFT' STRATEGIC INDICATORS FOR INTERNATIONAL CLIENT SATISFACTION

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ABSTRACT

Despite the increasing significance of the construction industry as an emerging sector of the Australian economy, there is inadequate research performed on construction design firms in terms of theoretical and empirical foundations. Although past research has identified the barriers and success factors for firm market entry, evidence suggests that to date no research has explicitly explored the sustainability of construction design firms in international markets. SMEs and their approach to firm internationalisation differ significantly from large manufacturing firms and a vast majority of construction design firms operate as SMEs. This paper develops a sustainable business model for construction design SMEs, which rely upon the development of clear Client Following (CF) versus Market Seeking (MS) strategies to support internal firm strategic and operational management. The understanding of these strategies is vital as the application of either will shape the design management approach of firms, which would in turn impact on the sustainability of these firms in foreign markets. Long-term sustainability of firms in international markets relies heavily upon client satisfaction. Client and project team participants' communication during various design processes has often been problematic and the added difficulty of communicating across international boundaries further compounds the problem of capturing and maintaining client's requirements. Therefore this paper develops a model for business sustainability of Australian construction design firms working in international markets by exploring factors that affect client satisfaction across international boundaries, through the development of business performance indicators. These include not only the critical financial capital but also other 'softer' indicators, namely: social, cultural and intellectual capital. These act as a firm's measure of success and the acquisition of this type of capital will provide significant advantages to firms' success, hence sustainability in international markets.

Keywords: strategic design management, social, cultural and intellectual capital

1.0 INTRODUCTION

The health and competitiveness of an industry is highly dependent upon its ability to actively export. A country's economic growth is reflected by its exporting activities through the various industries. According to Australian Federal Minister of Trade, the government aims to double the number of Australian exporters in the next five years by focussing on increasing the number of small exporting businesses (Anderson, 2003). Thus, the last decade has seen Australian governments actively seeking to improve the competitiveness of industries, including the construction industry through various programs and initiatives to support firms who export. A study by the Australian Industry Group in 2001 found that 'companies perform best where industries provide jobs, purchase raw materials and capital locally and look for markets both within Australia and overseas...industries that felt most optimistic about the future were those with more involvement in overseas markets' (AIG, 2001 as cited by Anderson, 2003).

The export of construction design services appears to be an important emerging sector for the economy. The export of construction design services in Australia has undergone a steady growth of 60% in the last five years from A\$399 mil in 1999 to A\$670 mil in 2003. At the same time the value of export services has decreased from 40% to 22% of the total export value (DFAT, 2003). This decrease in the export of services indicates the increasing significance of the internationalisation of architectural, engineering and construction design firms in Australia as a source of the country's export of services.

The economics of design is also fast becoming a significant growth area for countries. Creativity, innovation and design as a commodity and its ability to engender competitive advantage is appearing in a similar fashion as knowledge management and the commodification of knowledge did in the late 1990s. In this manner a fresh approach to what constitutes a design service in the construction and property industry is now considered. Rather than design being ascribed solely to architectural firms, the act of design is something that is found in a variety of firms. For the purposes of this paper construction design firms are categorised as follows:

- Those that provide a design service without a product and are primarily removed from the construction site; for example architectural, engineering, urban and landscape design consultants,
- Those that provide a design service associated with products that are not installed; for example, furniture systems, free standing fixtures such as lighting,
- Those that provide a design service associated with a product built off site which is installed; for example sanitary product manufacturers, product engineers and
- Those that provide a design service associated with a product primarily built onsite; for example specialist subcontractors including façade subcontractors, mechanical services subcontractors.

It is acknowledged that this wider perspective of construction design firms could be problematic however the developing theory of design management is the common conceptual framework. Design management theory is interdisciplinary and has been applied to architecture, graphics, multimedia and product design.

Design management is the strategy developed by organisations to deliver their design service to clients. This refers to the way in which an organisation's strategic design management policy for the external design service translates into internal organisational processes of individual project design management.

For effective utilisation of the potential to be realised by design expertise and skill, management of the design process is required both at the individual project level and the strategic level of an organisation. Design management supports the 'selling' of the design service and is integral to the competitive advantage of the organisation. It is similar to the business management concept of strategic management however with a focus on the activity of design.

In many markets the delivery of a design service to clients has often been problematic as it is characterized by a high level of uncertainty whereby client's requirements are negotiated, defined and challenged. Such an uncertain and creative environment requires a high level of communication. Communication in the design process has long been considered a complex and critical issue where the gap between expectations and realization is central to the problem (Brown, 2001; Emmit, 1999).

Design management in the international context is fundamentally impacted upon by cross-cultural communication. The added difficulty of communicating across international boundaries further compounds the problem of capturing and maintaining client's requirements (Howes and Tah, 2003). However, Pietroforte (1997) following a study on construction alliances between an Italian contractor and an American architectural firm cites the possibility of achieving client satisfaction through the implementation of several cooperative strategies in international markets through the formation of international alliances. With increasing clients' demands for customized services or products, international alliances provide many advantages toward meeting the changing client needs as 'alliances offer a wider range of strategic flexibility than a single firm would have on its own' (Pietroforte, 1997). Perhaps though there are a variety of ways for architectural firms to achieve international success.

The difficulties in entering new markets can often be traced back to the difficulties in developing relationships with clients. Notwithstanding assistance provided for design firms through international trade missions, organised export firm support networks and information packages by a burgeoning number of government agencies, evidence suggests that there are still perceived barriers to market entry (Draganich, 1998) and great difficulties in maintaining a successful international business.

This paper is within the Adaptive Performance Framework that has been developed by the research team working on the CRC-CI study 'Internationalisation of Australian Construction Design Firms'. The Adaptive Performance Framework is a sustainable business model for construction industry design firms, which is time-dependent and represents the firm's ongoing ability to increase project success. It draws together theories from:

- design management
- internationalisation process
- knowledge management

**Construction industry DESIGN firms
EEM (Export Enterprise Management)
SUSTAINABILITY BLUEPRINT**

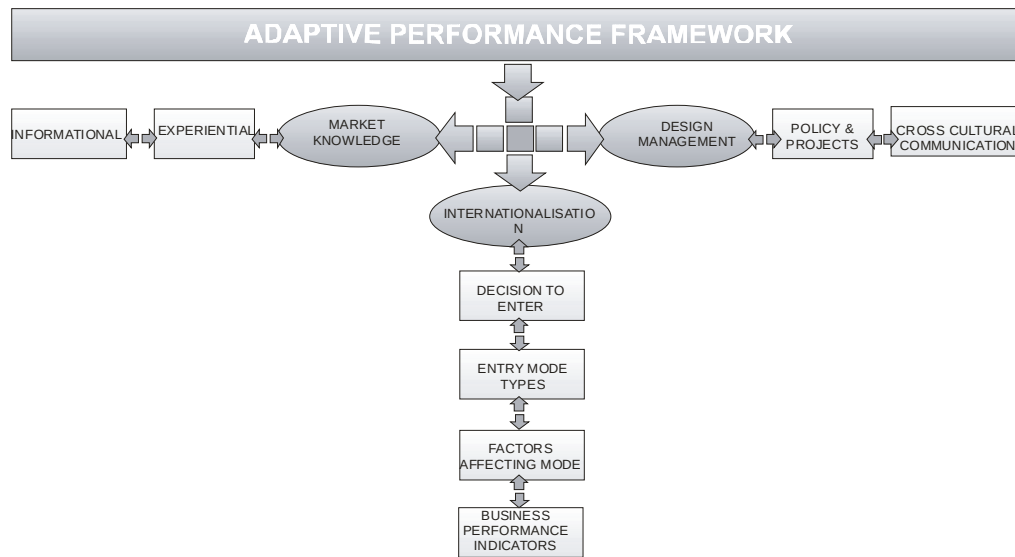


Figure 1.0: Adaptive Performance Framework for Sustainability of Construction Design Firms in International Markets

A sustainable business model for construction design firms would typically rely upon individual project success and a key part of how project success is achieved is through project and strategic design management. It has been identified that many of the factors affecting project management differ from country to country and project to project (Kramer, 1982; Cooke and Walker, 1994; Atkinson, 1995 as cited by Rowlinson and Root, 1997; Draganich, 1998; Loosemoore, 2001). Similarly, design management may be affected by country and project type. Therefore the continuous adaptation of the export enterprise part of a firm to changing market conditions and the new knowledge generated from each project is fundamental to the model.

Internationalisation theory suggests that exporting firms are already in growth mode and so with market success comes the possibility of new ventures in the international market and with that is associated a renewed consideration of market entry mode. Studies on the international construction business environment have been typically limited to exploratory case studies (Pietroforte, 1997; London, 2001; London, 2002) which only really sought to describe market entry strategies used by firms. Various innovative strategies exist for construction firms to enter markets (Doherty, 1999; Buckley and Ghauri, 1994) but less is known about entry modes and their relationship to *long term business sustainability for the individual firms* across national boundaries. The cornerstone of a sustainable business model is an understanding of what contributes to firm success and the measures or indicators of business performance. Long term sustainability is reliant upon capturing and maintaining client's requirements. Therefore such indicators should reflect client satisfaction.

This paper aims to develop a detailed discussion on the relationship between the firm's internationalisation process and client satisfaction. In particular this will include an examination of entry mode strategies and business performance indicators. The ultimate indicator of business performance is typically financial; however it is generally regarded that other "softer" and less tangible indicators are also important. International construction business is marked by trust by the client which comes in the form of social networking, relationship building,

international reputation, credibility and capability. The acquisition of these intangible elements by a firm are already recognised in the industry and research community but are not made explicit. The intangible elements include social, cultural and intellectual capital and the acquisition of each type of capital represents an ongoing ability by the firm to capture and maintain the international client's requirements. Different firms have unique design service philosophies and this may impact on entry mode strategies and firm capital (refer to Figure 2.0).

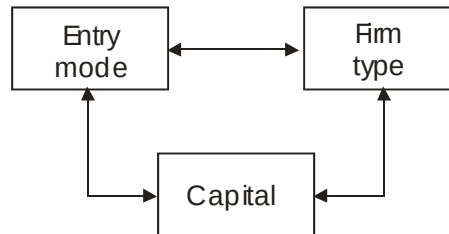


Figure 2.0: Relationship between Firm type, Entry Mode Strategies and Firm Capital (Developed for this study)

2.0 INTERNATIONALISATION PROCESS

The internationalisation process has been well established within the research literature. A research gap exists, however, through the emphasis in research having been given to large firms, and in particular those within manufacturing (Coviello and Martin, 1999). Consequently there is little known regarding the internationalisation of small to medium sized enterprises (SMEs), especially those which provide a service such as design firms. The importance of this research gap is reinforced through the differences between SMEs and larger firms as well as those between services and products. This is problematic because 93% of the construction industry is made up of SMEs and the majority of design related firms are delivering a service or a service combined with a product.

Internationalisation can be perceived as a part of the ongoing strategy process of most business firms (Melin, 1992). The main differences between internationalisation and other types of strategy processes (or growth strategies) can be found in the following dimensions:

- the firm transfers products, services or resources across national boundaries. This implies that the firm has to select in which country (or countries) the transactions should be performed.
- the firm has to select the international exchange transaction modality, that is, a foreign market entry strategy.

These two dimensions – international market selection and choice of entry mode – represent key strategic decisions in connection to a firm's internationalisation (Bradley and Gannon, 2000) and are both related to addressing client's requirements. For example, the capacity to be successful in competitions and tenders is integral to decisions about market selection by the firm.

International market selection is a pivotal aspect of international business and involves a firm deciding which country or regions will constitute target markets. International market selection has been described as a component of a firm's operations that needs to be executed correctly (O'Farrell and Wood, 1994; Kay, 1993). A number of factors contribute to international market selection including: business factors, chance and psychic distance.

After reaching the decision to enter a particular market, a firm needs to determine a mode of entry. Mode of entry has been described as utilizing an

institutional arrangement for organizing and conducting international business transactions (Erramilli and Rao, 1993; Root, 1987). Business transactions may take many different forms and can be affected by a number of factors. The following section describes entry modes in more detail.

2.1 ENTRY MODES

There are numerous choices related to foreign market entry mode and it is a function of a large number of diverse factors; which can be grouped as the following:

- product/service characteristics,
- firm characteristics and
- external environmental factors.

This section will review the literature concerned with entry modes and then focus on the concept of client following versus market seeking in relation to firm characteristics and firm types.

The choice of correct entry mode for a specific market was reinforced by Terpstra and Sarathy (1991, p.361) as '*one of the most crucial decisions in international marketing*'. Existing literature indicates that entry modes are most typically thought of in terms of the following:

- Joint venture
- Wholly owned
- Export subsidiary
- Agent/distributor exports
- Direct to customer exports
- Licensing/franchising

This typology has largely been developed based upon product manufacturers' entry modes. After the identification of entry mode type this categorisation is of little real use - of greater interest is the conceptual differences between services and products. The literature indicates that distinctive differences exist between services and products (Zeithaml et al 1985) and the distinguishing characteristics of services are their (Buckley et al, 1992):

- intangibility,
- heterogeneity,
- inseparability from production and consumption and
- perishability

The characteristics of heterogeneity and inseparability from production and consumption will now be discussed in detail. The tremendous heterogeneity which characterizes the service sector, leads to widely differing international trade and investment patterns in this sector (Erramilli and Rao, 1990). This poses a major challenge for researchers trying to study behaviour of diverse firms, for example, software companies, advertising agencies and architectural consultants, in one common conceptual framework. The problem of heterogeneity could be, to some extent, circumvented by performing industry-specific studies. Such an approach would however fail to provide insights on issues that extend across industry boundaries.

Contrary to the previous claim that services production and consumption can not be separated, Erramilli and Rao (1990) proposed that they can and that service firms could be classified into:

- *soft-service firms* with services for which it is extremely difficult or even impossible to decouple production and consumption such as car rentals, restaurants, and healthcare or
- *hard-service firms* with services for which it is somewhat more feasible to separate production and consumption such as architectural firms, engineering designers, consultants and software firms.

Such a classification provides insights into the variation of entry mode choice. Soft-service firms cannot export since exporting necessarily requires a separation of producer and consumer and have to rely on contractual methods of licensing or franchising or foreign direct investment of joint ventures or wholly owned subsidiaries to affect foreign market entry. Alternatively, hard service firms can and often do export; however, it is acknowledged that the separation process is not simple.

The high level of diversity of construction industry design firms makes it even more problematic to classify design firms into hard or soft service types. Firms can be both hard and soft service type as their relationship with clients may differ from project to project.

For example a sanitary product manufacturer may sell a sanitary product that is produced off site, which places it within the hard service framework. However, the same sanitary product manufacturer may be required by its client to install the sanitary product onsite thus placing it within the soft service framework.

2.2 CLIENT FOLLOWING / MARKET SEEKING ENTRY STRATEGIES

Within the hard/soft service typology firms lies another phenomenon characteristic of the service sector where firms can be further classified based upon the firms' decision to export. A firm's decision to export could be impacted by either:

- a proactive approach, which is determined by a firm's organisational goals of looking to expand its businesses (Market seeking) or
- a reactive approach, which is to achieve client satisfaction as a firm is asked by a client to export its services (Client Following)

A large number of service firms enter foreign markets primarily to serve the foreign subsidiaries of their domestic clients (Terpstra and Yu, 1988). For example, many American advertising agencies and banks follow their US clients to overseas markets. Similarly, Australian architectural firms designing high rise office buildings could follow their financial institution clients to international markets. Consistent with this is the actions of Peddle Thorp architects (Centre for Corporate Change, 1995) now known as Peddle Thorp and Walker who demonstrated a general conservatism in entering foreign markets through a reactive approach in the 1970's by following their clients into several foreign markets in Asia. This phenomenon of *client following* while not unheard of in the manufacturing sector, is nevertheless a unique characteristic of service firms in terms of its occurrence and importance.

In summary, there are two types of foreign market entry situations among service firms; *client following* (CF) entry and *market seeking* (MS) entry. This second entry situation refers to the case where a service firm enters foreign markets primarily to serve foreign customers, i.e. customers in that particular overseas market.

Examples of client following and market seeking strategies are offered by Erramilli and Rao (1990) (refer to Table 2.0).

Motives for entry	Soft service firms	Hard service firms
Client following	An advertising agency sets up office abroad to serve a domestic client's foreign subsidiary	A software company provides software support to the foreign subsidiary of a domestic client
Market seeking	A fast-food chain appoints a franchise in a foreign market to serve the local customers there	An architectural design firm sells blue prints to foreign customers

Table 2.0: Examples of CF and MS entry strategies and associated types of service firms (Erramilli and Rao, 1990)

The example given of an architectural firm as a market seeking (MS) hard service type firm is somewhat naïve because design firms can and often do operate as both client following and market seeking. In addition to that, the problematic separation process of design firms into hard/soft service typology further compounds the categorisation of firms because exporting design firms can be both hard and soft depending on a firm's relationship with its client. Therefore, firms can be both client following and market seeking and simultaneously be both hard and soft service type. Examples of client following and market seeking strategies used by design construction firms are indicated in Table 3.0.

Motives for entry	Architectural firm (restaurant design)	Engineering firm (bridge design)	Sub contractor (façade design)
Client following	A firm designs new chain restaurants in country A after having designed restaurants for the same client in its home country	A firm is asked by a local client to design a bridge overseas	A firm designs and builds the façade design for a building in country B after having handled façade designs of similar complexities in country C
Market seeking	A firm from country A designs restaurants in country C through selling its skill specialisation	A firm sells its services in country X with the desire to expand its firm's growth	An international subcontractor sets up an office in Thailand to shield away from local downturns and tenders for projects

Table 3.0: Examples of CF and MS entry strategies by construction design firms

It is clear that entry strategies are impacted by the type of firms and their unique firm characteristics, the service they offer and the market environment.

2.3 FIRM TYPOLOGIES

In the competitive realm of internationalisation of design firms, more and more design SMEs are recognizing the need to brand themselves strategically in order to market themselves to its intended clients.

'If you want a Gensler airport, don't hire Foster and Partners. If you want an Ove Arup Bridge, then you'd steer clear of Dissing + Weitling. The successful modern practice is also a clearly identifiable professional brand – suggesting a specific and unique approach to problem solving and stylistics' (Fox, 2000 p32).

In either approach of market seeking or client following, the design philosophies of firms need to be strategically incorporated into its marketing planning process (Kotler and Rath, 1984) to ensure the recognition of their brand by the right people. However, matching the changing requirements of clients is often problematic where Lupton and Stellakis state, 'A key issue is the translation of the employer's requirements, which may be subjective, prescriptive and conflicting as the basis for design work', the 'employer' meaning the client (Lupton and Stellakis, 1995 as cited by Brown, 2001).

As a result, design firms tend to position themselves either explicitly or implicitly by various design philosophies. For example, Albertsen observes that architectural firms can be positioned into the following three typologies in relation to the manner of which they 'sell' their services (Albertsen, 1996 as cited by Skaates et al, 2002):

- the artistic subfield: firms that differentiate themselves through selling signature designs and typically show 'little concern for marketing and business'. These firms often design out of instinct without prior market knowledge
- the professional subfield: firms that value a mix of artistic and technical aspects in their designs with the intention to cater to all markets.
- the technical-economic subfield: firms that place heavy emphasis on 'efficiency and productivity'. These firms are highly technical and often neglect the artistic or creative characteristics held by the artistic subfield.

This phenomenon is not restricted to architectural firms either; façade subcontractors likewise have market segmentation related to design philosophies. For example subcontractors can provide complex, unique and highly customized façade versus standardised components. Each type of design service firm can be segmented according to some service philosophy.

2.4 SUSTAINABILITY: CLIENT SATISFACTION

Export by construction design services is very much affected by entry modes; however entry mode is only one part of the internationalisation process. Too little attention in the literature has been paid to long term sustainability of firms in export markets. Long term sustainability in international markets is typically reflected in continued project success which typically arises from client satisfaction. Evidence suggests that exporting construction design services is marked by a high degree of relationship development based on social and professional networks (Draganich, 1998). Client satisfaction on one project is important for a number of reasons including:

- project success and client satisfaction is noted by other potential clients and social networks are developed and enhanced to develop trust
- project success and client satisfaction indicates a firm's achievements, capabilities and market credibility
- project success and client satisfaction adds to the knowledge base of the firm in terms of market knowledge in relation to information and

experiences; thus increasing likelihood of satisfying similar clients or the same client in the future.

These three themes can be considered within Bourdieu's concepts of a firm's 'capital'. Bourdieu suggested that there were four types of capital namely; economic, symbolic, cultural and social capital (Bourdieu, 1983 as cited by Skaates et al, 2002). The following section discusses the types of capital.

3.0 FIRM SOCIAL, CULTURAL AND INTELLECTUAL CAPITAL

The types of capital that have been adopted for this study in relation to Bourdieu's suggestion of the four capital (financial, symbolic, social and cultural) are financial, social, cultural and intellectual capital. Bourdieu relates symbolic capital to power accumulation of groups or individuals to define 'who or what is most 'legitimate' in various societies and societal groups' (Skaates et al, 2002). Skaates et al however suggested that such a definition of symbolic capital is highly complex in the field of architecture and 'difficult to capture over the span of a mere decade' (Stevens, 1998 as cited by Skaates et al, 2002). As the present study is related to design firms within the construction industry, the high level of diversity further compounds the complexity. Therefore symbolic capital has been excluded and replaced with intellectual capital, which is of more relevance to the study of internationalisation of design firms.

Social, cultural and intellectual capital should be considered in the early stages of the internationalisation process as they are organisational performance indicators; along with financial measures. There is the need to develop business performance indicators to determine the level of success of firms that enter foreign markets. To date these indicators have not been developed within the academic literature and thus there has been no measurement of the sustainability of firms that have entered international markets.

Kagioglu et al (2001) however have developed a performance management process framework (PMPF) which attempts to integrate the main features of performance management within a matrix based upon the balanced scorecard model. One drawback of this framework, as outlined by Kagioglu et al (2001, p.94), is that the framework has not been validated through 'extensive empirical evidence'. It does, however, provide a starting point for this study. Business performance indicators need to be developed in relation to entry strategies to contribute to the development of sustainable business into foreign markets by Australian construction design firms. This section will now describe the less tangible aspects of a firm's capital which are social, cultural and intellectual capital.

3.1 SOCIAL CAPITAL

According to Cohen and Prusak (2001, p4):

'Social capital consists of the stock of active connections among people: the trust, mutual understanding, and shared values and behaviours that bind the members of human networks and communities and make cooperative action possible'

In a study on the internationalisation of Danish architectural firms Skaates et al (2002) saw national construction industries as milieus or groups characterised by geographical areas which had a network of actors with a set of 'rules and norms regulating the interactions between these actors' (Cova and Ghauri, 1996). Consistent with Cohen and Prusak's definition, Skaates et al (2002) defined social capital as recognition by other actors within the construction industry that the firm is a member of 'their inner circle due to one's dispositions...or one's way of working and 'tacit knowledge'. Social capital has relevance for the project team networks and the organisation and client networks.

Cohen and Prusak (2001) observe the benefits of social capital for organisations as follows:

- Better knowledge sharing, due to established trust relationships, common frames of reference, and shared goals for firms to diverse their offering of services or products to match the changing needs of clients and to assist in the understanding of client's requirements.
- Lower transaction costs, due to a high level of trust and a cooperative spirit (both within the organisation and between the organisation and its customers and partners)
- Low turnover rates, reducing severance costs and hiring and training expenses, avoiding discontinuities associated with frequent personnel changes, and maintaining valuable organisational knowledge.
- Greater coherence of action due to organisational stability and shared understanding

Woodhead International is an example of an Australian architectural firm which has achieved phenomenal success in internationalising to China through the acquisition of social capital. The firm has 'recorded a 150% increase in business with the Asian country over the past year' (Property Australia, 2004). Although an impressive record, it is noted that this level of success has only been achieved after a registration process that took more than five years. Through indicating a long term commitment to the country, Woodhead International, among a few other international architectural firms has been granted a 20-year registration as a wholly foreign owned enterprise, which allows the firm to operate in China without a Chinese-owned company partner. This of course challenges the myth that to conduct business in foreign countries, particularly Asia and China, one requires a joint venture to achieve success. It does suggest that client trust and satisfaction is an important part of a sustainable international business venture.

3.2 CULTURAL CAPITAL

Cultural capital entails physical 'dispositions' such as 'building visible buildings, winning design competitions, or obtaining important tenders' (Skaates et al, 2002). These concepts are premised on the reputation of the firm in that the success of marketing architectural services 'depends upon the firm's ability to sell and deliver a credible promise' (Lowendahl, 2000).

It differs from social capital in that it is the high profile of a firm's projects that marks the firm as having acquired a high level of cultural capital. Therefore, cultural capital is the firm's highly regarded past achievements that create trust and credibility; which is different from trust that is formed through relationships or networks, which is social capital.

A firm acquires cultural capital through building successful buildings, thus creating a presence in the foreign market. It can be likened to achieving a foothold in a market, where success often breeds further success. More and more clients are relying on instantaneous recognition in their decision-making process when employing design firms and such recognition is gained through the creation of reputation. A firm's reputation is earned through a high level of cultural capital. Cultural capital can contribute to the knowledge developed by a firm; such knowledge can be termed intellectual capital.

3.3 INTELLECTUAL CAPITAL

Intellectual capital is an organisation's collective skills, experience, competences and knowledge and is critical to the sustainability of firms, particularly in international markets. According to Stewart (1998), the strength of a firm lies within its intangible assets, where he posits that intellectual capital of a firm is 'the talents of its people, the efficacy of its management systems and the character of its relationships to its customers'.

A 1998 national survey of Australian architectural firms (Draganich, 1998) identified the understanding of cultural issues and market knowledge as one of the key success factors for firms when exporting their services. A firm's market knowledge and understanding of cultural issues typically arises from individual experiences with particular markets, clients and projects. General knowledge of a foreign market and the client is improved through successive completion of projects and these experiences create tacit knowledge. Such tacit knowledge will contribute towards achieving client satisfaction.

A firm can also acquire its intellectual capital through establishing skills and niche expertise through by employing specific skilled staff members, which would enable the firm to respond to client's requirements more efficiently. A firm's skill specialisation which is accumulated through its involvement in previous projects and employment and can contribute to winning further projects as clients value a firm's expertise to deliver satisfying results.

4.0 STRATEGIC INDICATORS FOR INTERNATIONALISATION

Whilst the internationalisation process is often viewed as one of which necessitates extensive country-specific knowledge and significant financial resources (Eriksson et al, 1997), long term perspective afforded by the capital acquisition approach may provide advantages to firms attempting to internationalise into foreign markets. Scarce resources means one firm cannot supply all the necessary skills, knowledge and expertise for the process (Porter and Fuller, 1986). However, the dynamics of capital acquisition allows for a firm to build upon initial resources to achieve sustainability in foreign markets and to understand and contextualize the value of various forms of capital to a firm's internationalisation strategy.

An example of how a firm strategically manages its capital acquisition is the firm's conscious decision to penetrate a foreign market through heavy financial investments into that market without immediate return. Such investments may not lead to immediate financial success but will initiate the firm's acquisition of social, cultural and intellectual capital. As such the firm may build up its acquisition of capital by creating networks, gaining reputation and developing skills. This would in turn translate to financial success in the long term.

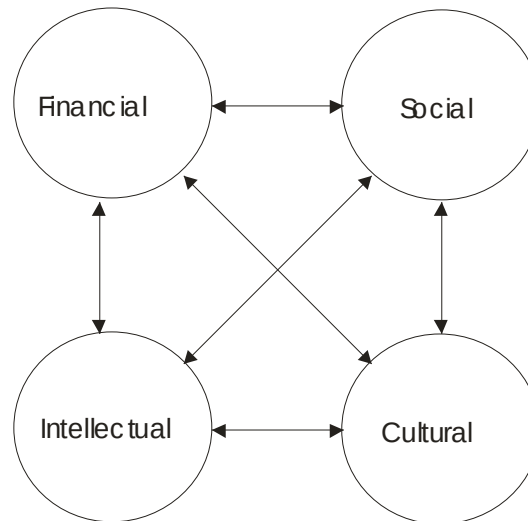


Figure 3.0: Relationship between capital (Developed for this study)

As shown in Figure 3.0, the four types of capital interact and impact upon each other because throughout the internationalisation process, a firm accumulates its social, cultural and intellectual capital to contribute towards its financial capital. After having been involved in several projects in a foreign market, a firm would have increased its cultural capital whilst building up its intellectual capital at the same time. Similarly, after having been employed in a certain number of projects thus acquiring its cultural capital, a firm would be working within a network of firms or would have developed a certain rapport with clients, hence accumulating its social capital.

The benefits of acquiring social, cultural and intellectual capital are strategic indicators of long term sustainability of firms in international markets. Therefore it pays to examine the characteristics of the many different firm typologies suggested earlier in this paper in terms of the level of capital accumulation required for a specific entry mode strategy in relation to a firm's organisational goals. Different firm types impact upon entry mode strategies and capital acquisition. For example, a firm from the artistic market that wishes to sell its services through market seeking strategy would most likely succeed in its endeavours by accumulating a moderate level of social capital, high level of cultural capital and low level of intellectual capital.

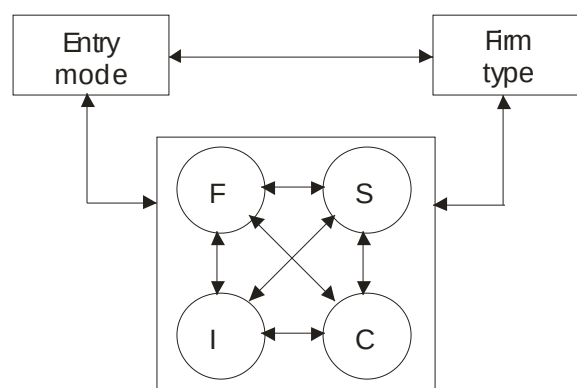


Figure 4.0: Relationship between capital, firm type and entry mode (Developed for this study)

The inter-relationship of the level of social, cultural and intellectual capital is affected by firm type and entry mode strategy as shown in figure 4.0 and will enable the effective positioning of the firm in international markets to achieve

client satisfaction. The following Table 4.0 has been developed to uncover potential relationships between entry mode strategy, firm type and capital.

		Social Capital	Cultural Capital	Intellectual Capital	Financial Capital
Type 1: artistic	CF				
	MS				
Type 2: professional	CF				
	MS				
Type 3: technical – economic	CF				
	MS				

Table 4.0: Impact of firm typologies and entry mode strategies on firm capital (developed for this study)

5.0 CONCLUSION

This theoretical paper examined the development of a conceptual framework for design firm internationalisation related to client satisfaction based upon firm internationalisation process, design management and market knowledge. More specifically the entry mode was considered in detail in relation to firm internationalisation. It is proposed that entry mode is dependent upon firm type. Firm type and entry mode strategies are factors which impact upon firm capital. Firm capital are the strategic indicators of long term sustainability. A firm's capital includes financial, social, cultural and intellectual dimensions. Sustainability is increasingly not only seen in terms of financial capital acquisition but also in terms of the acquisition of social, cultural and intellectual capital. It is becoming more and more significant in the economy.

"A great deal of attention worldwide is being directed toward the reporting activities of companies" (AGDH, 2004). Further to this the Australian federal government have recently recognised the significance of the concept of sustainability to the economy through the release of a national study, "The State of Sustainability Reporting in Australian 2004". This report defines sustainability reporting as the measurement of the economic, environmental and social dimensions of their activities, products and services. Organisations in all industry sectors are increasingly recognising the benefits of producing sustainability reports and have cited the key benefits of measuring success as the following (AGDEH, 2004):

- Reputation enhancement
- Gain confidence of investors, insurers and financial institutions
- Operational and management improvements
- Improved management risks

Reporting is one step in the process of making explicit and recognising the value to a firm's long term sustainability in international markets of softer and less tangible performance indicators. Social, cultural and intellectual capital along with financial profit are in the long term measurements of client satisfaction and have an important role to play in market entry, acquisition of new projects, maintenance of existing project performance and the maintenance of social and business networks. Firms who achieve long term sustainability in international markets are constantly adapting their

business model to achieve client satisfaction by a combination of self assessment, market assessment and project needs assessment. All successful firms ultimately achieve in local markets this but what is intensified in the international market is the need for flexibility and adaptability and continual reassessment as the market evolves in various localities. Flexibility occurs in resource management, design service/solutions and client responsiveness.

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STAKEHOLDERS

Full Paper

A MULTIPLE CRITERIA DECISION MODEL FOR ACCESSIBILITY ASSESSMENT

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ABSTRACT

Accessible or inclusive building design is one that enables everyone to gain easy access to a facility, regardless of the type or degree of flexibility. Since the introduction of the Disability Discrimination Act 1995 (DDA) in the UK, the consideration of issues such as access and inclusive design has become paramount. Space analysis is one of the important aspects of current accessibility assessment. Existing space analysis techniques, such as Space Syntax, have tackled the local and global accessibility of a building layout using the graph theory. However, there are difficulties in the automatic transfer the design information from architecture drawings into a space analysis tool. With the recent development of the building information model (BIM) and IFC (Industry Foundation Classes), it is possible to automate the transfer process through IFCs. This paper demonstrates the automation process and how it can be used in accessibility analysis.

Keywords: Accessibility, Building Information Model, Space Syntax, Graph Theory, Space Planning

1. INTRODUCTION

Current UK legislation regarding accessibility is governed by in the Building Regulation and Disability Discrimination Act (1995). This Act encourages the creation of environments that are accessible by all persons irrespective of any disability, including people with physical, sensory and cognitive impairments. The publication of BS 8300:2001 'Design of Buildings and their Approaches to Meet the Needs of Disable People – Code of Practice,' and the subsequent revision of Part M of the Building Regulation give detailed guidance on the design of domestic and non-domestic buildings.

The level of access of an existing building or new development is assessed through access audits and access appraisals; in addition, an Access Officer from the local planning office is involved in the development of all public facilities during the planning stage. :

- Access audit: An access audit is to establish how well a particular building or environment performs in terms of access and ease of use by a wide range of potential users. The audit report should recommend access improvements, prioritise action and indicate where improvements can be made. (Sawyer and Bright, 2004)
- Access appraisal: The Access appraisal is an audit of the proposals for a new development, refurbishment or alteration. This involves making a detailed assessment of the proposed level of accessibility in a building using drawings, specifications and consultation with architect or designer. (Sawyer and Bright, 2004)

However, the process of the both access appraisal and auditing can be lengthy and cumbersome, especially when the building is large and complex. It involves numerous site visits, field surveys and the overall assessment often solely relies on the access consultant or auditor's experience. It has also been acknowledged that it is not always possible to fully cater for every one according to their individual needs, although it is possible to create an environment that encompass wide range of users (Barker et al., 1995). Therefore, can the process be automated or simplified with aid of the technology? With the recent development of the building information model (BIM), it is possible that many aspects of accessibility assessment can be conducted on a virtual building model, such as spatial arrangement of the building, individual characteristics of building elements, etc. This paper aims to demonstrate how to use the building information model to analyse the space layout and how the accessibility requirements can be integrated.

2. SPACE ANALYSIS

The spatial design of a building is usually governed by building and fire safety codes. As the concept of the inclusive design becomes ever important in architecture design, the traditional fire safety rules may not provide an efficient solution to accommodate the new demand. A method of space analysis, Space Syntax was developed by Hillier and Hanson (1984), University College of London, is proven helpful for the organisation of space in architecture.

Space syntax is a set of techniques for representing space in a building or city concerning the social use of space. From the very beginning, space syntax research focussed on the relationship between space and social life, be this the social life of a

simple building, a complex building (or set of buildings), a settlement or an urban district. Using this technique, the probable outcome of design decisions can be forecasted during the design process. Designs can then be modified so they will achieve levels of movement and space use appropriate to the functions desired on the site. At that time, the approach pioneered by Hillier and Hanson was unique, as it involved analysing solely the spaces between buildings as opposed to a building's (or buildings') geometric form (Hillier and Hanson, 1984).

According to Hillier & Hanson (1984), the important property of quantification is the permeability of the system; that is, how the arrangement of cells and entrances controlled access and movement. These properties can be represented by making a graph of the spaces in a building, with circles or nodes representing spaces and linking lines representing entrances, and 'justifying' it with respect to the outside world. This method measures the connectivity of spaces within built environment for example, the number of doors you have to go through to get to a particular space. This enables the comparison between the most linked and most isolated space layouts. The average minimum steps required getting from one space to another space, term as the depth value is to show the relationship of connectivity. The smaller the depth value the more accessible is the space.

Space syntax analysis is beneficial for measuring the local and global layout of the building, however, it does not measure the distance taken to pass through from one space to another space. However, such analysis requires converting the building layout into a specific model that can be analysed by using Space Syntax techniques. With large and complex building, this task can be tedious and lengthy. With recent development of the building information model, the spatial relationship has already been built into the model and similar analysis can be directly performed upon. Furthermore, other aspect of information such as accessibility criteria can be included in the analysis. In the following section of the paper, the building information model is illustrated to demonstrate how the spatial analysis can be performed.

3. BUILDING INFORMATION MODEL

The concept of a building information model (BIM) was introduced in 1970s. Much of the research in this field has been undertaken by academics (Eastman, 1999). Until recently, leading CAD vendors, such as Autodesk, Bentley and Graphisoft, have started to heavily promote the concept, Building Information Model (BIM). The BIM is a digital data model of building design information, which may also contain information about the building's construction, management, operations and maintenance. Unlike traditional 2D CAD systems in which the building design is represented in multiple drawing files made up of lines, arcs and circles, the BIM is a single information model that is constructed with intelligent 'objects' which represent building elements like walls, slabs, roofs, doors and windows. If a window is moved in the elevation, the corresponding plan or section will be updated automatically to show the window's new location. If the design parameters of the window are changed in the window schedule, those changes are automatically reflected in the drawing views as well (Graphisoft, 2003).

Various technologies and research projects have demonstrated the benefits of building information model concept (Lee et al., 2003). However, these technologies are based on different standards that are not compatible to each other. An open and neutral data format is required to ensure the data compatibility across the different

applications. IFC (Industry Foundation Classes) developed by IAI (International Alliance for Interoperability) provides such capabilities.

3.1 Industry Foundation Classes

IFC is a comprehensive data representation of the building model and it is also a set of rules and protocols of how you define the data describing the building. IFCs have been defined by the AEC/ FM industry and provide a foundation for the shared project model. This works through the specification of classes of components in an agreed manner that enables the development of a common language for construction. IFC-based objects allow AEC and FM professionals to share a project model, yet allow each profession to define its own view of the objects contained in that model. This leads to improved efficiency in cost estimating, building services design, construction, and facility management. IFC enables interoperability among AEC/ FM software applications. Software developers can use IFC to create applications that use universal AEC/ FM objects based on the IFC specification. Applications that support IFC will allow members of a project team to share project data in an electronic format. This will ensure that the data is consistent and coordinated. Furthermore, this shared data can continue to evolve after the design phase and throughout the construction and occupation of the building. The information generated by the project design team will be available to the building construction team and building facilities managers in an intelligent, electronic format through their IFC compliant software (IAI-International, 2003).

3.2 IFC Space Model

In IFC model, a space is defined by *ifcSpace* entity, which represents an area or volume bounded actually or theoretically. Spaces are areas or volumes that provide for certain functions within a building. A space is (if specified) associated to a building storey (or in case of exterior spaces to a site). A space may span over several connected spaces. Therefore a space group provides for a collection of spaces included in a storey. A space can also be decomposed in parts, where each part defines a partial space (IAI-International, 2003).

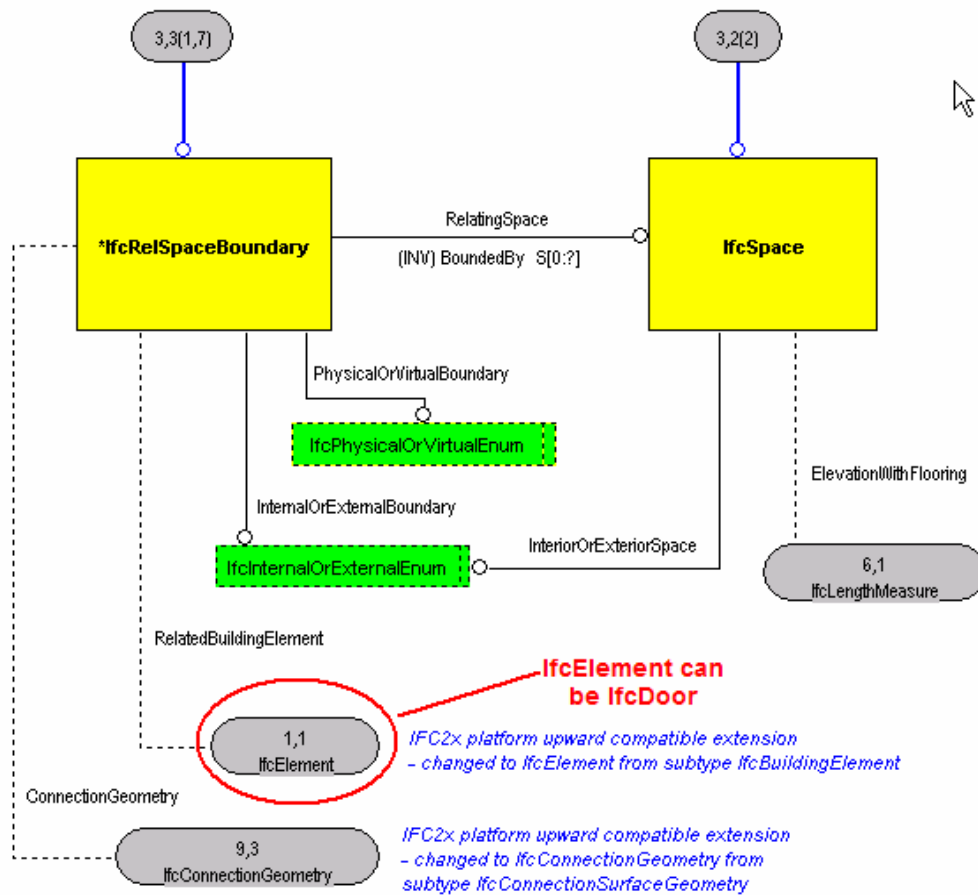


Fig.1 IFC Space Model (IAI-International, 2003)

The relationships between space and other building elements such as windows, doors, walls, are defined by *ifcRelSpaceBoundary* entity. The space boundary (*IfcRelSpaceBoundary*) defines the physical or virtual delimiter of a space as its relationship to the surrounding elements. (IAI-International, 2003) More detailed information about the IFC modelling specification can be found in IFC implementation guide (IAI-International, 2003).

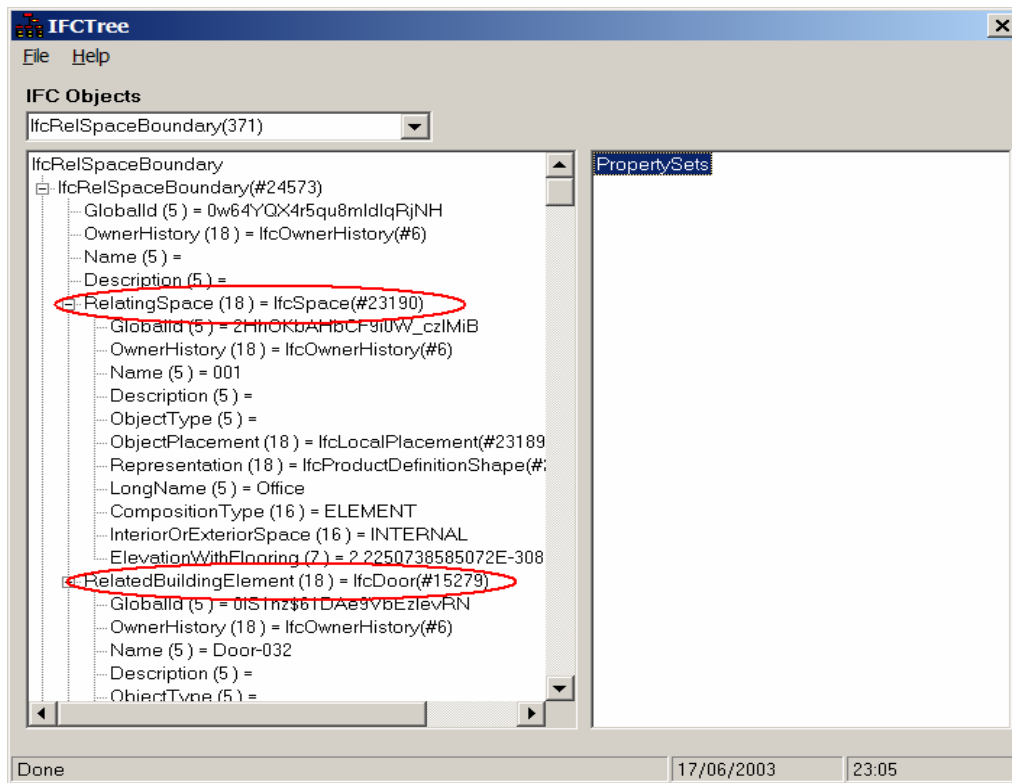


Fig.2 - an example of IFC space boundary definition.

The Fig.2 is an example of how to use ifcSpaceBoundary to define the relationship between a space and a connected door. It shows a space (ifcSpace, #23190) has a door (ifcDoor, #15279). It looks quite complicated and requires detailed knowledge of IFC modelling to implement relevant application. In order to ease the implementation, the IFC space model can be simplified into the following Graph (Fig.3), which only contains node (vertex) and links (edge) between the nodes (vertices). Graph theory is a branch of mathematics and a Graph is a very simple structure consisting of a set of vertices and a family of lines (possibly oriented), called edges (undirected) or arcs (directed), each of them linking some pair of vertices. In our model, vertex represents space and edge represents space exit (i.e. door).

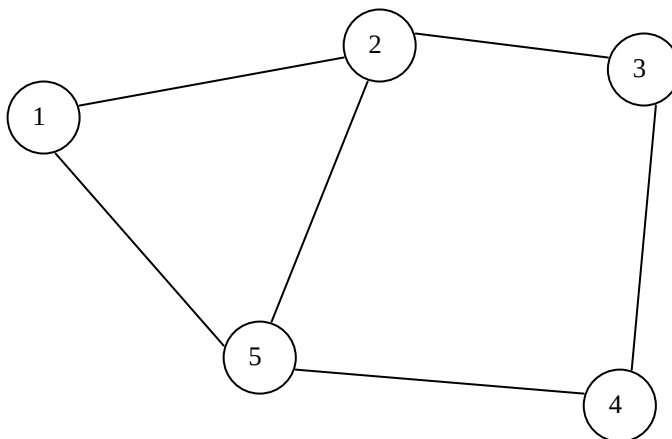


Fig.3 Simplified Space Model into Graph

4. GRAPH THEORY

The Graph Theory was developed in a research paper by Leonhard Euler in 1736 (Lloyd and Wilson, 1976). Euler discusses whether or not it is possible to stroll around Konigsberg (later called Kaliningrad) crossing each of its bridges across the Pregel (later called the Pregolya) exactly once. Graph Theory was born to study problems of this type. In the past two decades, graph theory has demonstrated that it is an effective tool for solving space problems/ floor planning (Grason, 1970, chwartz et al, 1994, Medjdoub et al, 2000).

A graph is a set of dots, called vertices or nodes, connected by links, edges or arcs. Depending on the applications, edges may or may not have a direction; edges joining a vertex to itself may or may not be allowed, and vertices and/or edges may be assigned weights, i.e. numbers. If the edges have a direction associated with them (indicated by an arrow in the graphical representation) we have a *directed graph*. Structures that can be represented as graphs are ubiquitous, and many problems of practical interest can be formulated as questions about certain graphs. (Wikipedia, 2003).

Although it is convenient to represent a graph by a diagram of dots linked by lines, such representation is not suitable for computer storing and processing. One way of storing a graph is by listing the vertices adjacent to each vertex of the graph, it can be represented by a matrix, which often called Adjacency Matrix.

Adjacency Matrix is quite simple. Given N nodes, from an enumerable set, just make an NxN matrix Adj. The value in Adj[i, j] says whether j is an immediate successor of i or not. For unweighted graphs, Adj[i, j] can just be true or false, or 1 or 0, e.g.,

- Adj[i, i] = 1, for every node i
- Adj[i, j] = 1 if node i is directly connected to node j, 0 otherwise

For weighted graphs, Adj[i, j] is a numeric value.

For above (Fig.3), the adjacency matrix would be:

$$\begin{bmatrix} 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 \end{bmatrix}$$

Depth first traversal algorithm (Tarjan,1972) can be used to find all the possible paths for given two nodes.

5. IMPLEMENTATION

The practical implementation consists of two stages. The first stage is to export the IFC space model into a graph. This requires using IFC toolbox (Yoshinobu, 2003 and Eurostep, 2003) to access IFC data model to extract relevant space information into

a database. The second stage of the implementation is to carry out analysis based on the graph. For example, path finding is one of the possible analyses. Both stages of the implementation will be demonstrated through the following example scenario.

Example Scenario

The building model of this example is a created by ArchiCAD (Fig.4). There are 8 spaces that are defined in this model:-

- Space 1 – Reception Area
- Space 2 – Corridor
- Space 3 – Corridor
- Space 4 – Office
- Space 5 – Office
- Space 6 – Office
- Space 7 – Office
- Space 8 – Office

The IFC data file is generated by ArchiCAD IFC add-on, here is a snapshot of how the IFC data file looks like.

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION (('ArchiCAD 7.00 Release 1 generated IFC file.', 'Build Number
of the Ifc 2x interface: 00102 (22-04-2003)'), '2;1');
FILE_NAME ('spaceExample.IFC', '2003-06-17T23:51:59', ('Architect'), ('Building
Designer Office'), 'PreProc - IFC Toolbox Version 2.x (00/11/07)', 'Windows System',
'The authorising person.');
```

```
FILE_SCHEMA (('IFC2X_FINAL'));
ENDSEC;
DATA;
#1 = IFCORGANIZATION ('GS', 'Graphisoft', 'Graphisoft', $, $);
#3 = IFCPERSON ($, 'Song Wu', $, $, $, $, $);
#4 = IFCORGANIZATION ($, 'University of Salford', $, $, $);
#5 = IFCPERSONANDORGANIZATION (#3, #4, $);
#7 = IFCSIUNIT (*, .LENGTHUNIT., .MILLI., .METRE.);
#8 = IFCSIUNIT (*, .AREAUNIT., $, .SQUARE_METRE.);
#9 = IFCSIUNIT (*, .VOLUMEUNIT., $, .CUBIC_METRE.);
#10 = IFCSIUNIT (*, .PLANEANGLEUNIT., $, .RADIAN.);
#11 = IFCMEASUREWITHUNIT (IFCPOSITIVELENGTHMEASURE
(57.29577951308232), #10);
.....
```

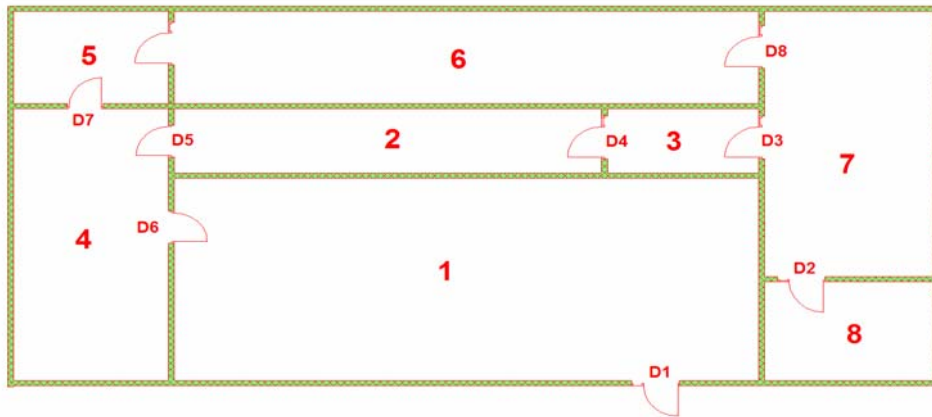



Fig.4 Example building model and IFC data file

5.1 Exporting IFC Space Model

First of all, a database needs to be developed to store space information from the IFC data file. The database structure is developed based on the simple space model shown in Fig., an entity relationship diagram is created to map the database tables (Fig.5). There are only two entities in the diagram, space and space exits (doors), the relationship between them is 'one space contains one or many space exits.' And 'one space exit is connected to one or two spaces.'

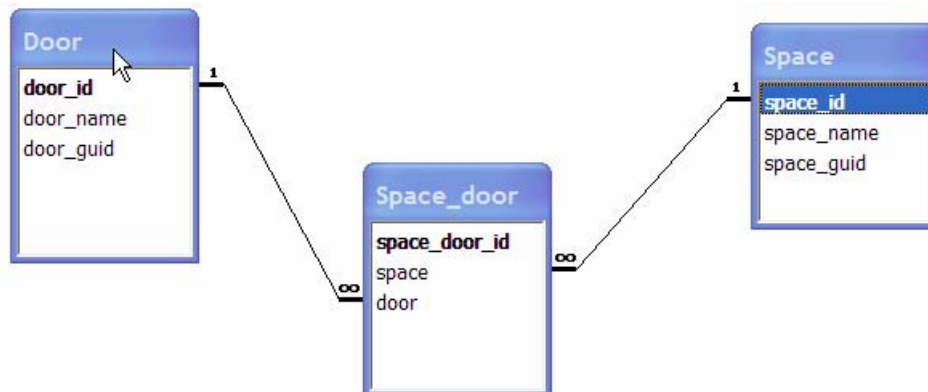


Fig.5 Space Data Table

The next step is to identify space information in IFC data file and export them to the database. The key IFC object for identifying the relationship between space and related building element is IfcRelSpaceBoundary, it has the following two attributes to enable the referencing.

- IfcRelSpaceBoundary.RelatingSpace – reference to a IfcSpace in question
- IfcRelSpaceBoundary.RelatedBuildingElement – reference to building element connected to above IfcSpace .

Here are the steps how to export the spaces information:

- Find all IfcSpace objects and IfcDoor objects to export into database
- Iterate through the IfcDoor objects and use INVERSE relationship with attribute, providesBoundaries to locate IfcSpace objects in the model which are connected to the IfcDoor object and export this information into database.
- From database, it is not difficult to establish a graph based on the space information, the spaces are the nodes (vertices) and the doors are the edges.

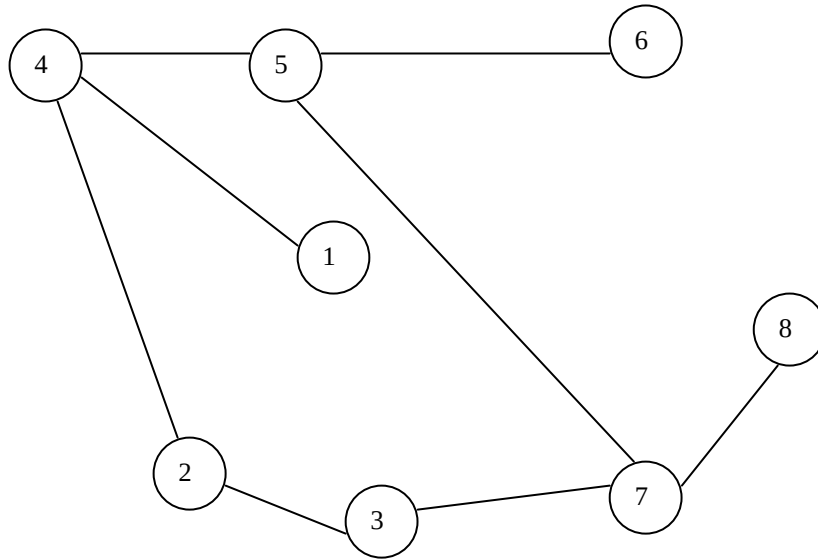


Fig.6 Graph Representation

The adjacency matrix of the above graph is:-

$$\begin{bmatrix}
 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\
 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 \\
 1 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\
 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\
 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\
 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 \\
 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1
 \end{bmatrix}$$

With depth first search algorithm, paths for given two nodes can be generated, which means all possible routes between two spaces can be identified. Since the Space Syntax techniques are primarily based on the graph theory, most of the Space Syntax techniques can be used for spatial analysis. In this paper, the authors are looking into how the accessibility design criteria can be integrated into space flow analysis.

6. INTEGRATION OF ACCESSIBILITY DESIGN CRITERIA

The Building Regulation and the Disability Discrimination Act 1995 (DDA) has a major influence on accessibility and its requirement should be taken into account in the design and management of buildings and the environment. From October 2004, it is intended that all service providers will have to make reasonable adjustments to the physical features of their premises to overcome physical barriers to access (Sawyer and Bright, 2004).

The Building Regulations that directly relate to access are Part M – Access and facilities for disabled people and Part B – Fire Safety. The Approved Document for part M regulation gives detailed guidance as to how the requirement may be met. It is overhauled to reflect the recommendations in BS8300:2001 (Sawyer and Bright, 2004). The following table is a summary of the accessibility criteria directly related to the space analysis based on the Approved Document and BS8300:2001. This list in the table is not exhaustive, and it is intended to highlight the areas for accessibility design criteria and how they can be analysed with the building information model. The italic texts inside brackets are the analysis methods that the author suggests to use in the proposed analysis model. 'Check in IFC model' means to check relevant IFC entity to extract the information for analysis, such as doors – ifcDoor, dimensions of the doors. Usually the information is already included in the building model (IFC model) and checking can be carried out automatically to ensure that the criteria are met. 'Flag as information' refers the information required to perform the analysis is not directly available in the building model (IFC model) and the accessibility criteria information can only be highlighted to remind user (designer) that this information has to be considered in the design.

Items	Criteria (<i>Analysis Method</i>)
Entrance	• Access by everyone • Visible on approach • Location relate to external route and car parking • Sufficient space • Lighting level
Entrance Door	• Minimum clear opening 800 -900mm for single leaf (<i>Check in IFC model</i>) • Minimum 300mm space beside the leading edge of the door (<i>Check in IFC model</i>) • Door closer should be avoided or adjusted to minimum force (<i>Flag as information</i>) • Outward opening door should be recessed or adequate swing area (<i>Check in IFC model and flag as information</i>) • Vision panels should be provided in frequent use door (<i>Check in IFC model and flag as information</i>) • Glazed doors and side panel require manifestation to increase visibility (<i>Flag as information</i>) • Edges of glazed door should clearly visible (<i>Flag as information</i>) • Door furniture should be distinguishable (<i>Flag as information</i>) • Lever handles allow use by elbows or edge of the hand (<i>Flag as information</i>) • A kicking plate can protect a door from wheelchair (<i>Flag as information</i>)

Automatic doors	• Automatic activation, manual activation should be clearly signed (<i>Flag as information</i>) • Swing door requires protection to swing area (<i>Flag as information</i>) • Sliding doors are generally preferred (<i>Flag as information</i>) • Doors should remain open for long enough (<i>Flag as information</i>) • Automatic doors require safety devices to ensure that the door does not close if there is an obstruction (<i>Flag as information</i>)
Thresholds	• Should be flush (<i>Flag as information</i>) • Maximum change in level is 15 mm (<i>check in IFC Model and Flag as information</i>)
Reception areas	• The waiting area should be quiet and well lit (<i>Flag as information</i>) • Sufficient space and unobstructed routes (<i>Flag as information</i>) • Furniture should be adequately contracted in term of colour and luminance (<i>Flag as information</i>)
Horizontal Circulation	• Clearly identifiable routes and layouts • Clear directional information should be provided
Corridor and passageways	• Minimum width of 1200 mm for corridors • Minimum width of 1800 mm when there are significant numbers of wheelchair users • Corridor widths should be unobstructed • Outward opening doors should be recessed
Surfaces	• Highly reflective finishes should be avoided (<i>check in IFC model and flag as information</i>) • Colour and luminance contrast will define different building element (<i>Flag as information</i>) • Floor surface should be firm, flush and slip resistant (<i>Flag as information</i>) • Carpet should be firmly fixed (<i>Flag as information</i>) • Surface-laid rugs and mats must be avoided in public buildings (<i>Flag as information</i>)
Internal Doors	• Minimum clear opening width 750-800 mm for single door (<i>Check in IFC Model</i>) • Sufficient space around door for manoeuvre (<i>Flag as information</i>) • Door opening into a circulation route should be recessed (<i>Check in IFC model and flag as information</i>)
Fire Doors	• Closing force exceeds 20 N, electrically powered hold open device should be installed (<i>Flag as information</i>) • Closing force with a push action in one direction should not exceed 30 N (<i>Flag as information</i>) • Smoke seals, install an angel seal as an independent item in the doorframe (<i>Flag as information</i>)
Visibility and Vision panel	• Similar to entrance door
Vertical circulation	• Ramps or lifts should be provided at all changes of level • All internal changes of level should be clearly indicated
Internal step and stairs	• Handrails should provided (<i>Check in IFC model</i>) • Isolated single step should be avoided (<i>Flag as information</i>) • Minimum width of stairs is 1000 mm (<i>Check in IFC model</i>) • Landing of minimum 1200 mm should be provided at each flight (<i>Check in IFC model</i>) • Maximum number of risers between landing is 12 (<i>Check in IFC</i>)

	<i>model)</i>
Risers and goings	• The height of the riser should be 150mm – 170mm (<i>Check in IFC model)</i> • The going should be 250 – 300mm, 300 mm is preferred (<i>Check in IFC model)</i> • Open risers and deeply recessed risers should not be used (<i>Flag as information)</i> • The nosing of each step should be adequately contrasted with the reminder of the step (<i>Flag as information)</i>
Internal Ramp	• Ramps in internal corridor should be highlighted to increase visibility. (<i>Flag as information)</i> • Ramps should always have suitably designed handrail (<i>Flag as information)</i>

Table 1 – Accessibility design criteria

Fig.7 is a flow chart for space analysis with accessibility perspective. It starts with calculating the possible routes for two selected spaces and all the possible routes information will be stored in a database. Each route in the database will be checked against accessibility design criteria. The accessibility design criteria is a rule based database that includes information such as dimension requirements of space, size requirements for doors, and functional requirements for space, etc. For example, typical rule is 'width of door shall be big than 800mm'. Therefore, each route is checked against all the rules in the database to ensure that the door is wider enough for wheelchair user, space is accessible to all users, etc. However, as listed in table 1, accessibility design criteria are not limited to the physical dimension of spaces or doors and it also includes lots of subjective requirements and such information can not be directly analysed by current proposed method. Other IT tools such as Virtual Reality can be used and further research of how other IT tool can support the accessibility analysis needs to be carried out.

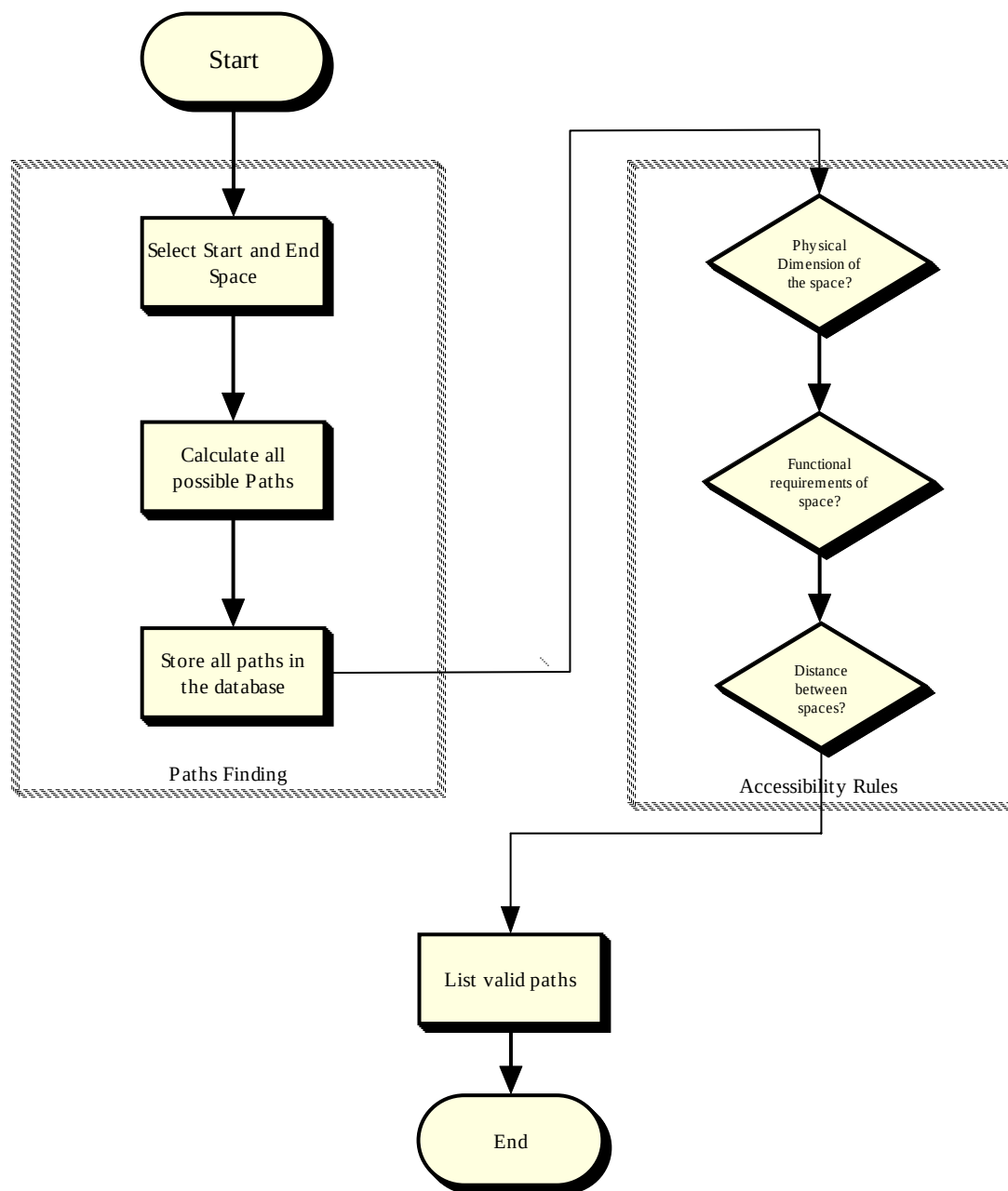


Fig. 7 Space flow analysis for accessibility

8. CONCLUSION

Over the years, inclusive design has become an important concept in the built environment. It aims to create a friendly and welcoming environment to everyone regardless of their age and physical ability. With the introduction of DDA and part M of the building regulations is going to take full effect in May 2004, the compliance of the accessibility design criteria is more important than ever before. This paper is an attempt of simplifying the accessibility assessment process through exploring the potential of the IFC based building information model with existing space analysis techniques. The research has demonstrated the capability of the technology and its potential.

However, further research is required to investigate how the more subjective information can be integrated and analysed and practical implementations need to be carried out to validate the outcome of the research.

ACKNOWLEDGEMENT

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STRUCTURING FINANCE TO MEET CLIENT'S NEEDS

Full Paper

RISK ASSESSMENT IN LIFE-CYCLE COSTING FOR ROAD ASSET MANAGEMENT

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ABSTRACT

Queensland Department of Main Roads, Australia, spends approximately A\$ 1 billion annually for road infrastructure asset management. To effectively manage road infrastructure, firstly road agencies not only need to optimise the expenditure for data collection, but at the same time, not jeopardise the reliability in using the optimised data to predict maintenance and rehabilitation costs. Secondly, road agencies need to accurately predict the deterioration rates of infrastructures to reflect local conditions so that the budget estimates could be accurately estimated. And finally, the prediction of budgets for maintenance and rehabilitation must provide a certain degree of reliability.

This paper presents the results of case studies in using the probability-based method for an integrated approach (i.e. assessing optimal costs of pavement strength data collection; calibrating deterioration prediction models that suit local condition and assessing risk-adjusted budget estimates for road maintenance and rehabilitation for assessing life-cycle budget estimates).

The probability concept is opening the path to having the means to predict life-cycle maintenance and rehabilitation budget estimates that have a known probability of success (e.g. produce budget estimates for a project life-cycle cost with 5% probability of exceeding).

The paper also presents a conceptual decision-making framework in the form of risk mapping in which the life-cycle budget/cost investment could be considered in conjunction with social, environmental and political issues.

1. INTRODUCTION

Australia has billions of dollars worth of civil infrastructure assets as roads, bridges, railways, buildings and other structures. Road assets alone are valued at around A\$ 140 billion. As the condition of assets deteriorates over time, Queensland Department of Main Roads spends approximately A\$ 1 billion annually in asset upkeep, which amounts to expenditure in the order of A\$27 million per day.

Effective investment decision support relies on comprehensive, relevant and quality data of asset conditions; asset condition prediction modelling; and reliability assessment in life-cycle costing.

Research in the first stage of a CRC research project titled “Investment Decision Framework for Infrastructure Asset Management” concentrated on developing an effective methodology and framework for life-cycle budget/cost estimates for road asset management. Figure 1 shows the framework. There are three important tasks in the framework, namely;

Task 1: Optimisation of data collection. The method is used for analysing optimal amount of data collection. A case study was conducted to identify optimal intervals for pavement strength data collection. The result showed that for the same budget, pavement strength could be collected fivefold of currently collected data.

Task 2: Calibration of road pavement deterioration prediction models. The method is used for calibrating deterioration prediction models of asset condition for local conditions. Accurately predicting the rate of asset deterioration would result in accurately predicting fund allocation for maintenance and rehabilitation.

Task 3: Risk-adjusted assessment for life-cycle costing estimates for maintenance and rehabilitation. The method is used for assessing risk of errors in budget/cost estimates.

This paper presents concepts and methodologies of these three tasks and links them to the life-cycle budget/cost estimate for road asset management.

A conceptual decision-making framework in the form of risk mapping in which the life-cycle budget/cost investment could be considered in conjunction with social, environmental and political impacts is also presented for illustrating the concept. This research outcome can be applied to other forms of civil infrastructure such as railways, buildings, bridges, etc.

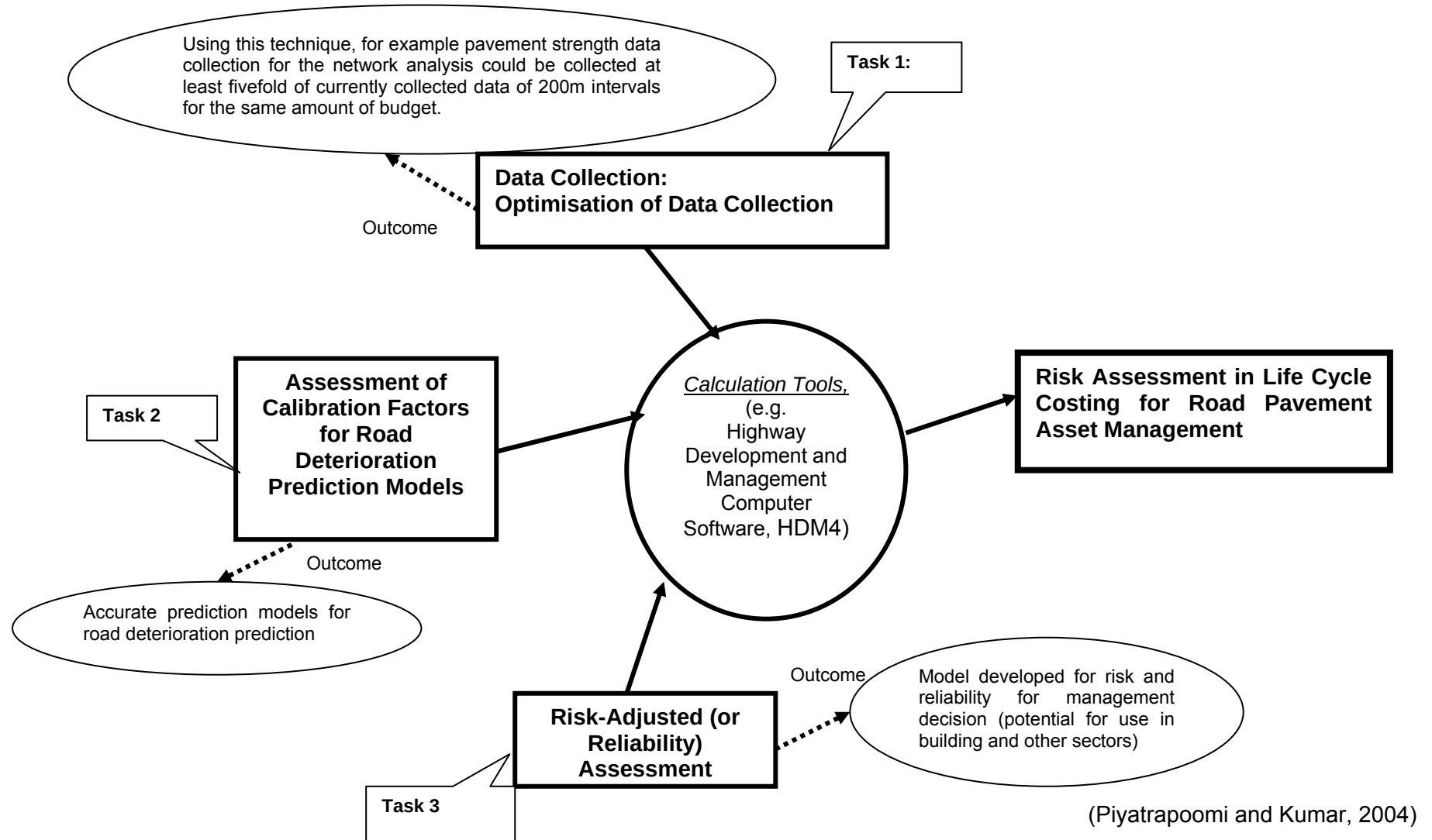


Figure 1 Investment Decision-Making Framework for Infrastructure Asset Management

2. METHOD OF OPTIMISING & RELIABILITY ASSESSMENT OF DATA COLLECTION

This method can be used for optimising data collection. A case study was conducted for identifying optimal intervals for road pavement strength data collection (Piyatrapoomi et al, Sept. 2003; Piyatrapoomi & Kumar, Jun. 2003). Methods for pavement strength data collection require test instruments to travel very slowly or to stop while loading the pavement and measuring surface deflections (a proxy for strength). Currently, pavement strength data are collected at 100m or 200m intervals which is time consuming and expensive.

Falling Weight Deflectometer (FWD) deflection test was used to collect the data (QDMR 2002). The data were collected at 200m spacing for outer and inner wheel paths for a 92km national highway in a tropical region of northeast Queensland.

It is hypothesised in the method that *“if the statistical characteristics (i.e. mean, standard deviation and probability distribution) of data sets were quantifiable, and if different sets of data possessed similar means, standard deviations and probability distributions, these data sets would produce similar prediction outcomes”*.

Optimisation analysis was carried out by reducing data from the original data set to create new sets, which were in turn, tested to see whether they had similar mean, standard deviation and probability distribution to those found in the original data set. If the new data set possessed similar mean, standard deviations and probability distribution, the new data set would provide similar prediction outcomes.

Figure 2 shows the cumulative probability distributions of the original data set of 200m spacing intervals for both inner and outer wheel paths. The means and standard deviations for outer and inner wheel paths are given below. The probability distributions were log-normally distributed.

$\text{Ln(Deflection in microns)} = N(6.05, 0.805)$ for outer wheel path
 $\text{Ln(Deflection in microns)} = N(5.95, 0.817)$ for inner wheel path

After the analysis, Figure 3 shows the cumulative probability distribution of 1000m intervals of the same 92km pavement strength data. The cumulative probability distribution of the data was fitted by a log-normal distribution with the mean and standard deviation of $\text{Ln(Deflection in microns)} = N(5.913, 0.795)$.

The results indicate that the mean, standard deviation and the probability distribution of the data set of 1000m intervals are similar to the means, standard deviations and the probability distributions of the data set of 200m intervals. From the hypothesis, it is assumed that these two sets of data would provide similar prediction outcomes. Next, it is necessary to test the reliability in using the pavement strength data set of 1000m intervals in predicting life-cycle costing.

In the reliability assessment, the term “reliability” is defined as the percentage of discrepancy between the 95th percentile budget/cost estimates and the budget/cost estimates calculated from the pavement strength data of 1000-metre intervals (Piyatrapoomi et al, Oct. 2004). The 95th percentile value is a value that is commonly selected to provide an appropriate level of confidence (Ang and Tang 1975, Billinton and Allan 1992).

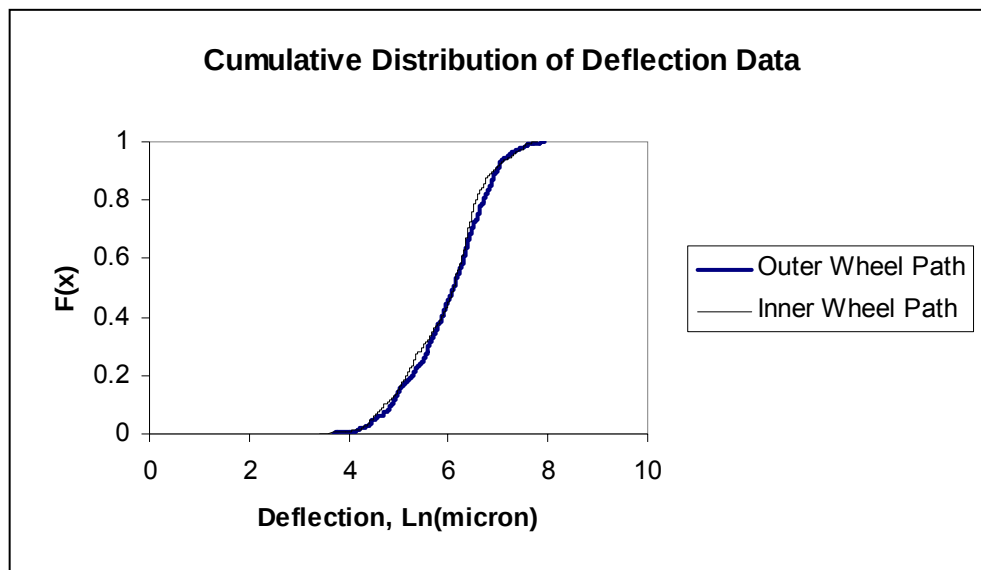


Figure 2 Cumulative distributions of pavement deflection sample data for outer wheel path and inner wheel path for a 92-kilometre national highway of Queensland

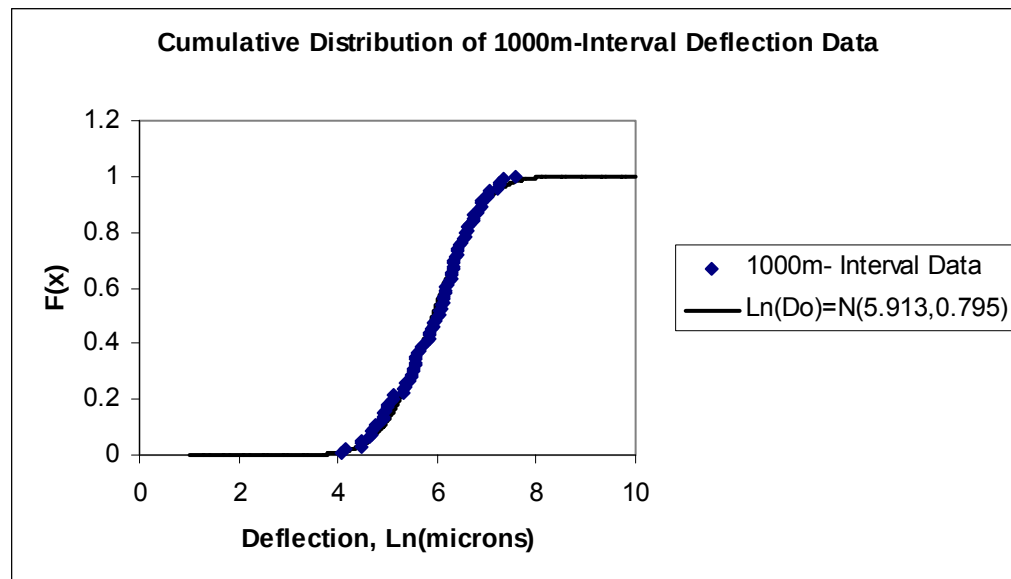


Figure 3 Cumulative distribution of deflection data set for 1000-meter interval of a 92-kilometre national highway of Queensland

The performance data of 92-kilometre national highway segment was used in the analysis. Maintenance and rehabilitation budget/cost estimates for 5, 10, 15, 20 and 25-year periods were calculated starting from 2003. In the study, Highway Development and Management (HDM-4) System software package was employed in the analysis. HDM-4, developed by the International Study of Highway Development and Management (ISOHDM 2001), is a globally accepted pavement management system.

In this study, only the discrepancy influenced by the pavement strength was considered and compared. Thus, the variability of pavement strength was used in the calculation, while other input variables remained deterministic in the budget/cost

estimates. The 95th percentile budget/cost estimate is obtained from the budget/cost estimates at the 95% probability of occurrence from the probability distribution as illustrated in Figure 4.

Figure 5 shows the discrepancies in percentage between the budget/cost estimates at the 95th percentile and the budget/cost estimates calculated from the optimal pavement deflection data of 1000-metre intervals. The differences between the 95th percentile budget/cost estimates and the budget/cost estimates calculated from the optimal data of 1000-metre intervals were calculated to be 12.23, 3.58, 2.85, 1.74 and 1.47, per cent for 5- and 10, 15-, 20- and 25-year periods, respectively.

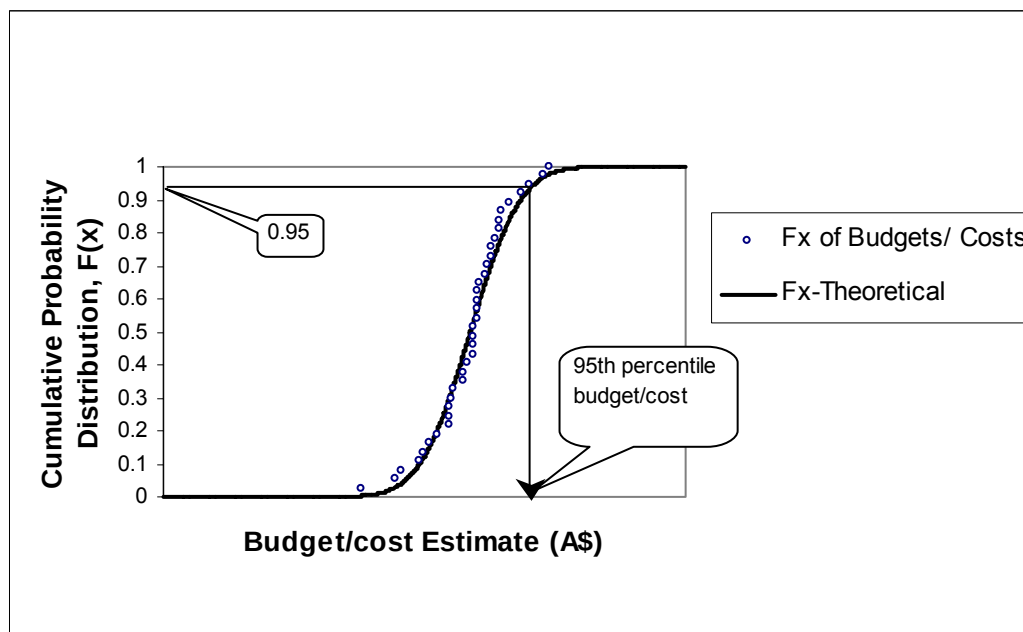


Figure 4 A typical cumulative distribution of budget/cost estimate

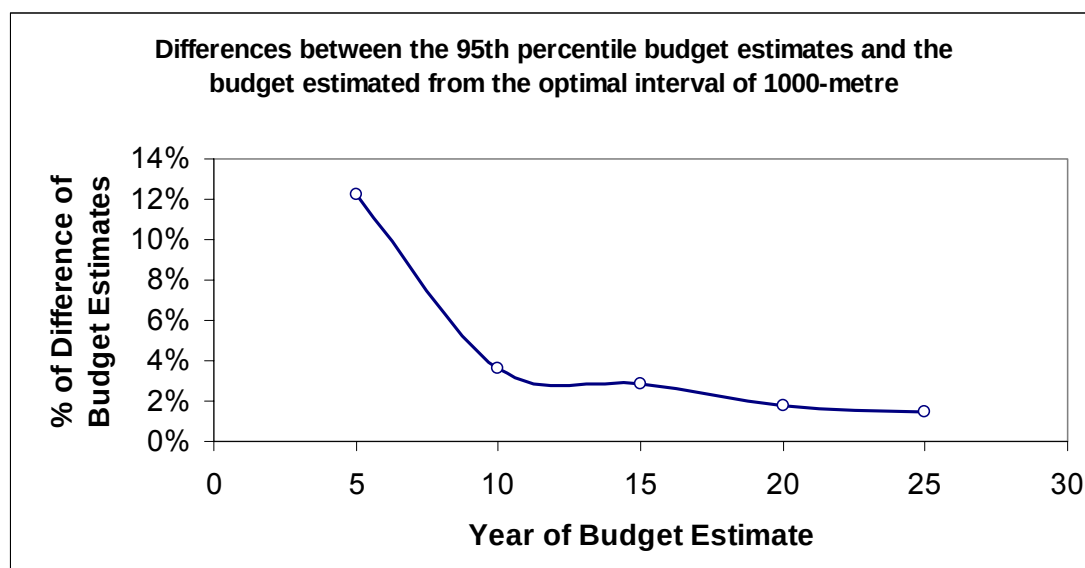


Figure 5 Percentage differences between mean budget/cost estimates and the 95th percentile budget/cost estimates for 5-, 10-, 15-, 20- and 25-year periods

It can be observed that the discrepancy between the cost estimated from the optimal pavement strength data of 1000-metre intervals and the 95th percentile for a life-cycle cost of maintenance and rehabilitation is very small (1.47%). In this case, by using this optimisation analysis method five times more highway strength could be assessed for structural strength within the same budget.

3. CALIBRATING DETERIORATION PREDICTION MODELS

The variability in road condition data may arise from the variability in climatic conditions, soil conditions, user vehicles, etc. However, when the functions do not show a strong correlation or relationship with recorded data, these functions provide less confidence in predicting the deterioration rate for local conditions.

In this study the probability-based method (Ang & Tang 1975) and Monte Carlo simulation technique (Gray & Travers 1978) have been adopted for calibrating road deterioration prediction models. The methodology was used for calibrating road pavement roughness prediction models for Queensland conditions.

One of such deterioration model for predicting the rate of change in road pavement roughness suggested by The International Study of Highway Development and Management (ISOHDM 2001) is given below:

$$\Delta RI = K_{gp} (\Delta RI_s + \Delta RI_c + \Delta RI_r + \Delta RI_t) + K_{gm} \times m \times RI \quad (1)$$

Where;

- K_{gp} = calibration factor, Default value = 1.0
- K_{gm} = calibration factor for environmental condition
- ΔRI = total annual rate of change in road pavement roughness
- ΔRI_s = change in roughness resulting from pavement strength deterioration due to vehicles
- ΔRI_c = change in roughness due to cracking
- ΔRI_r = change in roughness due to rutting
- ΔRI_t = change in roughness due to pothole

The last term in the right hand side of the equation takes into account environmental condition.

Where;

- K_{gm} = calibration factor for environmental condition
- m = a constant taking into account environmental effects
- RI = road pavement roughness of the start of the analysis year

Figure 6 illustrates the cumulative probability of annual rates of deterioration in road pavement roughness for three-year periods (i.e. 2000-01, 2001-02, and 2002-03). In this method, the input variables in Equation 1 are expressed in terms of the probability distribution. The rate of change (ΔRI) in Equation 1 will result in a probability distribution.

In the calibration, the probability distribution of the rate of change obtained from Equation 1 and the actual rate of change obtained from the recorded data are compared while the calibration factors are adjusted so that the two cumulative probability distributions achieve best fit.

Figure 7 illustrates the result of a comparison between the cumulative probability distributions of the actual rate of change of road pavement roughness and the rate of change of road pavement roughness obtained from Equation 1. Table 1 shows examples of calibration factors (Kgp and Kgm) of Equation 1.

The calibration factors (Kgm) are given for different percentiles that reflect the actual variability of the recorded data. The method yields calibrated models that closely replicate the actual variability in road network condition.

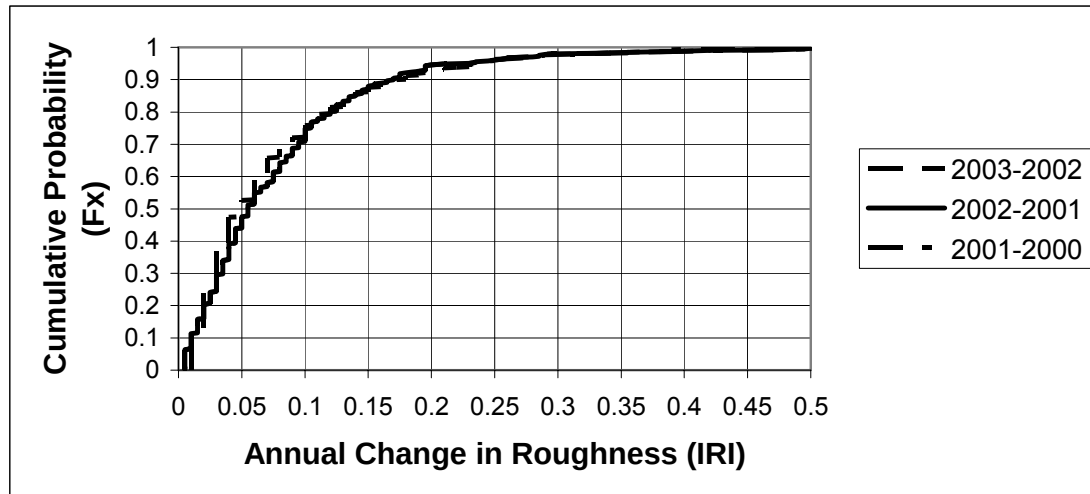


Figure 6 The cumulative probability distribution of the annual rate of change in road pavement roughness between the years 2002-03, 2001-02 and 2000-01

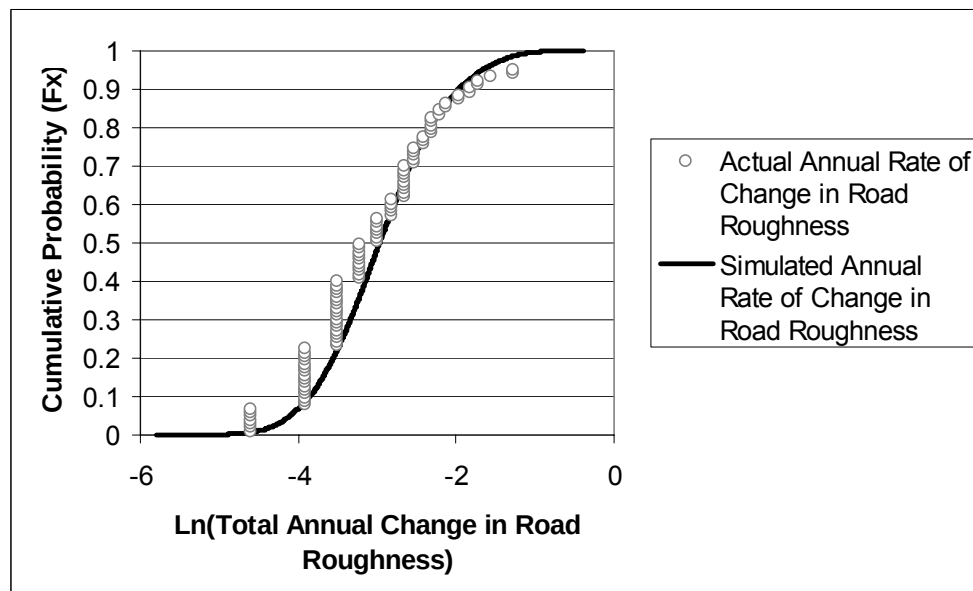


Figure 7 Comparison between the cumulative probability distributions of actual and simulated annual change in roughness for pavement thickness

Table 1 Calibration factors (Kgp and Kgm) for the annual rates of change in road pavement roughness

Calibration Factor (Kgp)	Calibration Factor (Kgm)	Calibration Factor (Kgm)	Calibration Factor (Kgm)	Calibration Factor (Kgm)
	50 th Percentile	70 th Percentile	80 th Percentile	90 th Percentile
0.20	1.0	1.20	1.70	2.90

4. RISK-ADJUSTED ASSESSMENT IN LIFE-CYCLE BUDGET/COST ESTIMATES

The preceding two sections addressed two important areas in assessing life-cycle budget/cost for asset management, namely;

- (a) Optimising data collection for monitoring asset conditions
- (b) Predicting the rate of change in asset deterioration

When it is affordable, overall current conditions of assets could be monitored and the rate of change in road deterioration is accurately predicted for local condition. The variability of budget/cost estimates arising from the variability of asset conditions remains an important issue.

This section presents a method that takes into account the variability of asset condition in assessing budget/cost estimates.

To demonstrate the methodology, only the variability of pavement strength was considered in the analysis. To assess the effect of the variability of input parameters on the output budget/cost estimates, the simplest method is to simulate representing values from the probability distributions of input variables and assess the variability of the output parameter.

The Latin hypercube sampling technique, as extensively studied by Iman and Conover (1980), appears to provide a satisfactory method for selecting small samples of input variables so that good estimates of the means, standard deviations and probability distribution functions of the output variables can be obtained. A practical method in assessing risk-adjusted budget/cost estimates is to adopt the Latin Hypercube Sampling Technique.

CASE STUDY

The performance data from the 92-kilometre national highway segment located in a tropical region of northeast Queensland in Australia was used in the risk-adjusted assessment of budget/cost estimates for road maintenance and rehabilitation as a case study.

The steps in the analysis are given below:

1. Establish probability distributions and statistical information (means, standard deviations) of input variables. In this case study, only the variability of pavement strength has been statistically quantified.

2. Simulate sampled data from the probability distributions of pavement strength to represent its variability in the analysis.
3. Conduct a series of analyses using Highway Development Management System (HDM-4) to obtain the statistics of the output budget/cost estimates (ISOHDM 2001).
4. Establish probability distributions and determine the statistical information of the output budget/cost estimates.
5. Assess the interested probability of occurrence of the budget/cost estimates from the output probability distributions.

Figures 8 and 9 show the mean and standard deviation of pavement strength for the 92km national highway. The probability distribution of the pavement strength was log-normally distributed.

For the analysis, the 92-kilometre road segment was divided into 92 sections of 1000-meter in length. Each 1000-meter section has its own pavement strength characteristic. For each kilometre, the variability of pavement strength characteristic is represented by the probability distribution of the Structural Number (SN). The variability of the pavement strength was taken into account in the analysis by using the Latin Hypercube sampling technique. In this study, forty sets of the Structural Numbers (SN) for each kilometre were simulated and used in the analysis.

Figure 10 shows a typical cumulative probability distribution of pavement strength sampled by the Latin hypercube sampling technique for one kilometre.

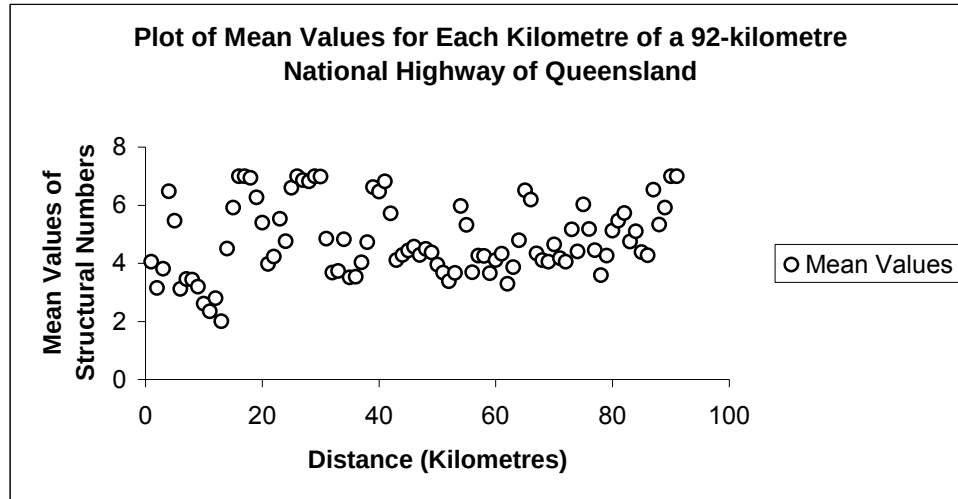


Figure 8 Mean values of each kilometre of a 92-kilometre National highway of Queensland

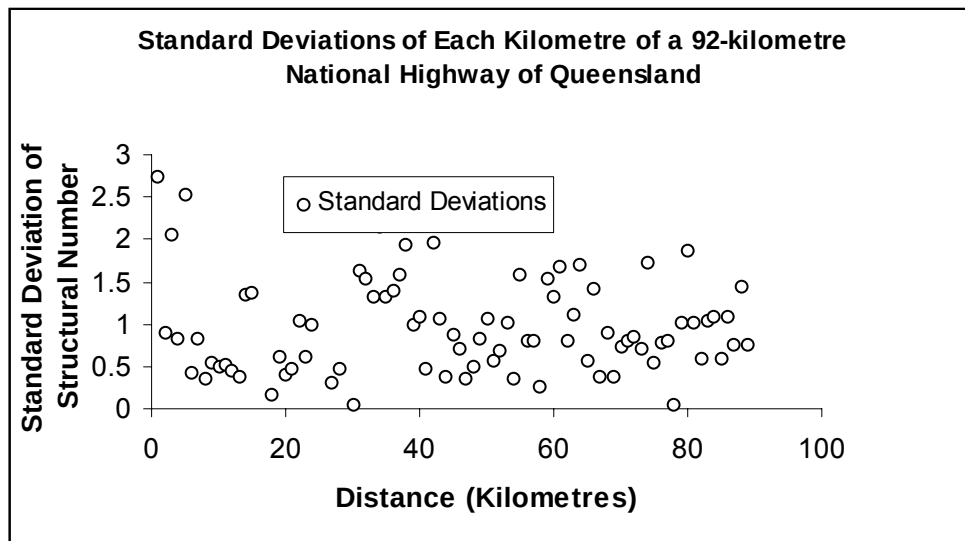


Figure 9 Standard deviations of each kilometre of a 92-kilometre National highway of Queensland

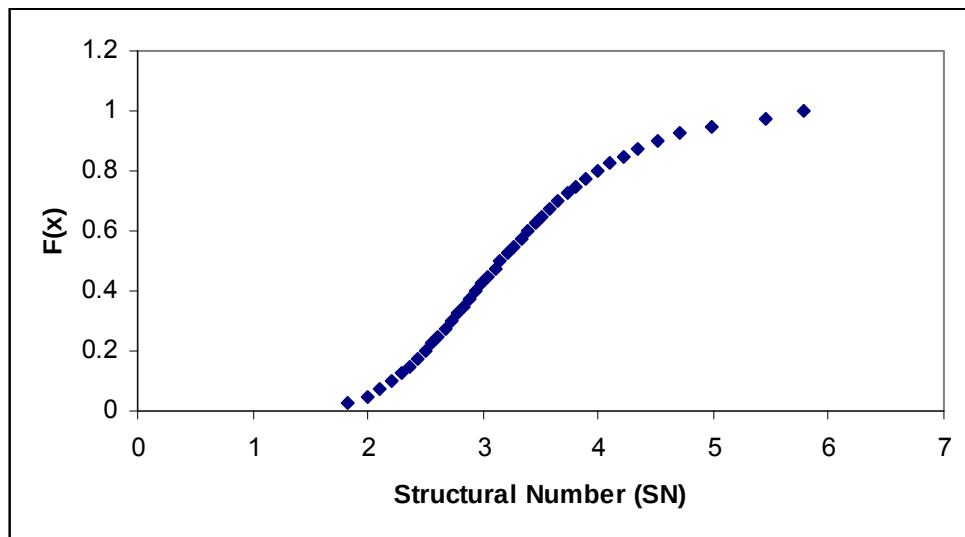


Figure 10 A typical cumulative distribution of Structural Number representing pavement strength sampled by Latin Hypercube Sampling Technique of one kilometre section for a 92-kilometre national highway

A series of analysis was conducted to obtain the statistical output of the life-cycle budget/cost estimates. HDM-4 computer software was used for this purpose. Details of the analysis can be found in Piyatrapoomi and Kumar (Aug. 2003).

Figure 11 shows the cumulative distribution of budget/cost estimate for maintenance and rehabilitation for a 25-year period. The probability distribution of the budget/cost estimates was log-normally distributed.

It can be seen from Figure 11 that the probability distribution can be explained by forty data points.

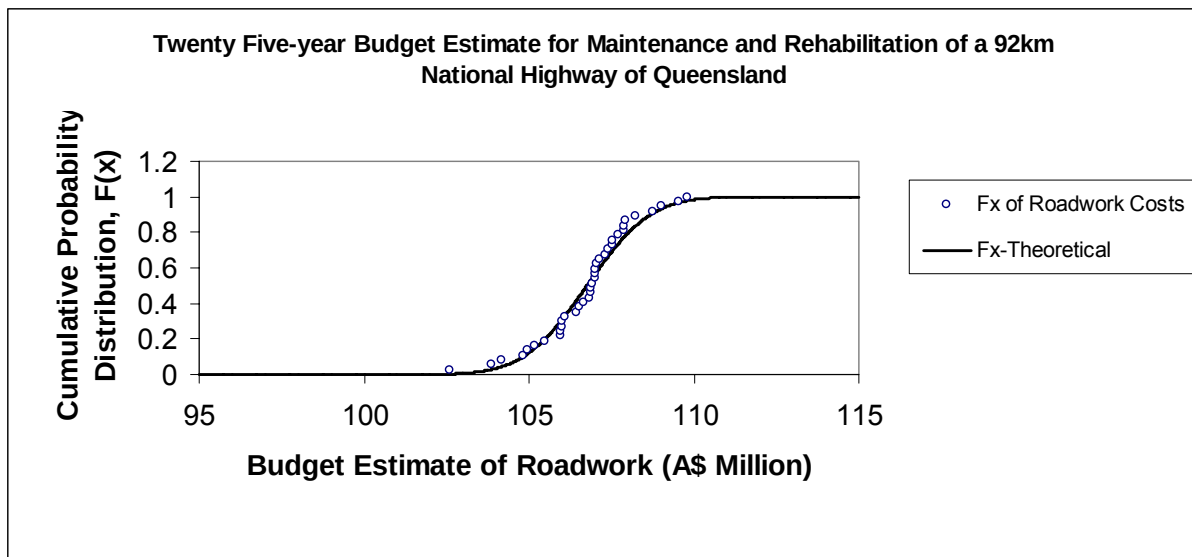


Figure 11 Cumulative distribution of budget/cost estimate for 25-year roadwork cost of a 92-kilometre National highway of Queensland (roadwork includes maintenance and rehabilitation)

The term “risk adjusted” in budget/cost estimate is defined as the budget/cost that is specified with a level of probability of occurrence. Asset managers could also make use of this information to select the budget/cost estimate of an appropriate probability of occurrence or with the probability of occurrence that they are comfortable with.

For example they may choose a budget/cost estimate of 5% probability of exceeding (or the 95th percentile budget/cost estimate). Figure 11 the budget/cost estimates which have 5% probability of exceeding was calculated to be A\$ 109 million for a 25-year budget/cost estimate.

5. RISK ASSESSMENT INVESTMENT DECISION FRAMEWORK FOR INFRASTRUCTURE ASSET MANAGEMENT

An investment decision framework in the form of risk map in which social, environmental, political issues and other risk related issues could be incorporated in the assessment has been introduced by Piyatrapoomi and Kumar (Piyatrapoomi et al 2004, Piyatrapoomi & Kumar, Jan. 2003).

The concept of risk mapping will be discussed in this section and illustrated using the risk information presented in the preceding section. In order to provide life-cycle budget/cost for maintenance and rehabilitation for the 92km national highway for a 25-year period, there may be two budget scenarios, namely:

Scenario 1: The government could provide a budget of A\$115 million

Scenario 2: The government could provide a budget of A\$ 95 million

The probability distribution of life-cycle budget/cost estimate shown in Figure 11 can be used to assess the probability of occurrence of these two budget scenarios. These two scenarios can be plotted in the risk map according to the probabilities of occurrences. From Figure 11, the quantitative measure of risk can be calculated as follows:

$$\mathfrak{R} = P(1-Pr)$$

Where:

$\mathfrak{R}$ = quantitative measure of risk expressed in terms of probability
 Pr = cumulative probability

Figure 12 shows the probabilities of occurrences resulting from the budget of scenario 1 (A\$115 million) and from the budget of scenario 2 (A\$ 95 million). The probability that the project would be successful with a budget of A\$ 95 millions was very low. The risk was almost certain that the project would not be successful. While the probability that the project would be successful with a budget of A\$115 million was very high. Thus, the risk was low.

This risk map can be used as a tool to manage risk and adjust project allocations based on cost-benefit and risk. In risk mapping, the levels of risk can be quantified qualitatively or quantitatively. The X-axis is the magnitude of the resultant consequences, which range from being insignificant to highly significant. The Y-axis is the level of risk, which ranges from rare chance to certain chance of occurrence. It could be expressed in terms of quantitative measures of probability of occurrence. Intolerable region is the region where risks are high and the impact of the consequences is significant. Tolerable region is the region where risks are low and the impact of the resultant consequences is low. Moderate region is the region where risks and the impact of the consequences are at moderate levels.

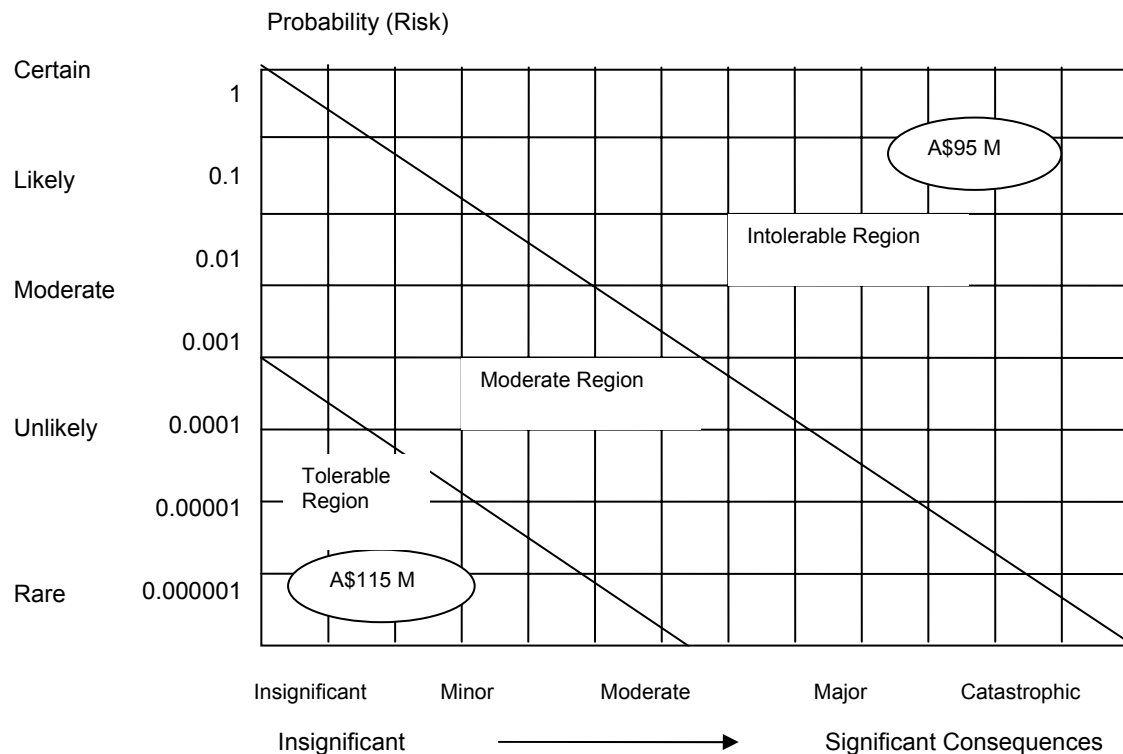


Figure 12 An illustration of plotting two budget scenarios into risk map

Decision-makers may need to incorporate other factors into consideration. These factors may include social, environmental, or political issues. Figures 13 and 14 illustrate this by plotting risks and consequences related to social, environmental and political issues into the risk map for the two budget scenarios.

In Figure 13, by providing a budget of A\$ 115 million for maintenance and rehabilitation of the 92-kilometre National Highway for a life-cycle cost of a 25-year period, risks and consequences on social, environmental and political issues were expected to be low.

Social issues that may involve traffic noises and accident rates could be kept at a minimum level since pavement conditions are kept in good condition. Road users would be happy with the service provided by the government. Political issue might not be a major concern. Environmental risk and consequences would be kept at a low level resulting from less fuel consumption, less tyre-wear and less expenses for vehicle maintenance and repairs.

In Figure 14, by providing a budget of A\$ 95 million for maintenance and rehabilitation, risks and consequences on social, environmental, economic and political issues are expected to be high.

Social issues on accident rates and the level of noise could be high since pavement conditions could not be maintained in good condition. Political issue might become a big issue. Environmental risk and consequences would be high since high fuel consumption due to delays, high tyre-wear and high costs for vehicle maintenance and repairs.

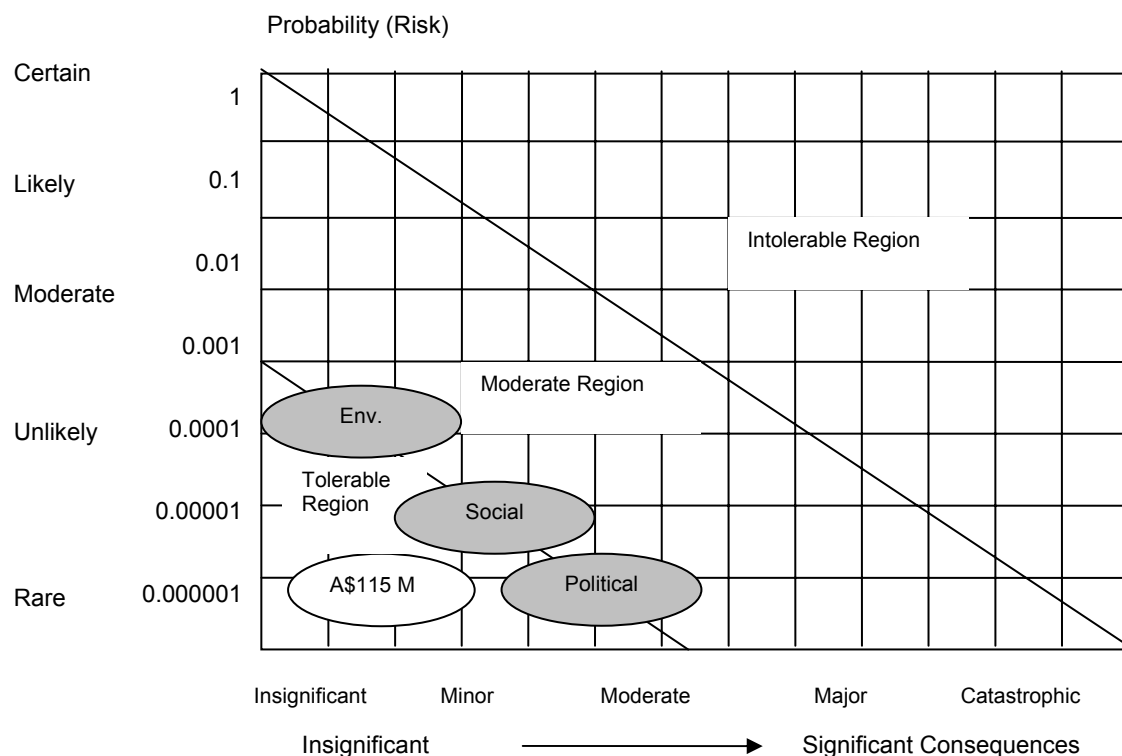


Figure 13 An illustration of plotting social, environmental economic and political impacts for budget scenario 1

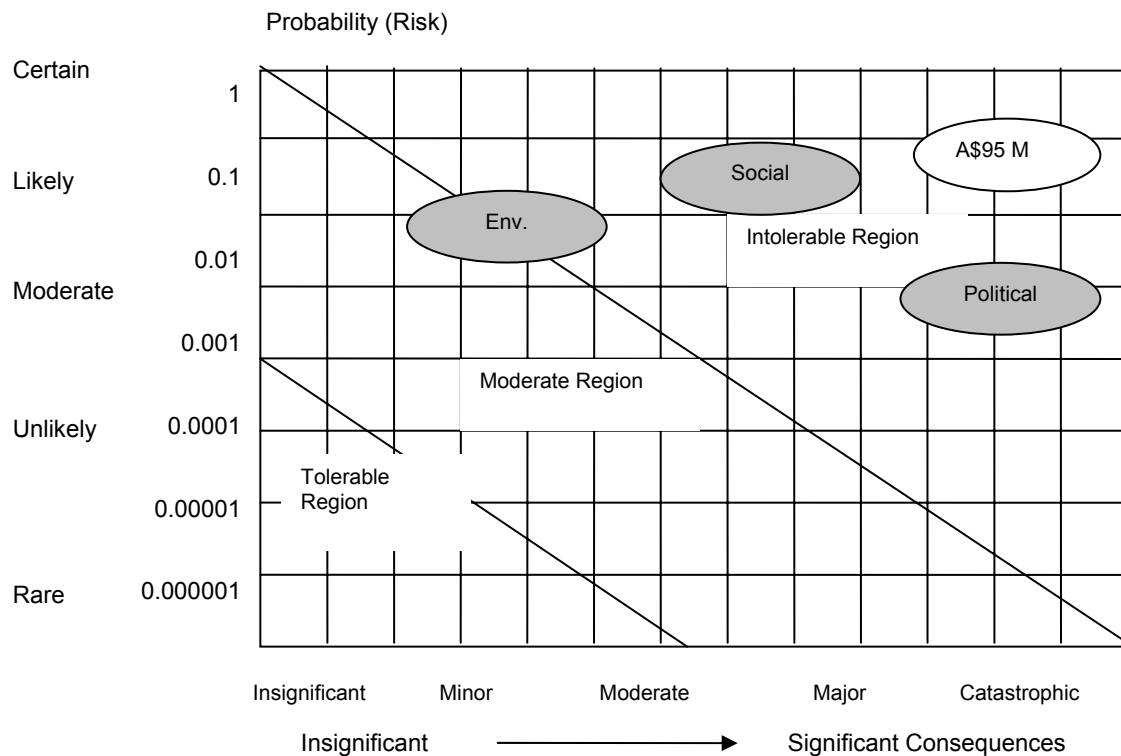


Figure 14 An illustration of plotting social, environmental, economic, and political impacts for budget scenario 2

Different scenarios would provide in depth information for decision-makers to trade-off between cost and benefit. Risk mapping provides information on risk levels and consequences of the decision-making.

In Figures 13 and 14, social, environmental and political issues were presented only for illustrating the concept of the risk map. Further assessment needs to be conducted to address risks and consequences of these issues.

6. CONCLUSION

In this paper, a methodology for assessing life-cycle budget/cost estimates for road asset management is presented. Three gaps have been identified and need to be addressed including data collection, calibration of road deterioration prediction models and risk-adjusted assessment in budget/cost estimates. The paper presented methodologies to solve these three issues.

The optimisation and reliability assessment method can be used in analysing optimal amount of data collection. More data could be collected for the same budget.

The calibration method can be used for calibrating deterioration prediction models in predicting deterioration rates of road infrastructures to suit local conditions.

The risk-adjusted assessment in budget/cost estimates can be used in assessing the variability of budget/cost estimates arising from the variability and uncertainty of critical input variables.

The paper also presented a risk map concept for investment decision-making in which social, environmental and political issues could be incorporated for consideration.

The methodology and concept could be used for other types of infrastructure asset management investment such as railways, bridges, buildings etc.

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CAPTURING AND MAINTAINING THE CLIENTS REQUIREMENTS

Full Paper

STANDARDISATION AND PRE-ASSEMBLY – CAPTURING CLIENTS REQUIREMENTS

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ABSTRACT

Rethinking Construction (Egan 1998), commissioned by the UK Government, identified barriers and recommended solutions for the construction industry in the UK. Standardisation and Pre-assembly (S&P), or off site production, was a principal recommendation from the Egan Report.

Loughborough University, in partnership with the Construction Industry Research and Information Association (CIRIA) and their core membership of industry clients, identified that negotiating project drivers (Gibb & Isack 2003) and constraints helped clients and their designers set out their requirements for a project. How to capture and maintain client requirements was a principal objective for the Project Toolkit.

The Project Toolkit is the output from a multi faceted demonstration project for the Department of Trade and Industry on behalf of the UK Government. It followed on from earlier research projects that investigated the extent and scope for S&P in the UK. The current work, a result of extensive field trials, focuses on the needs of occasional clients. Live and historic construction projects are used to demonstrate the benefits achievable from S&P.

This paper discusses:

- The application of the Toolkit as an instrument for advising the construction industry about S&P
- How project drivers and constraints were conceived to capture and maintain the clients project requirements for S&P
- The improved communication and design processes that deliver a project strategy and add to:
 - o Understanding of S&P between players in the construction process
 - o Delivering quality results

- o Managing requirements through project delivery

Current findings indicate both designers and clients do benefit from the Toolkit by:

- Understanding the meaning of S&P
- Defining their strategy and creating a plan of action for S&P
- Measuring the benefits
- Generating S&P indices for their project

INTRODUCTION

The concept of using off site production (OSP) techniques to deliver solutions that satisfy the building requirements of clients, their designers and contractors is not new to the UK construction industry.

Manufacturing off site for later assembly in construction on site in its various forms provides solutions for all types of construction application. These solutions can be mass-produced and are able to use innovative materials and techniques previously unavailable to traditional construction.

Manufacturing off site has variously been called pre-fabrication (White 1965) or as in the Rethinking Construction report (Egan 1998) standardisation and pre-assembly (S&P) to try and disassociate it from the prefabrication disasters of the 1960/70's. The technique is currently termed OSP in a current Department of Trade and Industry initiative called prOSP a (www.prospa.org) that aims to consolidate then build on previous research information and then disseminate that knowledge through an open web portal. Standardisation and pre-assembly was a favoured part of the Egan led initiatives of the late 90's and early part of the new millennia but the solution, though seen as a saviour of UK construction by the UK Government, had many unanswered questions posed by both the construction industry and its clients.

The UK Government is currently making OSP an obligatory consideration as part of their funding process whether it be for housing, defence, health service or infrastructure. The construction industry is also listening to its clients needs who are demanding better performance in terms of cost, time and quality (Gibb & Isaac 2001). Some of these solutions in their various forms are now being manufactured off site. The manufacturing process is conducted in a controlled environment using a multi skilled workforce to deliver a product designed to satisfy market driven needs. These manufactures are providing better quality products for the construction industry without escalating costs and they can supply their products to site with a guaranteed time of delivery.

Though being fostered through the need to meet a current skill shortage in traditional construction there is an underlying belief that there will be no turning back from OSP this time. However not all parts of the industry are happy that the current initiatives are providing the right solution to that problem with some believing that the initially enthusiastic reception for OSP will be short lived if history repeats itself and the products again fail to endure as indeed they did in the 1960's and 70's (White 1965). Recognising both opportunities and pitfalls, the UK Government through the Department of Trade and Industry (DTI) asked the Construction Industry Research and Information Association (CIRIA) to produce the Project Toolkit for Standardisation and Pre-assembly (Gibb & Pendlebury 2003) for the construction industry. The Project Toolkit asks clients and their designers to consider respectfully their approach to OSP. To develop sustainable strategies, monitor carefully the integration of different building techniques and measure their project outcomes.

This paper discusses the development of the Project Toolkit from an academic point of view and describes:

- 1) The Toolkit's historical evolution and the methodology that delivered a robust solution to a collection of aims and objectives.
- 2) How the construction industry and its clients influenced the research process.

- 3) How the Toolkit uses the concept of project drivers and constraints to engage clients and their design teams.
- 4) How project drivers and constraints can be used to determine a project strategy for OSP.

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THE HISTORICAL PERSPECTIVE

The Construction Industry Research and Information Association (CIRIA) choose their projects from requests by their Core Programme members who communicate their needs for detailed surveys of current trends and thereby influence CIRIA's collaboratively funded research programmes. Following the Government sponsored report, Rethinking Construction (Egan 1998), their members wanted to know how standardisation and pre-assembly (S&P) might benefit the construction process and the ways in which it was already being delivered over a variety of construction arenas. It was clear that opportunities existed and that some clients were already benefiting from the off site production (OSP) process both at home in the UK and overseas. As a result CIRIA, after first securing research grant funding from the UK Government's then Construction Directorate at the Department of Environment Transport and Regions (DETR), entered a competitive tender process and engaged Loughborough University as part of a research team that included both the Laing Technology Group and Arup & Partners as consultants, to deliver a series of authoritative reports. Table 1 lists a summary of all the CIRIA projects.

TABLE 1:
Summary of CIRIA research projects

No.	Reports significance/limitations	CIRIA Project No.	Deliverable/Output
1.	Designed to provide clients and their advisors with a summary of the potential benefits of standardisation and pre-assembly in design, specification and construction but not how to achieve those benefits for themselves.	RP532	Standardisation and Pre-assembly - adding value to construction projects (R176). a) SNAPSHOT report b) Full Report
2.	Designed to combine information on the benefits and critical success factors together with a toolkit to help the user identify opportunities, maximise benefits and measure the success of a particular project or series of projects.	RP579	Standardisation and Pre-assembly - Client's Guide and Toolkit (Publication C544)
3.	Turning the unwieldy paper version of the Client's Guide and Toolkit, by listening to industry professionals and their clients requirements, into a user friendly interactive CD version that uses project drivers and constraints to create a strategy for different stages in a project.	RP618	Standardisation and Pre-assembly – Project Toolkit CD (C593)

4.	Identified the shortcomings with the content of the Standardisation and Pre-assembly – Project Toolkit with respect to occasional clients.	RP652	Internal report to DTI on viability of a revising the Toolkit for use by Occasional Clients
5.	Designed to deliver a revised Standardisation and Pre-assembly – Project Toolkit CD that will include 150 example case studies, additional information and demonstration projects for occasional clients.	RP689	Standardisation and Pre-assembly – offsite Project Toolkit CD revised for Occasional Clients (not yet published).

Reports 1 and 2 provide construction industry clients and their principle advisers with a summary of the potential benefits of S&P in design, specification and construction.

These reports employed a robust research methodology that involved a comprehensive literature search and review, a series of workshops, interviews and site visits.

Formative workshops involved an assembly of key individuals, strategic thinkers able to use the input from the literature search and review to hone project definition and flush out the appropriate issues.

Project specific workshops were set up to discuss different aspects of S&P in its respective categories of standard components, non volumetric pre-assembly, volumetric pre-assembly and modular building.

All project specific workshops involved representatives from a minimum of four of the case studies for each category of S&P and where appropriate other experts were invited to take part (see table 2):

TABLE 2:
List of Experts

Purpose	Expert
Client\owner representative	May be an appointed project manager
Form and function	Architect
Structure and fabric designer	Structural engineer
Internal environment designer	Building services engineer
Manager of construction	CM, MC, main contractor D&B contractor etc
Supplier\installer	Works, trade, specialist contractor
Financial advisor	Quantity surveyor, cost consultant etc

Strategic workshops were used to validate the findings from the project specific workshops and conduct gap analysis to ensure nothing had been missed.

Individual interviews and site visits collected information from case studies, a strategic thinkers forum and other industries and sectors.

The first publication, *Snapshot* (CIRIA 1997) confirmed that the construction industry needed to change its culture. It was followed by *Standardisation and pre-assembly, adding value to construction projects* (CIRIA 1999). The reports investigated how OSP manufacturers designed and constructed their products. Led by an industrial

steering committee the reports looked at a variety of construction arenas ranging from the off site assembly of integrated components to the manufacture of modular buildings prior to final delivery to site.

The *Snapshot* was delivered as a high profile report. It defined what was implied by the term S&P and confirmed that whereas both standardisation and pre-assembly are complementary there are distinct approaches for both with different implications for the various participants and the construction process. It suggested that construction should change from dirty, dangerous and difficult to a customer focused service that involves change and cost friendly products to continuously improve both design and production.

It confirmed that standardisation was not new but that when combined with pre-assembly significant benefits were achievable over a range of headline issues.

At the same time it warned that the critical 'window' of opportunity significantly changed when adopting these new processes when compared to traditional on site construction. Therefore a clear procedure should be in place for individual designers and/or project teams to follow. The report also listed the prompts and pitfalls that organisations should take account of to ensure these do not frustrate the project, such as understanding and commitment by everybody involved, establishing critical information ASAP in the project process, the different effects on design decisions and the significant change required in project management.

The *Standardisation and pre-assembly - adding value to construction projects*, report that followed was produced as a book. The full report, initially for CIRIA Core Programme members listed numerous case studies and cited successful examples of pre-assembly on construction projects to show that it need not lead to standardised buildings. This book provided valuable recommendations on the procedures for gaining maximum advantage from S&P. The authors drew on experience from the construction industry overseas including Japan and the USA and from other activities that make extensive use of S&P, such as the automotive and aerospace industries, with input from David Gann (then at SPRU now at Imperial College). The report went into extensive project detail discussing and defining value for money. It also argued the principle case for S&P, that of increased predictability and efficiency and described how to best achieve practical implementation by applying a simple, standardised procedure for optimising S&P. This it claimed should be applied at agreed evaluation points, where the project team should briefly evaluate the opportunities for improvement by the use of standard frameworks or conventions for geometric fit and compatibility as well as using project specific standards. They should also consider standard components and methods, together with pre-assembled components and/or modules.

Adding value to the construction process with its companion publication *Snapshot* became an authority for anyone interested in standardisation and pre-assembly and greatly informed the next stage in the CIRIA research process, that of delivering practical guides and toolkits.

The *Standardisation and Pre-Assembly - Client's Guide and Toolkit* (Gibb 2000) followed (we call it the Client's Toolkit for short). It investigated the optimised use of standardisation pre-assembly and modularisation and presented a clients guide for construction industry clients and their advisers. The output was a practical guide and toolkit that contained a list of actions, options and rational procedures backed by detailed supporting information. The Client's Toolkit built on the previous research and suggested that its users investigate client drivers to help them understand how they impact on the pre contract decision making process. The research derived a list

of client needs and found that, above all, client's want value for money in terms of lower whole life cost, lower costs for a given quality, higher quality for a given cost and a consistency in the level of quality.

Research by Gibb and Isack (2003) qualified those drivers in terms of what clients see as the benefits of pre-assembly, i.e. cost, time and quality. For the Client's Toolkit (Gibb 2000) the drivers were extended to include the terms profitability, predictability and productivity. Gibb and Isack (op cit) later confirmed that client's also perceived disadvantages to S&P and cited a variety of reasons from products that are poorly built to inadequacies in the supply chain.

The principle drivers were presented as part of a collection of issues that might have either positive or negative effect on a project. It was clear that where there were advantages and there were also disadvantages and that they could have a significant impact on the successful implementation of standardisation and pre-assembly. Those positive and negative attributes were revisited in the next CIRIA/Loughborough research project RP618 called the *Demonstration of the Client's Toolkit for optimised use of standardisation and pre-assembly in construction*, it was won in open tender to the then DETR and its objectives were to provide a much wider appreciation of the advantages that can be gained from appropriate application of standardisation and pre-assembly to construction projects. To demonstrate that the Client's Toolkit, developed in the earlier project (RP579), can be used effectively to improve construction projects in terms of productivity, predictability, quality and speed and provide better value for money. It would use feedback from the experience of detailed practical application of the Client's Toolkit to refine the procedures and techniques and deliver them in a user friendly electronic system (CD-ROM or equivalent), for ready application in design offices by all members of the professional team.

One of the aims was to expand the portfolio of case studies to better explain the benefits achievable by adopting S&P, CIRIA and its partners proposed the demonstration project would have five major outputs:

1. Six detailed case studies which would test the Client's Toolkit on live projects.
2. Examine the response of industry and produce a revised Client Guide and Toolkit.
3. Provide a final output deliverable in the form of an interactive CD.
4. High Impact publicity document.
5. A final report to the DETR.

This research project which we called the Project Toolkit was later published by CIRIA as the *Standardisation and Pre-assembly - Project Toolkit* (Gibb & Pendlebury 2003).

PROJECT TOOLKIT METHODOLOGY

The research programme for the Project Toolkit employed formative demonstration workshops on live projects to collect data and strategy review by steering committee focus groups to direct and guide the research progress. The programme included review workshops, specialist interviews to examine historical data and Delphi surveys to deliver the CD content.

The Delphi Study methodology (Linstone & Turoff 1975) was considered appropriate as the research team needed a method of generating ideas and facilitating consensus among individuals who have special knowledge to share. The research team would collect data from a variety of real world sources where they would need

to facilitate consensus among individuals with special knowledge, conduct personal interviews and then convene focus group workshops to examine and test all the developing theory. The focus group would need to be available for workshops and separately, to receive and analyse the data at different stages in the process. CIRIA identified a collection of specialists from their Core Member programme and some would serve both as steering group members and form the Delphi panel later in the project. Using a data collection method called a "ranking-type" Delphi survey (Schmidt 1997) allowed the research team to canvas a rank-order list of issues for the drivers and constraints, developed for the CD. This served the dual purposes of soliciting opinions from experts and having them rank the opinions according to their importance. Schmidt's (op cit) methodology involves three general steps:

1. Brainstorming for important issues.
2. Narrowing down the original list to the most important ones.
3. Ranking the list.

After consolidating the data it was returned to the panelists, as a grouped list of issues, for validation.

Project Drivers and Constraints

During the formative workshops, the merits of standardisation and pre-assembly (S&P) were debated and the applicability of the toolkit questioned. One of the findings was the existence of a close similarity in the project drivers for both traditional and S&P techniques. What stood out as missing and what construction professionals needed was an appropriate balance to the Client's Toolkit's pro S&P bias. Working together with the research team they found that by identifying disadvantageous project attributes and aligning them against the project drivers a project strategy started to evolve.

These attributes were used to engage invited clients and design professionals during a series workshops used to test the accessibility of the Client's Toolkit. The initial part of the research found that most design professional were already aware of the benefits S&P offered to them. They were not looking for an educational tool but were looking for a tool that would help them determine viability and influence the outcome when applying S&P techniques on their particular project. They required this tool to involved their clients in the decision process, to help with the creation of a project strategy and to assist in the measurement of benefits from the implementation of that strategy.

A close examination of how the Client's Toolkit presented its information was made, the output of that examination was brainstormed with an industry led focus group to establish the best way to respond to the needs identified in the formative workshops. The toolkit was then redesigned into a format that delivered three principal components:

1. Background information that includes opportunity identification and case study sections.
2. Strategic tools and advice aligned to a generic process map.
3. Measurement advice for both benefits and the creation of indices.

Redesigning the Client's Toolkit also necessitated a change in the way its information was accessed and a study group for the CD design was assembled to test the toolkit proposals. They elected to start the strategic tools by asking the Toolkit user for project information and then use this information to help create a project strategy.

The sets of positive and negative attributes were re-examined. It was decided to restate original project driver sets of cost, time and quality and in addition create sub-sets to accommodate the major variables under those headings. These drivers would be used in the initial creation of a project strategy. It was noted that the verified list of benefits in the original Client's Toolkit provided both positive and negative benefits for S&P and it was these attributes that would determine the use of S&P on a project. The positive influences evolved into generic driver subsets and the negative influences, termed constraints to the process, focussed on the applicability of S&P. Initially these were presented as a list of nineteen drivers and twenty two constraints. The constraints being the most likely to inhibit implementation of S&P on a project or reduce the likelihood of achieving the potential benefit when applying S&P techniques. These drivers and constraints now required testing and verification by industry.

Further workshops with construction clients and their designers were convened to examine the new toolkits conformity to their brief. Some beneficial changes were made with the addition of environmental issues and the transfer of some constraints to the drivers section when it was discovered they sat in both camps, i.e. both driver and constraint at the same time.

The list was again presented to the focus group for them to negotiate both context and meaning before re-presenting the proposed mark two version of the toolkit to designers. Some reviewers thought the systematic layout employed by the drivers should also be used for the constraints section. Consequently a set of headings were provided to separate out the constraints into site constraints, process constraints and procurement constraints. The final negotiated list of drivers and constraints is given in Table 2.

When the drivers and constraints had been finalised the Delphi study group were again employed to help generate and deliver appropriate advice under the headings

- Standard processes.
- Standard components.
- Pre-assembly.

The process proved so successful that when the final draft content for the CD was completed a separate group of experts were convened to wordsmith the content before presenting it back to CIRIA for publication.

CONSTRUCTION INDUSTRY INFLUENCE

It is often said that researchers for construction seek topics that they believe will benefit their benefactors most, then they pursue their holy grail without listening to the real and changing needs of clients and industry. At CIRIA the research is driven by their membership for their membership. When a research project is given the go ahead a steering committee is assembled, first from the Core Programme members then from others able to contribute their specialist knowledge to the research focus. Throughout the research period workshops and committee review meetings direct and validate the research findings. The steering committee have under the authority of their chair person, where they feel the original aims and objective are not being met, the ability to change the course of the research. They can also introduce additional resources when in their professional opinion they consider it prudent to do so. Throughout each of the profiled research projects a variety of industrial input was sought. At the strategic level, forward thinking captains of industry set objectives that were tested with clients on live projects, then re-examined by practitioners at grass roots level to confirm the theory generated before final publication.

TABLE 2:
List of Drivers and Constraints

DRIVERS	CONSTRAINTS
Section 1: Health and Safety Driver	Site Constraints
1.1 Reducing health and safety risks	C1 A problem transporting manufactured products to site
Section 2: Cost Drivers	C2 Limitation to movement of pre-assembled units around site
2.1 Ensuring project cost certainty	Process Constraints
2.2 Minimising non construction costs	C3 Short overall project time scales
2.3 Minimising construction costs	C4 Unable to freeze design early enough to suite pre-assembly
2.4 Minimising overall life cycle costs	C5 Limited capacity of suppliers
Section 3: Time Drivers	C6 Not possible for follow-on projects to use the same processes
3.1 Ensuring project completion date is certain	C7 No opportunity for component repeatability on this or future projects
3.2 Minimising on-site duration	Procurement Constraints
3.3 Minimising overall project time	C8 Project team members have no previous experience of S&P
Section 4: Quality Drivers	C9 Obligated to work with a particular supply chain
4.1 Achieving high quality	C10 Not willing to commit to a single point supplier
4.2 Achieving predictability of quality	C11 Obligated to accept lowest cost rather than best value
4.3 Achieving performance predictability throughout the lifecycle of the facility	C12 Key decisions already made preclude S&P approach
Section 5: Sustainability Drivers	C13 Limited expertise in off-site inspection
5.1 Reducing environmental impact during construction	C14 Early construction/manufacturing expertise and advice unavailable
5.2 Maximising environmental performance throughout the lifecycle	C15 Obligated to accept element costing based on SMM
5.3 Implementing Respect for People principles	
Section 6: Site Drivers	
6.1 Restricted site layout or space	
6.2 Multi trade interfaces in restricted work areas	
6.3 Limited or very expensive available skilled on-site labour	
6.4 Live working environment limits site operation	
6.5 Site restricted by external parties	

CONCLUSION

This paper has presented a catalogue of research that has examined the process and development of a Toolkit for off site manufacturing or standardisation and pre-assembly for the UK construction industry. It confirms the fluid nature surrounding the reintroduction of these techniques for construction and the care taken by the UK Government to ensure it does not become another short live construction initiative. In addition it has demonstrated how the Construction Industry and its clients directly influenced the research process and explains how academic research has responded to the needs of industry, with its reports and the development of both the Standardisation and Pre-assembly - Client Guide and Toolkit and the Standardisation and Pre-assembly - Project Toolkit CD. The research projects were designed to both inform and assist design team professionals and their clients create and implement a project strategy for standardisation and pre-assembly in construction. The paper has

explained how academic rigor has necessitated the application of a variety of research techniques to satisfy the demanding aims and objectives presented to the research team by the CIRIA research managers at the outset.

CIRIA and the research team are currently developing a toolkit for occasional clients that will be the subject of further papers in this series. They will discuss case study research and the development of interactive IT teaching media for higher education.

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INTERNATIONAL INNOVATION

Full Paper

STUDYING COLLABORATIVE DESIGN IN HIGH BANDWIDTH VIRTUAL ENVIRONMENTS

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ABSTRACT

In today's global design world, architectural and other related design firms design across time zones and geographically distant locations. High bandwidth virtual environments have the potential to make a major impact on these global design teams. However, there is insufficient evidence about the way designers collaborate in their normal working environments using traditional and/or digital media. This paper presents a method to study the impact of communication and information technologies on collaborative design practice by comparing design tasks done in a normal working environment with design tasks done in a virtual environment.

Before introducing high bandwidth collaboration technology to the work environment, a baseline study is conducted to observe and analyze the existing collaborative process. Designers currently rely on phone, fax, email, and image files for communication and collaboration. Describing the current context is important for comparison with the following phases. We developed the coding scheme that will be used in analyzing three stages of the collaborative design activity.

The results will establish the basis for measures of collaborative design activity when a new technology is introduced later to the same work environment – for example, designers using electronic whiteboards, 3D virtual worlds, webcams, and internet phone. The results of this work will form the basis of guidelines for the introduction of technology into global design offices.

Keywords: Collaboration, Architectural Design, Communication Technology

1. INTRODUCTION

Recent developments in networked 3D virtual worlds and the proliferation of high bandwidth communications technology have the potential to transform the nature of collaboration in professional design. There have been numerous studies of collaboration in Europe and the USA that have resulted in system architectures to support data transfer and information sharing. However, the impetus for these initiatives has been mainly system-driven as distinct from user-driven. Whilst these initiatives have undoubtedly led to important advances in the enabling technologies required to support changes in global economic practices, the lack of attention to the way people actually work together leaves a large gap in understanding their needs.

This is not a new problem but has persisted whenever new technologies are proposed as solutions to market driven changes without first trying to understand the problem that needs to be solved. In the architecture and construction industries, there is insufficient evidence about the way designers collaborate in their normal working environments using both traditional and digital media. It is this gap that our research addresses. This project focuses on collaboration among designers in the early stages of design in which conceptual, and then more detailed, models for a project are being developed.

There are two basic research objectives: one is to obtain evidence about design practice that will inform the architecture and construction industries about the impact and potential benefit of using digital collaboration technologies; the second is to add to long term research knowledge of human cognitive and behavioural processes based on real world data. In order to achieve this, the research methods must be able to acquire a rich and heterogeneous set of data from design activities as they are carried out in the normal working environment. This places different demands upon the data collection and analysis methods to those of laboratory studies where controlled conditions are required. In order to address this, the research approach that has been adopted is ethnographic in nature and case-study-based. A series of in-depth studies are carried out in order to provide baseline results for future research across a wider community of user groups. An important objective has been to develop a methodology that will produce valid, significant and transferable results.

The research will contribute to knowledge about how architectural design and the construction industry may benefit from the introduction of leading edge collaboration technologies. The outcomes will provide a sound foundation for the production of guidelines for the assessment of high bandwidth tools and their future deployment. The knowledge will form the basis for the specification of future collaboration products and collaboration processes.

2. STUDYING THE IMPACT OF HIGH BANDWIDTH VIRTUAL ENVIRONMENTS ON COLLABORATIVE DESIGN

In order to understand the potential impact of high bandwidth environments on collaborative design, we first need to have data that characterises collaborative design activity without the high bandwidth environment. In this research we undertake a series of studies into how designers work collaboratively using both traditional and digital media. The research involves the observation and

analysis of designers working remotely on commercial projects in their normal environment, an architectural design office. There are three separate phases to this study in which the designers and the design offices are the same, but the collaborative technologies change. The change in collaborative technologies is incremental, moving from the technology already in use to the use of a high bandwidth virtual environment. The data collected in these phases will be coded and analyzed, and then compared to determine the impact of the change in collaborative technology.

The three phases are:

1. A collaborative design process in which designers work with their current design and communication tools.
2. A collaborative design process in which we introduce a shared drawing system with synchronous voice and video in addition to the currently used design and communication tools.
3. A collaborative design process in which we introduce a 3D virtual system in addition to the current design and communication tools.

2.1. SET-UP FOR FIRST PHASE: USE OF CURRENTLY AVAILABLE DESIGN AND COMMUNICATION TECHNOLOGY

The first study is an investigation into the existing practices for early stage collaborative design in a specific architectural firm when designers in different offices are collaborating. The main aim is to establish a baseline for comparing conceptual design processes before we introduce new collaborative technologies. Processes to be examined include communicating and designing from different locations considering duration of tasks, and use of design tools and channels of communication.

For this baseline study, the research process includes:

- Preparation of the study context: identifying participants, physical locations.
- Selection of data gathering methods: audio-video recording devices, field diaries.
- Collection and collation of data: logistics, checklists, storage, security.
- Analysis of data and reports of the results: viewing, coding, documentation

The setting for the study has been established in two geographically distant locations, one office in Sydney and the other office in Melbourne. The project study area is as near as possible to the normal space the designers work in, and is one where they have all the facilities they would typically expect to have on hand. The work area includes such things as a large desk or table where large drawings can be laid out, a large wall to pin-up images, posters and other material, and sufficient space around to freely move about. These requirements were met by a space called 'library' in the Sydney office (see Figure 1) and a similar space in the Melbourne office of Woods Bagot Pty Ltd.

2.2. SET-UP FOR SECOND PHASE: INTRODUCTION OF SHARED DRAWING WITH AUDIO AND VIDEO COMMUNICATION

The second phase is an investigation and comparison of designers using a shared drawing board with audio and video conferencing. The purpose of this

study is to introduce collaborative technology that facilitates communication without altering the current sketching and drawing processes used in current practice. Figure 3 shows a snapshot of the plasma screen with pen interface that we are using for this phase. The plasma screen allows the participants to draw on the shared whiteboard without the shadow cast by a front projection system. Our initial trials do not use the video conference image because the participants thought it uses bandwidth unnecessarily, but the participants do have audio contact.



Figure 1. Designing space in Sydney office

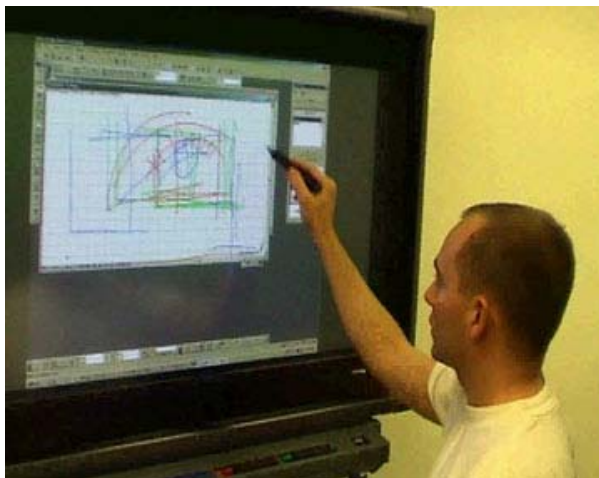
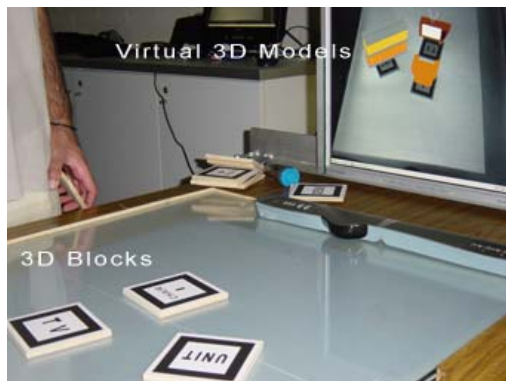


Figure 2. 2D Shared White board

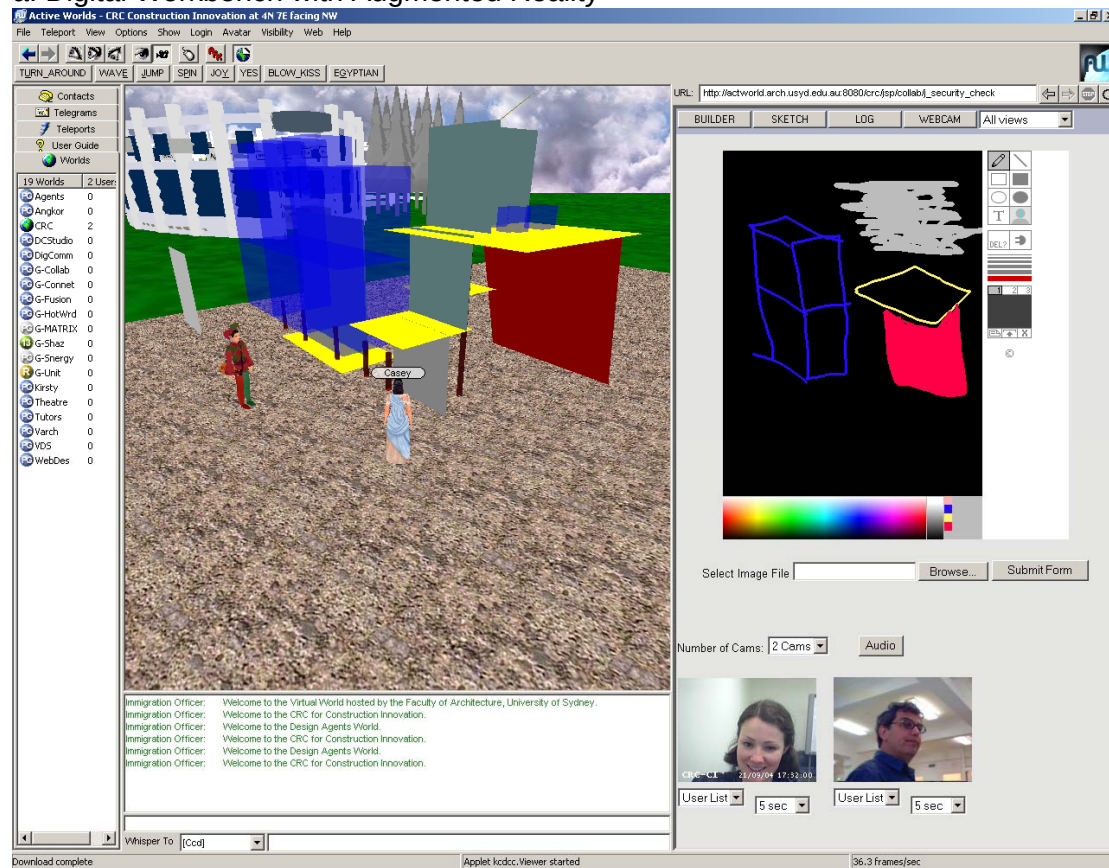
2.3. SET-UP FOR THIRD PHASE: INTRODUCTION OF 3D VIRTUAL ENVIRONMENT

The third phase is an investigation and comparison of the same designers in the same offices, using a high bandwidth environment in which 3D models are built, discussed, and modified. We will consider two approaches to introducing high bandwidth 3D modeling: a workbench, which moves the design drawings and models back to a horizontal surface, with 3D augmented reality; and an immersive 3D virtual world in which the designers are represented as avatars within the design model. The purpose of this study is to introduce technology

that significantly alters current practice. Figure 4a and 4b illustrates the two approaches for this phase.



a. Digital Workbench with Augmented Reality



b. 3D Collaborative Virtual World

Figure 3. 3D Virtual Environment

3. OBSERVING AND ANALYSING COLLABORATIVE DESIGN ACTIVITY

Collaboration is an essential part of human activity and a dominant mode of work activity. Computer support for such activity is a relatively recent development in design and other related domains. Essentially, the development of effective collaborative systems has to be based on analysis and evaluation techniques that deal effectively with collaborative activity. Although there is now

a large body of empirical work on the human-computer interaction (HCI) domain, little progress has been made with determining factors that influence the organization or design of collaborative work with the use of techniques or methods that provide for systematic analyses.

Communication has a central role in many human activities, even for tasks and technologies that are strictly individual (Suchman, 1987; Heath, 2000). Consequently, interpersonal communication is the basis for collaborative design and for innovation, since these interactions provide for the creation of shared understanding (Saad and Maher, 1996). Thus, it is critical to first examine the social and interactional dimensions of work, in order to make suggestions about the design of computer support and high band-width support for collaborative design. The understanding derived from observations of design practice can then be used to inform the design of appropriate technology. We took the approach of analyzing human behavior and intentions in collaborative activity, considering that a static and inflexible conception of collaborative activity has prevented the evolution of useful environments where people can work and socialize with each other in a socially natural way (Heath et al. 1995). Typically collaborative design in architecture is a common occurrence with architects communicating their ideas to their peers in the form of verbal representations voiced or typed and graphical representations (Gabriel and Maher, 2002).

Protocol analysis has been accepted as a prevailing research technique allowing elucidation of design processes in designing. And whilst the earlier studies dealt mainly with protocols' verbal aspects, later studies acknowledge the importance of design drawing, associating it with design thinking which can be interpreted through verbal descriptions.

The protocol analysis technique has been adopted to understand the interactions of design teams (Cross and Cross 1996; Mazijoglou et al 1996; Stempfle and Schaub 2002) and design behaviour of teams (Goldschmidt 1996; Günter et al. 1996; Valkenburg and Dorst 1998). Protocol studies of collaborative industrial/architectural design concern the understanding of team collaboration, in terms of use of communication channels and design behaviour variables (Mazijoglou et al. 1996; Vera et al. 1998; Kvan and Candy 2000; Gabriel and Maher 2002). On the other hand, protocol studies in the engineering design domain focus on the work environment context and the social interaction discourse as well as design behaviour and communication (Badke-Schaub 2003; Glock 2003). The emphasis becomes the analysis of conversation patterns, to gather information about the team dynamics, individual motivations, social interpretations etc.

Protocol studies of architectural design in practice have rarely been done because of the difficulties in collecting protocols - architectural design often being an individual practice. Nowadays, with the globalisation of design offices, architects have to collaborate with each other as well as with professionals from other disciplines. As a result of this change, design process increasingly occurs as a social process through "communication of ideas" and "communication with drawings". Thus it is possible to collect a reasonable amount of rich protocol data from a team of architects in real work environments.

A Methodology Combining Ethnography, Context Analysis and Protocol Studies

We have combined context analysis and protocol study methodologies for the collection and analysis of data about collaborative design as it takes place in a natural environment. The context analysis continues over the research timeline, and the protocol analysis occurs during the intensive period where the video recording is employed, as illustrated in figure 5.

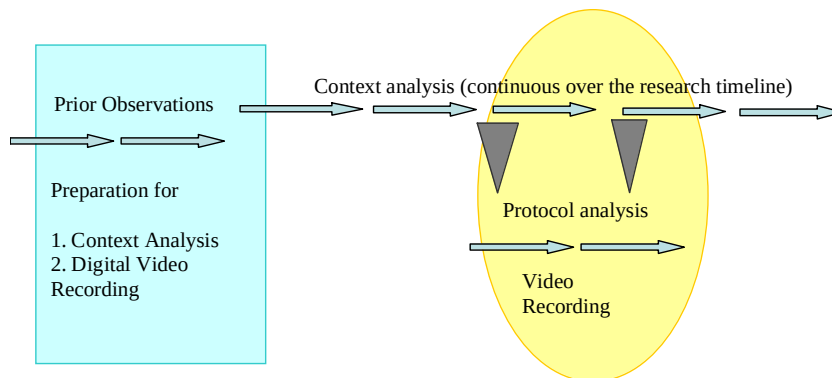


Figure 4. Context and protocol analysis

Context analysis is the end product of a continuous direct observation in workplace studies. Direct observation is the data collection technique whereby researchers are present at the scene and record the events that take place in field diaries sometimes supplemented by audio tape recording. Such observation is usually undertaken in as unobtrusive a manner as can be achieved. And to that end, the researchers become part of the normal working environment by taking up residence sometime before the actual observation work takes place. In this case, the researcher was resident in the company for two days per week and was a familiar figure to the designers taking part in the study. In this way, he was able to familiarize himself with the general working practices of the design office and to see how the subjects worked with their colleagues at a general level. The researcher observed interactions, listened to conversations in situ, had informal talks with the site staff and collected material on how the tools, instruments or technology was used.

The study employs a second observation method - using multiple video cameras to monitor and record activities of designers. Video recording sessions had to be done in a common meeting space in the company office since the set-up has been fixed in that area. Video recordings were limited to specific design sessions where the architects meet to review and resolve problems of the design project at hand. The advantage of these recordings is that a lateral in-depth analysis of the protocols can be done with a formal approach. Other than the times captured by video, designers exchange information and ideas continuously in the office within smaller time intervals. Thus, the limitation of video recording is that it is harder to get an insight about the complete picture of the work practice. However sufficient data about the work practice has been collected (using the informal context analysis approach) in order to describe architectural context in the present study.

4.1. PROTOCOL ANALYSIS

By recording and measuring the design tasks, we can look for differences and correlations between design activities and communication channels using different technologies.

4.1.1. Experimental Set-up

The method to collect protocol data is to monitor and record using multiple video cameras. The data captured enables precise inspection of the events and actions by rewinding and forwarding the video thus helping the researcher to fill in the gaps in direct observation records and to focus on specific aspects of the process. Our aim is to record the designers' activities and verbal exchanges when they are engaged in a collaborative design activity at a distance.

The placement of the cameras is an important issue, since all participant movement, verbalizations, gestures and the drawing actions and outcomes must be recorded. Camera 2 and 3 in both study settings capture the gestures, general actions (such as walking, looking at, moving to the side etc) while camera one has to capture the drawing process in detail (see Figure 5). Camera one is mounted on the ceiling, while the other two cameras stand on tripods.

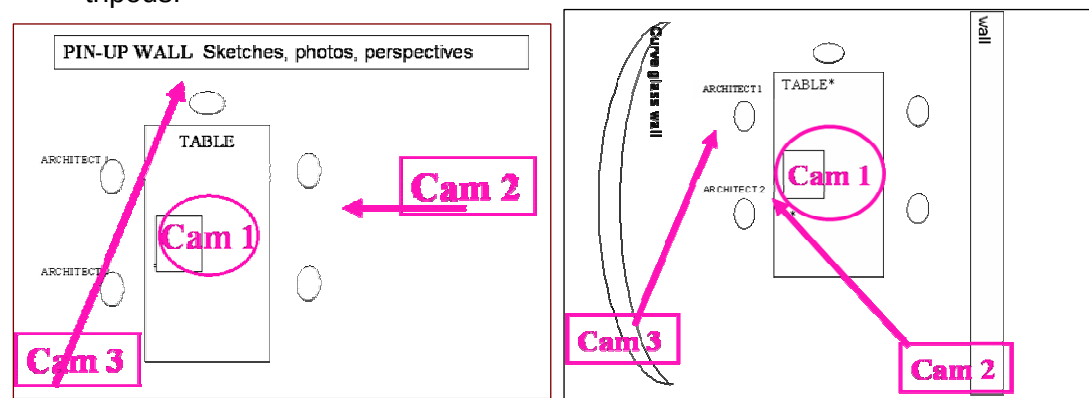


Figure 5. Camera positions (Left: Sydney office, Right: Melbourne office)

4.1.2. Segmentation

The data collected is a continuous stream of voice and video. In order to analyse the data, it needs to be segmented. The smallest segmentation definition is an event. An event is an optimal definition in behavioural research because happenings are arbitrary and actions change in relatively small and unpredictable time intervals. Typically in collaborative design, actions and intentions change arbitrarily because architects draw and communicate interactively. Thus the events should reflect WHO is doing WHAT in a collaborative environment. When WHO or WHAT items change, this starts a new event. This segmentation provides the elements of the data that are associated with a code for analyzing the entire recorded activity.

4.1.3. Development of the coding scheme

The basis for the development of a coding scheme is a consideration of the expected results of the study. We expect that the communication channels will have an impact on the design process, so we need to measure the changes in the use of communication channels and the amount of time spent in different design activities. In reflecting on this, we have identified three categories of

information we want to record and measure: “who” is present during the collaborative activity, “how” they are communicating, and “what” they are doing.

“Who” is involved in the collaboration at any given time is coded as the participants. Further, the coding should allow the analyst to understand how and in what way each person in the team joins in the collaborative activity. Thus every action is coded associatively with each team member.

“How” they are communicating is coded as the medium of communication, such as:

- face to face
- telephone
- fax
- email
- messenger
- shared or single person drawing
- shared or single person modeling
- video conference

These channels give us information about whether the current collaboration type in the activity is synchronous or asynchronous. In terms of content, this may be design-related or design-free communication. We refer to design-free conversations as an interruption to communication, because of our interest in analyzing design-related conversations which affect collaboration. Another interruption type is defined as the breakdown of communication because of a technical problem.

The “What” category refers to what the designers are doing . Our classification of tasks is into three categories: “Design Process” which reflects the content of the designing process, “Access Information” which reflects the referred domain knowledge, and “Team Communication” which reflects the conversation patterns in a group.

Analysis of the designing process is based on theories which consider design as a problem solving process that is ill-structured and opportunistic in nature. In order to analyze the designing process we adopted codes from a process-oriented coding scheme (Gero and McNeill, 1998). The scheme is based on problem understanding and solving strategies, and it involves categories of analysing a problem, evaluating a problem, proposing solutions, as well as the knowledge types referred to. The coding scheme was used to analyse individual designers as well as team work (Purcell et al., 1996). In addition to the selected codes two more actions are added: analysing/ understanding representations and evaluating/ reworking the representations. The reason for additional codes is to better represent the nature of the architectural design activity. It was observed that the architects were either trying to understand the previously produced representations, discussing how to represent design elements, or whether the drawing needs specific lines or shadows etc. Thus analysing or evaluating representations was an important part of the process, as well as analysing or evaluating the design solutions or concepts. Design process and information accessing codes are listed below:

Design Process:

- propose a new idea/concept/ design solution
- clarify meaning or a design solution, expand on a concept

- analyse a proposed design solution
- analyse/understand a design representation
- re-work/elaborate/ evaluate a design representation (propose or negotiate modifications on a representation, or add to a previous version)
- analyse/understand one's view/concept/idea or a problem
- identify or describe constraints/ violations
- integrate/combine ideas in the team or adapt existing solutions to meet new constraints and objectives

Access Information:

- consult external information (request/search for information about a previously-introduced concept/idea/design solution. Ask for a partner's idea/view/decision)
- Refer to design brief/client requirements

Another category in "what" designers are doing relates to decomposing the team's communication. We borrowed the category codes from Milne and Leifer (2000) in which the authors named this category as "navigation" - it refers to handling and exploring the issues in a design team discussion. Codes like intervene, manage, coordinate, reflect, rationalize, reflect the conversation patterns in a team. The breakdown of the "team communication" codes is as below:

- reflect: Comment on group process, assess progress, measure against previously developed goals, review path of discussion
- coordinate: solicit feedback, check for consensus from the group (or the other participant)
- intervene: Redirect the focus of discussion, propose a new area/ category for discussion/exploration, look ahead to possible new goals for the group discussion
- manage: model activity, delegate/assign tasks, cause others to modify actions, guide group in its mode of activity through reiterating goals, including level on which to hold discussion
- affirm: provide positive feedback, express assent or agreement, agree on an idea/concept/ solution
- orient: Introduce personal background, express personal perspective not tied to a piece of information, only reflecting on personal experience
- rationalize: Provide justification background for suggesting a course of navigation

4.1.4. Software support

A software application is needed to manage the audio-video recorded data as well as to capture actions and verbalizations with precise timing. Reviewing the software alternatives, and considering the coding process, we decided that multiple tasks such as managing the codes, accessing the multimedia stream, and seeing the coding scheme, as well as presentation and management of the data should preferably be done in one interface. For these reasons we chose to work with INTERACT. Additionally the software enables watching multiple video streams simultaneously, within one single coding session. So that It is possible to analyse several videos at the same time that were recorded from different camera views of the same scene. The interface for the INTERACT software is shown in Figure 6. In the analysis shown we had only one video camera on the

designer being studied. The interface shows how we can move through the video and attach a code to segments of the video.

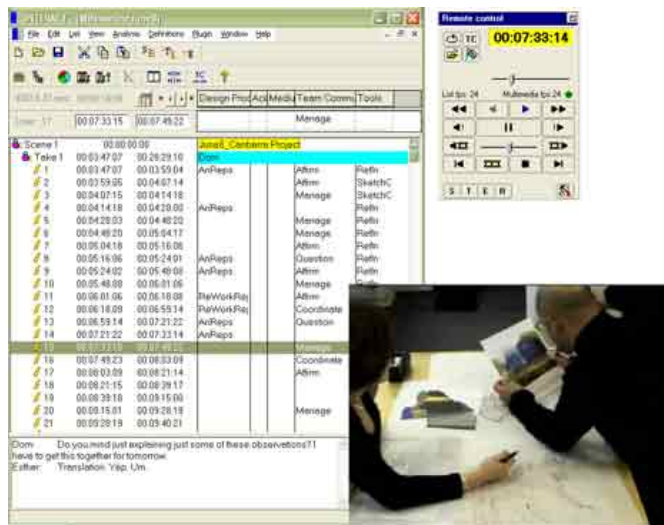


Figure 6. INTERACT interface

5. SUMMARY

The research approach and the coding scheme described here present an analytical framework that can be applied to characterize the activity of design teams. This paper presents a structured approach for detailed analysis of design team activity that distinguishes between factors of collaboration (who, communication channels, tools), designing activity, and communication in the team. There are two outcomes from the research so far. One outcome is the definition of the phases of the study which allows a comparison to be made and the impact of high bandwidth virtual environments to be measured and described. The second is the methodology and coding scheme that defines how the data is collected and analysed. We propose that the developed coding scheme can support qualitative and quantitative analysis of design team activity that more precisely reveals the nature of team processes than unstructured video analysis methods. The first outcome is transferable to other research projects by using the same incremental phases approach and varying the discipline and/or the technology being studied. The second outcome is transferable to the study of any collaborative process.

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OCCUPATIONAL HEALTH AND SAFETY ... THE CARING CLIENT?

Full Paper

TOXIC MOULD AND ITS EFFECT ON CLIENTS.

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ABSTRACT

Evidence now suggests that the mould, *Stachybotrys chartarum* (S. atra), is not only damaging property but causing health problems and may become the asbestos of the 21st century. Buro Happold (2004) warned recently that councils and social landlords are particularly at risk when attempting to deal with this problem. Research at Salford University supports the belief that landlords may be ignorant of the extent of this problem within their properties and are running the risk of massive claims for damage to health following incorrect diagnosis or delay in eradication of this type of mould growth.

Litigation following health damage said to have been caused by S. atra (more commonly known as 'toxic mould') in the US has already reached billions of dollars (CIOB; *Construction Manager*; March 2004) and contractors, clients, consultants and (in particular) landlords are warned that ignorance of the facts relating to this mould and the consequential delays in its eradication from their property will not protect them from severe financial penalties.

HSE statistics (2003) show that asbestos related mesothelioma claims are still rising and insurance companies in the UK are studying the US 'toxic mould' experiences and considering how they can best protect themselves (and their clients) from possible long-term financial damage.

The virulence of S. atra and its associated micotoxin is especially harmful to humans and in particular those with asthma; of particular concern is evidence that such toxins also form part of the arsenal of biological warfare weaponry. Maintenance contractors must be especially careful when exposing their surveyors and operatives to housing affected by damp induced mould growth.

This paper outlines the current situation in the north-west of England regarding S. atra and in particular considers the impact of damp housing conditions on personal health and upon a large regional public housing client.

Keywords: toxic mould; mycotoxins; mycotoxicosis; *Stachybotrys*; T2 Toxins, toxigenic fungi

GENERAL INTRODUCTION AND BACKGROUND

MOULD IN BUILDINGS

A characteristic '*mouldy*' or musty odour encountered when entering some older buildings comes from volatile organic compounds (VOC's) such as pentane, heptanes, octane, 2 hexanone, and undecane exuded by mould organisms established within the structure. The smell is probably one of the first indicators of the ultimate condition of the building. Further critical examination of the building often reveals a lack of investment in routine maintenance, and in the worst cases some elements of the structure may be in the final stages of decay and possible collapse.

Building Surveyors and Facilities Managers surveying 'old-stock' buildings might expect to find both superficial and structural damage caused by fungal growth; especially from the *Conifera puteana* (cerebella) or '*wet-rot*' and *Serpula* (*Merulius*) *lacrymans* – '*dry-rot*' varieties. The latter is generally perceived as being the most dangerous variety and presents to the surveyor with large and often active soft hyphal growth similar in appearance to cotton wool:



Fig 1. *S. atra* on glass slide. 2000x mag. Source Harvard Univ'y.

Mould spores are present in the atmosphere in abundance and poor environmental conditions in some areas of buildings allow spores to establish and grow rapidly, establishing usually within dark and damp basements or other closed areas such as sub-floors, roof spaces and built-in cupboards. Mould typically obtains sustenance from condensation and bio-degradable organic building components and some sources mistakenly attribute growth mould across inorganic

substances and components as a sign of its ability to live off virtually anything – more careful examination however, reveals an underlying organic contamination providing the fungus with sustenance – e.g. dust, grease and oil contamination on (say) steel, iron and glass (Fig. 1).

Until comparatively recently it was not considered too much of a health risk to enter and survey an existing building (other than perhaps when the building was structurally unstable). However, health and safety risk assessments now identify the need for suitable protective clothing and high quality breathing masks (filters) when surveying or working in buildings affected with dry or wet rot.

Evidence, particularly from the United States, describes the threat from a previously little known mould that is creating a new genre of litigation and proving to fit the definition of a 'litogen' (substances inducing more litigation than injury). It has also received the media-created name: '*Toxic Mould*' but carries the correct name of *Stachybotrys chartarum* (synonyms: *S. atra* & *S. alternans*). *S. atra* is common in soils

and plant debris but is also been found (along with other 'toxic' moulds) in cereal animal feedstuff. It is considered to be the cause of many animal deaths in Eastern Europe due to mouldy straw feed and more recently implicated by Flappan et.al. (1999) in numerous cases (and deaths) of Infant Pulmonary Haemorrhage (IPH) in the United States (Cleveland, Ohio) dating back to 1993. In addition, Elidemir et.al. (1999) 'confirms' one case in which *S.atra* was isolated from the bronchoalveolar lavage fluid of a child with IPH. *S.atra* was later recovered from the child's water-damaged home and happily, in this instance, the child recovered following medical care and eradication of the source of contamination. However, the current situation regarding *S.atra* causing IPH is still uncertain due to a lack of rigorous scientific investigation, although there is now a body of anecdotal (and some investigative) evidence leading to logical hypotheses in this context.

The two most common pathways for exposure to moulds are through inhalation and dermal contact. Personal sensitivity will affect the human response time varying between almost immediate (6 minutes), to somewhat delayed (several weeks). Infants under 6 months of age seem to be more at risk as do the elderly; those with an immune deficiency; asthmatics; those with a genetic disposition; and those undergoing chemotherapy or suffering long-term illness.

S.atra forms a greenish-black mould on material with high cellulose and low nitrogen content, such as wallpaper, fibreboard, gypsum board, paper, dust, and lint. Growth occurs when there is, or has been, a very high moisture level from water damage e.g. excessive humidity, water leaks, condensation, water infiltration, or flooding. *S.atra* is present in the soil and is freely carried into properties during the course of a flood.

In the United States mould related lawsuits are now affecting all members of the construction community including home builders, real estate agents, prior owners, landlords, housing associations, local authorities or just about anyone connected with the construction and maintenance of a structure. They have been held responsible for negligent design, construction or mismanagement of buildings that can be shown as promoting conditions favourable for mould growth above background levels. Examples of such conditions include: enclosed areas with insufficient air flow; recurrent moisture sources; defective damp proof coursing; leaking pipes or HVAC contamination. Poor construction practices are particularly targeted, e.g. the inadvertent creation of an environment favourable to mould initiation by failing to give interior woodwork or other absorbent material time to dry before being sealed up.

MOULD TYPES AND INDOOR CONDITIONS

Modern construction methods produce airtight indoor environments that are positively welcoming to the rapid growth of mould. Previously, draughty buildings with many air-changes per hour diluted the concentrations of mould spores and mycotoxins in the internal air. Nowadays, the move towards more environmentally friendly and sustainable methods of construction (e.g. timber-frame) provides a ready source of food for the mould spores – this is especially the case when sloppy production methods are allowed (or overlooked) and parts of the building are sealed up before they are fully dry. Leakey & Lewin (1996) estimate there are approximately 1.8 million species of fungi, some of which we choose to consume without injury or other ill effects and most of which we have yet to identify (or even discover!). Like plants, fungi take root, but unlike plants fungi cannot photosynthesise and therefore have no chlorophyll (thus are not green). They generally grow directly on their food source, hence their appearance on timber or any other organic substrate and they can 'eat' the sulphur off concrete walls. When suffering from depleted resources fungi may

escape by aggregating hyphal structures (called strands or rhizomorphs) and grow beyond the zone of depletion, crossing great distances and in so doing, locate further food and water resources. Spore sizes of airborne fungi range between 3 – 60 µm and they cannot be seen without a good microscope; instead they appear as a cloud of 'smoke' when discharged or disturbed. In Europe the most common fungal species appear to be *Penicillium chrysogenum* and *Aspergillus versicolor*. (Cole and Cox 1981). Some *Aspergillus* and *Penicillium* spores although appearing dormant may remain viable for 12 years or more before activating when moisture becomes available.

Normally, builders and surveyors would be concerned with the effects of mould upon timber and its removal prior to general repairs, however, given sustenance, moulds can grow on virtually any substrate, e.g. kerosene (including jet-fuel), petrol, paint, rubber, textiles, insulation lagging, electrical equipment, glass and stainless steel. Inadequate kiln drying or seasoning of timber leaves sap within the structure which whilst not affecting the strength of components does encourage the growth of mould, subsequently leaving it susceptible to further attack by more vigorous mould strains.

Wood-rotting Basidiomycetes are perceived to be the only group of fungi of special significance in wood deterioration; however the potential for damage to human health caused by the *S. atra* fungal strains cannot now be overlooked. Metabolic activity of most fungi occurs at about 75%RH although *S. atra* generally requires approximately 93%RH and 25° C (Kuhn and Ghannoum 2003):

In this context mould growth and damage will readily occur in properties suffering the after-effects of flooding. A report from the Building Research Establishment (Sanders and Cornish 1982) established that 12% of UK housing stock, equating to approximately 2.5 million dwellings, suffered from serious dampness but this was mostly (60%) due to condensation rather than flood damage. This contrasts with the Royal Institution of Chartered Surveyors (RICS) current estimate of 3 million properties suffering from (*incorrectly named*) '...mildew'. (The Move Channel - News Report 2002).

Geographical location also plays a part and in the UK the number of properties built on flood plains should be a cause for concern by building users and owners. Insurance companies may wish to review their risk exposure not only because of the potential for damage to property from flooding but from the consequential personal injury claims resulting from exposure to toxic substances resulting from the negligence of the construction and property community. In November 2001, in a written answer to a Members question in the House of Commons, the Secretary of State for Transport, Local Government and the Regions (Ms Keeble) stated:

'...some 14500 (11%) new houses built during 1998 were built on flood plains...' and '...for the 10 years from 1989–98, 9% of the land changing to residential use and 10% of the almost 1.4 million new dwellings built were within the indicative flood plains. This compares to the 12% of all land in England that is within the indicative flood plains.'

The difficulties in isolating and identifying mould spores from inside buildings cannot be over-emphasised. Several studies have shown that the

'...indoor environment contains a wide range of microorganisms, including bacteria (e.g. legionella); mycobacteria; and moulds, as well as their products, including endotoxins and mycotoxins...' (Kuhn and Ghannoum 2003).

Following exposure to mould spores persons exhibit upper airway symptoms similar to those exhibited by persons allergic to dust mites and thus, because of a lack of

understanding and investigation, symptoms may not be correctly ascribed to mould exposure. Any resulting misdiagnosis may be contributing to a distortion in statistical findings.

McCrary (1999) explains that the normal ideal mould environment ranges between 0°- 40°C, pH 3 to 8 although some fungi can flourish at temperatures below freezing and as high as 50°C. These wide ranging temperatures, humidity and pH create a dilemma for building managers, users and owners. Environmental responses to building management require high quality relatively 'tight' structures and inappropriate construction solutions may be out-of-balance with the requirement to keep the inside air quality healthy – preferably without the use of forced air-conditioning/handling systems. Keeping buildings warm may be desirable but the ventilation requirements for the maintenance of a healthy 'mould-free' zone may be at odds with this.

MYCOTOXINS AND S.ATRA

A mycotoxin is a poison. In the context of fungi it is a metabolite (by product) of the growth of moulds. Mycotoxins have very real toxic side-effects on plants, animals and humans and when moulds are shocked by sudden fluctuations in temperature (freezes or hot spells) they exude mycotoxins. They are generally less selective of the hosts they attack and are shown to cross plant species. Some mycotoxins are able to suppress the human immune system. (McCrary 1999).

There are hundreds of known or suspected mycotoxins, but mycologists suggest the list may turn out to be in the thousands. Several mycotoxins have gained some notoriety e.g. Aflatoxin B1 (potential carcinogen) and Satratoxin H (see below) and trichothecenes. The five most important mycotoxins to human health are aflatoxin (produced by *Aspergillus*); ochratoxin (produced by *Penicillium*); fumonisins; trichothecenes (as produced by *Stachybotrys*) and, zearalenone. The species of any given genus may produce few toxins (e.g. *Aspergillus* species), or they may produce many e.g., *Penicillium* species, which produce more than 100 – some of which are beneficial. However, trichothecene may be a different proposition:

'Trichothecene mycotoxin (T2) can theoretically be used in aerosol form (yellow rain) to produce lethal and nonlethal casualties. T2 is one of the more stable toxins, retaining its bioactivity even when heated to very high temperatures. T2 can enter the body through the skin and aerodigestive epithelium, without being inhaled, and quickly inhibit protein and nucleic acid synthesis (Texas Department of Health. 2004), (Office of the Special Assistant for Gulf War Illnesses. 2003)

The use of mycotoxins as an agent in bioterrorism is by no means a trivial assertion and the use of 'Aflatoxin B1' by Iraq are a documented part of their weapons of mass destruction programme (UNSCOM 1998) however, there is some conflict as to the toxicity of this particular *Aspergillus* mould derived mycotoxin and while The Physical and Theoretical Chemistry Laboratory at Oxford University produce data sheets stating that this mycotoxin is '*...extremely hazardous...*' and '*...may be fatal if even very small amounts are absorbed through the skin...*' (Oxford University 2003), (See website: http://physchem.ox.ac.uk/MSDS/AF/aflatoxin_B1.html) other US sites suggest the quantities required to successfully deliver a lethal dose to a population make its use improbable if not impractical. (See website: http://www.gulflink.osd.mil/bw_ii/bw_tabf.htm)

The RICS warned surveyors to exercise vigilance when conducting surveys of buildings and be particularly watchful for *S.atra*. They estimate that with almost 3 million affected UK homes there may be serious consequential damage to owners and tenant's health who present with cold-like symptoms, rashes, and aggravated asthma. They go on to describe the dangers to operatives involved in building work where widespread fungal contamination exists, stating that they '*...could also be at risk from developing Organic Dust Toxic Syndrome (ODTS)...*'. (The Move Channel 2002)

ODTS is also known as Pulmonary Mycotoxicosis; Silo Unloader's Syndrome (SUS) or *Atypical* Farmers Lung. Although OTDS is not considered as serious as Farmers Lung it is more common and generally occurs after a delay following high-level exposure to various dusts (mouldy grain, grain dusts, mouldy silage, wood chips, foul dust, swine dust) and a call for assistance in preventing OTDS has gone out from the Centers for Disease Control and Prevention in Atlanta, Georgia, USA. CDC (2004). The common link here is the reference to mouldy grain, symbolising some of the first reported instances of *S.arta* affecting animals in the Ukraine in Eastern Europe in the 1930's. (Nelson 2001).

Considerable argument exists between researchers on the subject of *S.atra* being especially harmful to humans. The debate relates to the identification and levels of the harmful species in the bioaerosol. Many species of fungi spores are present when samples are taken: particularly the *Penicillium*, *Cladosporium* and *Aspergillus* species. (Hunter et.al. 1988; Grant et.al. 1989). Indeed, over 66 different fungi and yeasts were found to be present in 94% of properties in a US survey. (Kuhn and Ghannoum 2003).

Penicillium and *Aspergillus* are already well known as mycotoxin producers having a serious effect on humans, while *S.atra* produces the mycotoxin Satratoxin H which at best, produces cold and flu-like symptoms, headaches, sore-throats, and diarrhoea but is further cited in many areas as suppressing the immune system affecting the lymphoid tissue and the bone marrow. Animals injected with Satratoxin H exhibited the following symptoms: necrosis and haemorrhage within the brain, thymus, spleen, intestine, lung, heart, lymph node, liver, and kidney. Effects by absorption of the toxin in the human lung are known as pneumomycosis. (UMN 2004) Table 1 (overleaf) gives a breakdown of the human response of exposure to mycotoxins.

Table 1. Measuring Toxigenic Mould Exposure and Health: Adapted from: Univ of Minnesota study (2004)

Agent in Environment	Human Exposure	Molecular Response	Symptoms - Disease
- Possible to determine, typically not measured until after onset of illness. Later measurements may not be reflective of the environmental conditions present at the time illness was developing (changes in moisture, temperature, food sources, or other growing microorganisms can all affect mould growth). - Inconvenient for typical consumer - Can vary depending on measurement methods used. Can make comparisons difficult between studies using different testing methods.	Often measured via self-reported mould and/or moisture problems at home or workplace as a proxy for mould-specific indicators of exposure and dose. - Results of environmental testing in the home or workplace are also used as a proxy for indoor mould exposure. - Both measures are very crude measures of dose. - Not yet possible to measure mycotoxins in human or animal tissue.	Few toxicological studies have been performed using inhalation as a route of exposure. - Most of what is known about the physiological response to mycotoxin/ mould exposure is derived from animal studies using ingestion as a route of exposure; respiratory defence mechanisms differ from those present in the digestive system. - The limited numbers of inhalational in-vitro studies suggest that some moulds produce haemolysins and other iron-scavenging substances that result in the destruction of RBCs. - Also implicated in allergic responses and cytotoxicity.	- No effects are specific to either indoor moulds or particular toxigenic species of mould. - Makes establishing associations with indoor mould exposure more difficult. - Three categories of effects: 1) Infection (only applicable to susceptible populations (e.g. immunosuppressed people) 2) Sensory Irritation 3) Allergy 4) Immune effects (e.g. inflammatory response, immunosuppressant) - Suspicion of toxins produced by <i>Stachybotrys chartarum</i> as a possible cause of infant pulmonary haemorrhage has existed since the early 1990s. Only recently has this mould been isolated from the lung of an infant suffering from this condition (Elidemir O. et al. <i>Paediatrics</i> 1999).

THE UNIVERSITY OF SALFORD STUDY

The objective of the Salford University exercise was to discover the levels of knowledge and experience of S. atra among housing professionals within the Salford and Wigan areas of north-western England. There is much social housing in this

region and it might normally be expected that local construction professionals would have a high level of understanding of mould infestation criteria. In addition, given the climate and socio-economic status of the region many of their tenants would find it difficult to cope with moisture levels following a flood or deal with the very high internal levels of condensation during a very cold winter when the drying of clothes outside was not possible.

Fifty persons in six target groups connected with the design, management or surveying of housing were initially contacted and thirty firm responses were obtained. From the thirty responses, twenty-four finally agreed to be interviewed and also responded to a brief questionnaire. This small sample population included: architects; facilities managers; general practice (GP) surveyors; housing managers; housing surveyors and maintenance managers who between them had responsibility for over 25000 properties. The survey drew general conclusions but identified the direction the wider investigation will take to ascertain the real picture among the industry's professionals. It is however a pointer to levels of understanding within the construction community.

The following is a synopsis of the survey from what may be termed as the professional housing sector in two large authorities. The targeted groups were asked a series of questions ranging from: practice area; building category; witness to internal dampness; causation and, user complaints from tenants and owners. The latter part of the questionnaire deduced knowledge of the term '*toxic mould*' and the respondent's profession.

Causes of and witness to internal dampness:

All members of all target groups had witnessed internal dampness in property that had been caused by most of the common conditions including: defective DPC's, sewer damage and defective rainwater goods, condensation, leaking appliances and pipe-work etc. This produced a baseline of understanding from which the remaining questions were examined.

Experiences of mould growth:

Some 92% of the respondents indicated that they had experienced or seen mould growth within properties – this includes all of the GP surveyors, maintenance managers and housing managers. However, only 33% of architects had witnessed it. One inference that might be drawn from this response may be that architects neither get onto site nor do they get involved in maintenance works often enough; another may be that within large housing organisations maintenance and repair work is often handled by internal 'works departments, who are left to deal with the damage and restore elements of the structure without reference to a design professional.

The worst and most consistent cases of mould growth were seen in Residential Care Homes for the elderly, where on a regular basis, the normal internal daily temperatures exceeded 25°C with 95% RH values; often as a result of limited ventilation in an (damaging) attempt to conserve fuel and power by extensive draught-stripping and sealing of openings in the structure. In addition, most of these premises undertook extensive food preparation and washing, daily generating high humidity levels.

Flood damage:

Only 38% of all respondents had dealt with or witnessed flood damage, two of whom (housing surveyor and housing manager) stated they, '...dealt with flooding issues on

a yearly basis...'. However, the bulk of respondents had never had to react to floodwater inundations within properties in their charge.

S.atra growth is particularly prevalent in these circumstances as it is expected that it will be carried into the property by floodwaters. There is a natural reaction on the part of the landlord or owner to get tenants back into the property as quickly as possible and this may lead to shortcuts being taken during the restoration process and, the property being handed over before it is fully dried out. Social housing owners (in particular) have a responsibility to ensure that their property is safe, both to hand over and to occupy.

Client complaints concerning mould:

When questioned about their experiences with clients, all of the housing managers, housing surveyors, and 60% of GP surveyors had suffered complaints from clients about mould in their property following exposure to damp conditions. It is of no surprise to find that maintenance managers had little (40%) experience of client's dissatisfaction – this may be due to their arrival on the scene after the event - usually to rectify the damage.

In a similar vein, none of the architects had experienced client dissatisfaction. There may be a case for architects to re-visit their clients following some years of building use – this could form part of their design-feedback loop, enabling them to witness the problems of poor or over simplistic specification and construction techniques.

Client complaints of ill-health:

When clients complained about ill-health they did so to all housing surveyors and GP surveyors. None of the other professionals had experienced this issue. It was found that the first port of call for all clients was their 'landlord' in the case of tenanted accommodation - they then passed the complaint on to the housing surveyor to determine the cause of the complaint. In the case of owner-occupied dwellings the normal route was to contact a GP surveyor, who then determined the cause of the mould infestation.

The alarming situation regarding temperatures and humidity levels in care homes for the elderly leads to a number of speculations as to the well-being of the inhabitants, many of who are too infirm or possibly disabled to easily 'get out' into the fresh air. The surveyors/managers responsible for these homes were not requested to record their concerns about these premises although it is clear that a comprehensive and dedicated survey of such premises may yield some difficult and challenging results.

'Toxic mould' knowledge:

This is perhaps the most surprising result of all. Only 38% of the targeted group had heard of the term '*Toxic mould*'. The media coverage during (particularly) the last two years has been considerable, with most of the professional journals carrying considered and reflective reports of the fungus. At the same time there have also been 'scaremonger' reports in the daily press, likening S.atra to Asbestos and stating that UK insurance companies were about to face massive and very long term claims from mycotoxin affected claimants. Some US insurance companies will no longer hold cover on S.atra infected or asbestos contaminated properties. When asked (during a follow-up telephone interview) to describe, *in one word*, what 'Asbestos' meant to them – the overwhelming responses from all interviewees were the words: 'deadly'; 'lethal'; and 'cancer'. The message has clearly got through about the effects of asbestos on the human body however; issues surrounding the body's reaction to mycotoxins emanating from mould infestation in property have not – yet.

Facilities management:

Most disturbingly, the group of professionals consistently unable to produce a knowledgeable answer to most of the questions were the facilities managers. If this trend is reliable, there are many issues for this growing and relatively new profession to resolve in respect of their understanding of buildings, particularly those that may be classified as 'sick buildings'.

CONCLUSIONS

The study concludes that there is a growing body of evidence suggesting *S. atra* and its mycotoxins of Satratoxin H and trichothecenes have a harmful effect on human tissue especially among those with immune deficiencies or who are 'weak' e.g. infants, the infirm and the elderly. The isolation of *S. atra* spores from the many fungal spores present in any building due to natural environmental conditions is especially difficult and further work needs to be done in this respect. The use of forced-air collection systems rather than passive (e.g. agar slides) is preferred when collecting evidence of mould spores within properties.

Humans are exposed to mould spores in the natural environment all the time and most of us are immune, normally not suffering any ill or side-effects. However, some of the *Stachybotrys* mycotoxins (particularly the T2 strains) have a severe and debilitating effect on human tissue and because of this the procedures for removal of moulds from within property should be speedy and precise; operatives must be well trained and given protective 'all-over' Hazardous Materials (HAZMAT) suiting containing complex breathing filtration systems that are robust enough to enabling operatives to safely handle and dispose of contaminated building products.

With the exception of one case in the US (Elidemir et.al. 1999) the link between the presence of agents in the environment to human exposure data and subsequently to molecular alterations and disease still leaves many researchers unconvinced of the connection between damage to human lung, intestinal, brain and other vital organs in the body following exposure to the singular *S. atra* mould and its mycotoxin – however, the evidence is growing and litigation (particularly in the US) is driving forward the body of knowledge relating to this quiet menace.

The best way of dealing with mould is still to deny it any moisture. This simple action will stop mould growth and underpins the assertion that adequate, unobstructed ventilation is still paramount as is the need to fully dry properties subsequent to flood inundations. Similarly, sloppy construction practices that allow damp timber or other construction elements to be enclosed (sealed) during the construction phase must be condemned. Speedy identification and removal of dampness problems must be given a higher priority by social housing landlords not only to reduce their potential for exposure to litigation but also to improve the health and well-being of their clients. A recognition that the removal of mould growth from properties can be an extremely costly, time consuming, hazardous and difficult exercise – it may seem very extreme but in difficult cases the outcome may be to burn the dwelling to the ground in order to totally eradicate the presence of mould and the potential for human suffering. (Mold Reporter 2002).

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INNOVATIVE ASSET MANAGEMENT

Full Paper

EXTERNALISATION AS A SOURCE OF INNOVATIVE ASSET MANAGEMENT : THE CASE OF THE TRANSFER OF THE UK DEPARTMENT OF SOCIAL SECURITY ESTATE TO THE PRIVATE SECTOR

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ABSTRACT

During the last ten years, there has been a growing tendency towards externalisation (outsourcing). This situation results from technological developments, fierce competition, changing market conditions and the need to focus on core business. This trend affects companies from the private and the public sectors. In Europe, several public administrations have decided to outsource the management of all or parts of their estates. But none have been so far as the UK Government departments.

In April 1998, the UK Department of Social Security (DSS) signed an agreement to transfer the ownership and management of almost all its estates to a private consortium. The aim of this paper will be twofold :

- The first is to explain the contractual arrangements at work between the consortium and the Department.
- The second is to examine whether this transfer leads to innovative asset management and to the delivery of better services to the clients.

We will investigate these questions through the lenses of transaction cost economics. The choice of the case study results from the unusual features of this project : its size (1.64 million square metres have been transferred), its innovative asset management scheme and the role of the service in this transfer.

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I. INTRODUCTION

During the last ten years, there has been a growing tendency towards externalisation (outsourcing). This situation results from technological developments, fierce competition, changing market conditions and the need to focus on core business.

Technological changes and the introduction of new information technologies transform relationships between clients and suppliers. Intensified competition places increasing pressure on organisations to reduce total operating costs and to focus on their core business. Moreover externalisation favours flexibility and facilitates both efficiency and cost-effectiveness. Outsourcing decisions often appear to be based on the idea that market forces can lead to an improvement in service quality innovation, a reduction of costs and a creation of economic value within the supply chain.

Conversely excessive outsourcing is also presented as a way to loose its learning capacity and its competitive advantage (Foss, 1996).

Outsourcing is not limited to repetitive tasks. Even activities such as R&D which have been considered as strategic, have been partially outsourced (Quinn, 2000; Ulset, 1996). This trend affects companies from the private and the public sectors.

According to Barrett, outsourcing (or externalisation) refers to *"one type of contracting-out; namely, the process by which a user employs a separate company (the supplier), under a contract, to perform a function, which had previously been carried out in-house; and transfers to that supplier assets, including people and management responsibility"* (Barrett, 1995, p.124).

In Europe, several public administrations have decided to outsource the management of all or parts of their estates. But none have been so far as the UK Government departments.

In April 1998, the UK Department of Social Security (DSS)¹ signed an agreement to transfer the ownership and management of almost all its estates to a private consortium. This transfer known as the PRIME project², is the largest property transaction ever conducted by a UK Government department. Its net present value was £2.008 billion (using the government's real discount rate of six per cent).

The strategy literature has paid a great deal of attention to the factors that lead organisations to outsource part of their functions. Transaction costs economics and the agency theory have emerged as the main theoretical frameworks to explain outsourcing decision and contractual agreements. However the theoretical approaches slightly differ. The transaction cost theory is concerned

¹ The Department of Social Security is now known as the Department for Work and Pensions (DWP). In 2003, the contract between the DWP and the consortium was expanded to include properties from the former Employment Service estate. Now the former DSS and ES estates are run as one, under a single contract expiring in 2018. In this paper, we will only refer to the first contract and to the DSS instead of the actual DWP.

² PRIME stands for Private sector Resource Initiative for the Management of the Estate.

"with organisational boundaries, whereas in agency theorising the contract between cooperating parties, regardless of boundary, is highlighted" (Eisenhardt, 1989, p.64). Because boundary choices are predominant in the decision of the British Department of Social Security estate to transfer most of its estate to a private consortium, we will use the transaction cost framework. Our aim will be twofold :

- The first is to explain the contractual arrangements at work between the consortium and the Department.
- The second is to examine whether this transfer leads to innovative asset management and to the delivery of better services to the clients.

The full paper is organised as follows. Section 2 presents the transactions costs economics. Sections 3 describes the case study. In Section 4, we propose a theoretical interpretation of the transfer of the estate to the private consortium through the lenses of transaction costs economics. Finally, we examine whether the contractual agreements between all partners improved the quality of the service.

2. OUTSOURCING IN TRANSACTION COST ECONOMICS

The transaction cost economics provide a framework to compare alternative modes of governance : markets, hierarchies and hybrids. *"What matters is not the absolute amount of transaction costs, but the relative ranking of transaction costs associated with different organisational or contractual choices"* (Wang, 2003, p.4).

According to Williamson (1991), two behavioural assumptions and four attributes of transactions are especially important for understanding economic organisation and relationships between economic agents.

The four principal dimensions of transactions are asset specificity, uncertainty, the frequency of transactions and the ease of measurement. *"Of these four, asset specificity – which has reference to the ease with which an asset can be redeployed to alternative uses and by alternative users without loss of production value – has had the greatest significance for examining the governance of contractual relations"* (Williamson, p.79-80, 1991).

These characteristics of transactions become significant because of the behavioural assumptions : bounded rationality and opportunism.

Bounded rationality suggests that the human agents experience limits in formulating and solving complex problems. This will lead them to write incomplete contracts.

Opportunism is usually associated with the actions of economic agents which disclose information in a selective and distorted manner. This entails information asymmetries and organisational problems. These asymmetries are very strong for new services (Djellal and Gallouj, 2000).

Different combinations of asset specificity, frequency, uncertainty and measurement problems will determine which governance structure is best adapted to manage transaction :

- The market is the appropriate mode of coordination for non specific assets and occasional transaction. All the contingencies that might affect the contract are foreseen by the agents. Consequently, the client and the supplier are able to write a clear and enforceable contract. The uncertainty is limited and it is easy to implement and monitor tasks. However, the market principle may fail because participants often adopt short-term oriented strategy and for each transaction it is necessary to learn about the other (Imai and Itami, 1984). In this case, outsourcing, characterised by classical and complete contracts, is appropriate.
- When transactions are recurrent and involve specific assets, outsourcing is not appropriate. Because of the specificity, the contracts are incomplete, complex and difficult to monitor. Consequently, the hierarchy is chosen.

For example, by outsourcing some specific activities over a long period to a supplier, a client may have made himself dependant upon its supplier. Conversely, the supplier may have invested in a specific equipment. This creates a bilateral dependency. In such a situation, vertical integration is best adapted to avoid opportunistic behaviours. This strategy also reduces procurement and negotiations costs.

Conversely, the hierarchy might reduce the flexibility of the enterprise and decrease the performance level. Indeed, according to the agency theory (Jensen and Meckling, 1976), when an internal contract is established between a principal (for example the manager of the housing company) and an agent (for example a maintenance company), it is necessary to find an incentive system to avoid shirking behaviour (from the agent) and a loss of productivity.

Moreover, the internal organisation of supporting activities might lead to the development of routines and to the limitation of operational efficiencies.

The hybrid forms (between markets and hierarchies) are better suited when asset specificity is intermediary, transaction neither recurrent nor occasional. Williamson considers that this form of coordination is unstable and temporary. As soon as uncertainty increases and/or assets become more specific, hybrid forms entail transaction costs and vertical integration becomes more advantageous. The hybrid forms cover a wide range of organisational forms. Outsourcing and strategic alliances are some of them.

Outsourcing with neo-classical contracts characterised by long-term arrangement can be adapted even when high asset specificity dominate. Uncertainty and measurement problems just need to be low.

Notwithstanding the interest of this approach to provide an analytical scheme for the study of externalisation, several limits remain :

- First, according to this theory, arm's length agreements are costly. First agents are engaged in negotiations to define the terms of the contract. Once the agreement is signed, they will undertake inspection to make sure that their partner is not shirking (ex post opportunism). Given these assumptions on opportunistic behaviours, transaction costs should reach prohibitive levels when new and complex contracts are involved. However, this is not the case. In fact negotiations which lead up to a

bargain could be considered as an investment instead of a cost (Everaere, 1993). Agents rely on this process to learn about their mutual needs and to make decision to avoid bottlenecks during the implementation of the project.

- Secondly, the theory considers that there is a perfect substitutability between external and internal activities. But when a resource is integrated to an enterprise, it becomes more and more specific. *"There cannot be substitutability because a resource entering into the firm acquires new qualities and changes its nature"* (Foray, 1991, p.395).
- Finally, the transactional approach puts too much emphasis on opportunism. However, *"an organisation should be understood at least as much as a mechanism to enhance co-operation than as a device to reduce cheating and shirking"* (Menard, 1992). By and large recurrent transactions lead partners to gradually trust one another. These collaborative relationships entail learning (Lundvall, 1993).

3. THE CASE STUDY

3.1 PFI AND THE TRANSFER OF THE UK DEPARTMENT OF SOCIAL SECURITY ESTATE

The transfer of the UK DSS estate to a private consortium (the PRIME project) is part of the "Private Finance Initiative" (PFI) launched in 1992. By November 2003, 617 projects had been signed under the PFI with a capital value of over £56 billion.³

"The PFI extends the role of the private sector in the provision of what are generally considered to be public services (such as health, education, transport infrastructure, prisons and the administration of the function of the state) by signing contracts with private sector partners to design, finance, build and manage assets and to deliver associated services" (Froud, 2002).

The DSS estate was the largest civil estate in UK Government. 700 buildings covering a total floor area of 1.64 million square metres were transferred to the consortium.⁴

3.2. KEY FUTURES OF THE CONTRACTUAL AGREEMENTS

The consortium acquired the ownership of the freehold properties (37 per cent of the estate) and responsibility for rental costs on leased buildings (both

³ This figure was doubled in 2002 and 2003 by the signing of contracts totalling £28 billion for the London Underground (IFS, 2003).

⁴ In 2001, a similar contract (the STEPS Deal) was signed between another consortium and several Departments (the Inland Revenue, HM Customs and Excise and the Valuation Office Agency). 698 buildings covering a total floor area of 1.44 million square metres were transferred to the consortium (NAO, 2004).

historic and modern leases). It also supported the cost of upgrading the buildings (NAO, 1999).

During the 20 years of the contract, the Department retains rights to occupy the estate. But on expiry of the contract, the estate will remain in the ownership of the consortium. During that period, the DSS may also vacate up to 35 per cent of the estate without charge. 10 per cent of the estate was declared surplus at the start of the contract (164,000 square metres). Because the level of vacant space was expected to increase, the department negotiated rights to vacate 2 per cent a year of space agreed to be flexible during each of the first 15 years of the contract (this "flexible" part concerns 25 per cent of the estate).

The Department also transferred its existing contracts for the 13 facilities management services to the consortium. Consequently, the Department will deal exclusively with one contract rather than 160 service contracts during the 20 years of the PRIME project.

To provide services to the users of the buildings that were transferred, the consortium subcontracts building maintenance, catering, cleaning, security, energy and utilities management, equipment and landscape maintenance and waste management. The contracts between the consortium and its subcontractors were initially signed for five years. In 2003, all of them have been extended till 2018.

3.3. THE INNOVATIVE ASPECTS OF THE PRIME PROJECT

The PRIME project was very innovative from several perspectives :

- It was the first transfer of a Government department estate ever realised.
- The size of the project increased the complexity of the deal.
- The consortium members were at the origin a property investment fund, property investment specialists and facilities management companies. They almost started from scratch. They never worked together before PRIME and all of them were pursuing different strategic objectives. However this potential risk was mitigated by the competences and the financial reliability of the consortium members (the leading property investment fund was managed by the US investment bank Goldman Sachs).
- The consortium established several innovative arrangements with its service providers.
- The flexibility introduced for the estate management was also very innovative. The contract agreement allows the DSS to vacate without charge up to 35 per cent of the estate over the life of the contract. However the DSS had to pay additional costs when the deal was implemented, to compensate for the transfer of risk toward the consortium.

4. PRIME THROUGH THE LENSES OF TRANSACTION COSTS ECONOMICS

Based on the theoretical framework presented in section 2, we will examine the transfer of the DSS estate to the private sector. We will look at uncertainty, asset specificity and measurement problems

4.1. UNCERTAINTY

Innovation usually leads to an increase of risks and uncertainty. Despite the aforementioned innovative characteristics of the contractual agreement, the uncertainty of the project could be considered as medium.

Indeed several ex-ante and ex-post transaction elements contribute to reduce the uncertainty :

- The estimated project procurement costs increased between the start of procurement work in 1996 and the implementation of the deal in April 1998. During that period, consultants, financial advisers, local property lawyers and agents helped the DSS to finalise the contract. Total costs reached £10.68 million. This was mainly due to the inability to predict the workload of external advice. But this increase of project procurement costs could also be considered as an investment. It helps the DSS and the consortium to get reliable information on the estate and to limit contractual incompleteness. Consequently, it reduces uncertainty and potential ex post contractual problems.
- The five month period that followed the selection of the preferred bidder were dedicated to negotiations between the consortium and the DSS. Lots of estate data were not assembled in advance. Consequently, it was necessary to spend time and money to remeasure the buildings and to evaluate the assets. After the remeasurement, the estate was found slightly larger than the DSS previously thought. This operation lead to an increase of £ 44 million of the price of the deal but it also reduces potential disturbances during the life of the contract.
- The 13 facilities management services that were transferred to the consortium were not considered as sensitive functions. Catering, cleaning, security, landscape maintenance and waste management are mainly repetitive tasks that are among the most frequently outsourced services (SESSI, 2001). All of them can be considered as non-core business functions for the DSS. So uncertainty was relatively limited. Before PRIME, most of them were already provided by several private sector contractors. But contract duration was never more than three years. Conversely some activities such as IT hardware, software or infrastructure, telephony, switchboard, that are subject to technological evolutions, were not provided by the contract.
- Uncertainty can also be reduced through information disclosure. *"Because of the limited role of the price mechanism and of the uncertainties surrounding the appropriation of rent, information disclosure will be essential to the existence and stability of hybrid forms"* (Menard, p.159, 1996). In the case of PRIME, the DSS and the consortium agreed to

introduce information disclosure in the contract to preserve the stability of the agreement. Information disclosure will allow them to share the benefits of improved operations of the estate. For example in the case of maintenance, the DSS will *"receive one quarter of savings from the deferral of avoidance of maintenance over a three year period"* (NAO, 1999, p.18). But to keep some incentives, they will not share in higher than planned costs. The sharing arrangements also concern the development of properties, utility cost savings, changes in contractor's service methods...

In the first three years of the contract, 3% of the energy costs have been saved through investment and management.

However, despite the pre-operating investments, the contract was not completely secured. The start of the contract revealed that some risks were underestimated by both partners. For example, the consortium had to pay extra costs to provide buildings with security. Conversely, the DSS believed that they transferred the landlord service charges for leasehold to the consortium. But the risk was kept by the DSS.

4.2. ASSET SPECIFICITY

The transferred estate was classified into three parts : Freehold properties (37%), historic leases (14%) and modern leases (49%). It consisted mainly of traditional office buildings located in or close to the centre of British cities. So it seems that physical assets, and particularly the freehold properties that were acquired by the consortium, could be easily redeployed. As one of the UK's leading providers of total property outsourcing solutions, the consortium had the in-house expertise and was better placed than the DSS to find solutions to redeploy the estate. In the past, the performances of the DSS in this field were quite poor. Just before the transfer, the vacant space was spread over some 140 locations. It concerned 158,000 m² and cost the tax payer over £12 million every year.

The results so far seem to indicate that physical assets was not so specific and that the risk was appropriately estimated. For example, overall development gain share totalled £12 million in March 2001.

Conversely the consortium had to make specific investment to manage the estate and to provide the services required by the contract.

- It created a database that is updated every month to manage the estate. This database is associated with a strategic management and planning tool that was developed by the consortium to manage portfolios and compare alternative proposals for accommodation strategy. Before the DSS did not have any incentives to make such an investment. The accommodation and office services were fragmented between individual business units.
- It established a call centre based in London to handle all calls and work orders from the potential customers in the estate (on average it receives 25,700 calls per month). This customer service centre is crucial for the service quality delivered to the DSS. All the Department's staff can call the centre 24 hours a day. Then the calls are directed to the service

providers. The efficiency of the centre is at the core of the service performance associated with the contract. Work orders have to be handled as fast as possible to avoid penalties.

- Working in the customer service centre requires quite specific skills. The consortium decided to develop in-house expertise by recruiting skilled staff and training them in technical and customer service issues. The staff has to identify the nature of the property service required and to direct the call to the appropriate service providers. This first diagnosis will determine the service quality to the end user. Such an investment was required because the customer service centre is at the core of the performance of the estate management strategy. It confirms that among the skills which contribute to the in-house expertise, human assets are very specific. *"These are probably the most important core skills when moving out of the realm of traditional manufacturing industries. In the service industries human asset specificity is probably the only asset that can give organisations relative advantages. Core skills here are know-how, experience, organizational routines and culture"* (Reeve, 1990, p.140).

All these investments would not have been possible under classical market contracts. A period of three years is too short and not adapted to the features of a transaction that requires specific investment. Because of the 20 years contract the consortium had incentives to develop such specific assets.

4.3. The measurement problem

Measurement issues have been ignored by the empirical literature (Poppo and Zenger, 1998). *"There are two conditions for measures to be effective : observability and verifiability. The first is the possibility for the principal to observe the performance of the agent. The second is the capacity of the principal to verify observations and supply evidence by measures"* (Aubert and al., 1996, p.59).

In the case of PRIME, several procedures have been established to observe and verify how the activities are performed :

- Firstly, the contract detailed all activities to be performed. A Performance Measurement System (PMS) has been established for the 13 services. Then 54 Key Performance Indicators (KPI) have been defined according to the expectations of the DSS. The level of achievement for each KPI is monthly reported for each property. In case of poor performance or buildings unavailability the payments of the Department to the consortium can be reduced. For example, if no heating is available for two hours, the DSS will not pay for the availability of the building that day.
- Secondly, the records and history of all calls and work orders addressed to the Customer Service Centre are contained in an information system that provides service performance statistics.
- Thirdly, several audit procedures have been established and are supported both by the consortium and the DSS to examine all aspects of service delivery across the portfolio. To manage the contract and perform the audit, the DSS still employs about 128 people (instead of 210 before PRIME). The Department can also order external audits and charge the costs to the consortium in case of failure (until a ceiling of £500,000).

- Finally, the consortium tries to benchmark its sub-contractors. For most services and at the level of the whole estate, it relies on two service providers. For example, it is the case for cleaning and maintenance.

5. OUTSOURCING AND THE QUALITY OF THE SERVICE

Customer satisfaction surveys are regularly conducted. In March 2002, the first survey indicated that 87% of DSS staff were satisfied by the level of service provided by the consortium. A further customer satisfaction survey was carried out in March 2003 which resulted in 90% of DWP staff being satisfied with the level of service. No similar studies was carried out prior to PRIME but it seems that the transfer of estate has increased the quality of the service delivered to the end user of the buildings for at least following three reasons :

- The contract allows each partner to develop its own core competencies. The aim of the transfer was to allocate risk to the party best able to manage it.

Before the transfer, the 160 local service contracts were not managed efficiently. Most of them were for three year periods or less. These 160 separate contracts were not standardised and costly to manage (about £5 million a year for staff costs alone). Some directorates gather several services under one single contract whereas others had separate contracts for each service. The management of the services associated with the estate was not the main expertise of the DSS. Conversely, the consortium members were at the origin a property investment fund, property investment specialists and facilities management companies. Its core competencies concern property financing, facilities services, capital project delivery, estate strategy and asset management and provision of new space. Because of its competencies, the consortium was better placed than the Department to manage the 13 facilities services and the disposal of surplus space. Moreover the consortium will benefit from economies of scale. Service providers will buy some components at a lower price than the former sub-contractors of the estate.

So far the consortium has been able to develop an effective estate strategies which meet the needs of the DSS and to reduce maintenance costs by investing in the refurbishment and the renewal of the estate.

It seems that by transferring the responsibility for managing the estate to the consortium, the Department started to concentrate its resources on its core business : the management of the Social Security system.

- The consortium had to comply with the requirements of the contract. Before the transfer of its estate, the Department did not have sufficient resources to refurbish and to maintain the estate. Statutory requirements such as compliance with health and safety legislation were not fully met⁵. The estimated cost to fully comply with the legislation was £9.7 million of work. The contract provides for refurbishment and maintenance of the estate by the consortium. For example the consortium had two years to

⁵ The Department already undertook all Category 1 health and security checks.

comply with statutory requirements and he still has to support risk of non-compliance.

- The length of the contract enables the consortium to make specific investment. It also provides partners with opportunities to learn from one another. It contributes to the establishment of common codes of information between partners. By providing the DSS and the consortium with an identical set of references, it favours communication, develops the stability needed for exchange and enhances the efficiency of coordination. For example, the consortium and the DSS develop several Estates Committee Structure to resolve contractual issues, to discuss service and property related issues and to address local issues of customer concern.

The features of the PRIME contract also lead the consortium to sign long-term contracts with its service providers. Contracts between the consortium and its sub-contractors were initially signed for three years with a possible extension for two more years. In 2003, the contracts ended but the consortium decided to sign a new contract for 15 years with each of its service providers. The aim of these unusual and long term contracts is to enable the service partners responsible for maintenance, catering, security, cleaning, equipment maintenance and furniture to invest in the service.

For example, the security company developed an access control system with the consortium. It was in charge of the development of the software. It would not have invested in this system and make the right commitment to the partnership without long-term agreements with the consortium. Five years are usually too short to recover the initial investment.

Even service providers tend to cooperate together. Initially, there was no partnering between competitors (two service providers). But as time goes, they tend to share their best practices for their mutual benefits. For example, one company changed its way to operate with the help desk by adopting its competitor solutions.

On the long run, these elements should contribute to an increase of the quality of the service.

Despite the increase of service quality and the global satisfaction with the level of service provided by the consortium, some critics remain : Despite the procedures established to measure the performance of the consortium, there is still a problem to define the output and to measure the quality of the service. It appears more difficult to define a service than a product. For some services such as cleaning, there is a lack of tangible indicators. So it appears that the consortium is rewarded according to its compliance with method statements (for example its frequency of cleaning) and its ability to respond in time (and not always for the quality of the service).

This confirms that services are difficult to determine a priori. *"Each service transaction may be considered as unique as long as it is produced on demand (tailor-made) in interaction with the client or as a response to a specific, not standardisable problem, and in different environments"* (Sundbo and Gallouj, 2000, p.44).

PRIME also shows the difficulties to have the same measurement performance system for about 700 buildings, located everywhere in the UK and having different characteristics and end users.

6. CONCLUSION

In this paper we proposed a theoretical framework to analyse the way the UK Department of Social Security transferred its estates to the private sector. According to the transaction theory, outsourcing and long term agreement characterised by high asset specificity can be efficient when uncertainty and measurement problems are low. It appears from the analysis that several procedures have been set up to measure the performance of the consortium and that uncertainty has been mastered through information disclosure, the measurement of the buildings and the evaluation of the assets. The time and the money spent to get reliable information before the implementation of the deal, reduced contractual incompleteness. This could be considered as a success factor. The contract is one way to "enforce" the trust between partners and to limit opportunism (Brousseau, 1997).

The length of the contract appears so far as another source of success. It lead the private consortium to innovate and to take risks that he was able to handle. Then the consortium also established innovative arrangements with its service providers by signing long-term contracts. Without such long-term agreements, it is doubtful that the partners would have made specific investments. After five years, this win-win strategy seems to have contributed to a better service performance.

On the basis of this analysis, the PRIME project appears to be quite successful. But further research would be necessary. Indeed, the STEPS deal that started in 2001, was similar but not as successful (NAO, 2004) due to ex-post opportunism of the consortium.

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STRUCTURING FINANCE TO MEET CLIENT'S NEEDS

Full Paper

A STAGE-BY-STAGE FACTOR CONTROL FRAMEWORK FOR COST ESTIMATION OF CONSTRUCTION PROJECTS

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ABSTRACT

Construction companies compete primarily on time and cost. Central to cost-based competition is the capability to accurately predict the cost of delivering a project commonly referred to as cost estimation. Typically, estimation of project effort needs to be made at various stages of a project. Little extant literature investigates the effects of factors critical to effective estimation at various project stages. Most literature on cost estimation focuses on specific estimation methods as generic technique and little attention has been paid to the unique requirements at each project stage. This study attempts to identify the critical factors for effective estimation at various stages of typical construction projects.

Drawing from organization control theory and cost estimating literature, this paper develops a theoretical framework that identifies the critical factors for effective cost estimation during each of the project phases of a conventional and/or a DB (Design-Build) construction project. The underlying logic is that as a cost estimating effort progresses, both task programmability and output measurability improve. As a result, control effort will shift from input-oriented control to a combination of output and behavior control.

Keywords: cost estimation, construction project, organizational control, input control, output control, behaviour control.

1. INTRODUCTION

Construction contractors compete primarily on time and cost for delivering projects. The benefits or cost of early or late project completion, respectively, can be converted into monetary values for the clients. Essentially, competition is based on cost of delivering projects to the client. Central to cost-based competition is the capability to accurately predict the cost of delivering a project—commonly referred to as cost estimation. Overestimated cost could result loss of opportunities by the client and loss of contract by the contractor. On the other hand, both client and contractor could incur significant losses due to underestimated cost. Accurate cost estimation reduces the risk of cost overrun, provides confidence on project outcomes to the management and therefore contributes to the strategic management of the organization. As stated by Hicks, “without an accurate cost estimate, nothing short of an act of god can be done to prevent a loss, regardless of management competence, finance strength of the contractor” (Hicks, 1992).

Typically, estimation of project effort needs to be made at various stages of a project. At the conceptual stage, a ball park figure is needed to ascertain whether the feasibility of the project would allow a start. Later at the bidding and construction stages, fairly reliable estimates are needed for tendering and budget control purposes. Due to differences among different project stages on estimation objectives and in the availability of information required for using various estimation methods, effective estimation at different project stages is likely to depend on different sets of factors at each stage. Most literature on cost estimation focuses on specific estimation methods as generic techniques with little attention on the effects of factors critical to effective estimation at various project stages.

This study attempts to identify the critical factors for effective estimation at various stages for two dominant types of construction projects, conventional and Design-Build (DB) project, respectively. This paper starts with a review of current cost estimation literature on construction projects. Emphasis is on the accuracy level, critical factors and characteristics of different stages. Then, drawing from organizational control theory, a framework for grouping critical factors at different project stages is proposed. Finally, conclusions are drawn and implications for further research are discussed.

2. PRIOR RESEARCH

2.1 FACTORS INFLUENCING THE ACCURACY LEVEL

Forecasting construction price is heavily dependent upon historical price data, professional expertise and judgment. Limited design and construction information about a proposed construction project at early design stage may mean that quantity surveyors must rely on assumed or default values for many of the project details, which may cause inaccurate estimates if those assumptions or default values do not hold in the subsequent design and construction.

One of the critical indicators of the effectiveness of estimation is the accuracy level. Table 1 summarizes findings on cost estimation accuracy for construction projects dating back to the 70s'.

Typically, estimation accuracy is defined as the ratio between actual cost and estimated cost (Flanagan and Norman, 1983). However, the definition of actual and estimated cost varies. For example, lowest bid was used by Flanagan and Norman (1983) as actual cost while Morrison (1984) used mean bid received as actual cost. Similarly, pre-tender estimation has been used as estimated cost by some (Flanagan and Norman, 1983; Morrison, 1984) while contract value was used as estimated cost by others (e.g. Gunner and Skitmore, 1999).

There are also slight variations in the focus used to calculate the accuracy levels among the studies. For example, Barnes and Thompson (1971) and Gunner and Skitmore (1999) used statistical methods such as Mean Magnitude of Relative Error (MMRE) and Coefficients of Variation (CV) to test the accuracy level from the cost data of past projects while others (Cheong, 1991; Huxley, 1991) used survey to obtain project managers or quantity surveyors' recollection on accuracy levels. Despite the inconsistencies, the accuracy from these studies portrays a general picture of the trend and level of construction cost estimation accuracy over the last three decades. It shows that estimation accuracy level for construction projects hardly changed over the past 4 decades and remains at around 10% level.

Table 1 Summary of Literature on Estimation Accuracy

<i>Source</i>	<i>Year project undertaken</i>	<i>Accuracy (Range)</i>	<i>Sample size</i>	<i>Estimation Method</i>
(Barnes and Thompson, 1971)	1970	6%	159 contracts	Unit rate Bill of quantity
(Barnes, 1972)	1972	10% (7%)	228 Projects	
(McCaffer, 1976)	1976	5.17%	132 Projects	
(Flanagan, 1980)	1970-1974	5.49% (8.22%)	64 Projects	Elemental pricing bill of quantities
(Flanagan and Norman, 1983)	1971-1978	11%	166 Projects undertaken by 2 country council	Approximate Quantities
(Jupp and McMillan, 1981)	1981	5%	49 Projects	
(Morrison, 1984)	1978	11.97% (8.88-12.86%)	557 Projects undertaken by 7 quantity offices	Elemental pricing bill of quantities
(Cheong, 1991)	1991	5% -10%	1 quantity surveyor company	
(Huxley, 1991)	1978-1989	10%	1310 projects that attached 7287 bids	Survey from project manager
(Gunner and Skitmore, 1999)	1980-1991	10%	181 Projects	Elemental pricing bill of quantities
(Ling and Boo, 2001)	1992-1998	9% (4%-12%)	42 projects from six quantity surveyor company	

A wide range of factors influencing cost estimating have been identified by extant literature. Koehn, Fallon et al. (1978) found that government regulations, plan changes, quality of the contractor management team, priority on construction deadlines, and completeness and timeliness of project information impacted on

construction cost. Shash and Al-Khaldi (1992) identified bidding situations, project characteristics, experience on similar type of project, delays in periodic payments, type and size of contract, project location and the estimating process itself as factors influencing estimation accuracy. Similarly, a study by Al-Harbi, Johnston et al. (1994) reported that major problems facing cost estimators included, in order of importance, intense competition, incomplete project scope definition, unforeseeable change in material prices, changes in owners' requirements, current workload, and error in judgment. In addition, experience (Lowe and Skitmore 1994), project complexity, technological requirement, project information, project team requirement, construction arrangement, project duration and market requirement (Akintoye 2000) were found to influence estimation accuracy, while season, location, type of project, contract duration, and contract size were also found to influence estimation accuracy by impacting on contract cost (Hegazy and Ayed 1998).

More recently, studies on cost estimation seem to have shifted away from earlier focus on identifying cost factors and focus more on developing and testing mathematical models that produce estimates through factor analysis and regression analysis. For example, Trost and Oberlender (2003) identified eleven factors from 45 elements through exploratory factor analysis, including basic process design, team experience and cost information, time allowed to prepare the estimates, bidding and labor climate, and site requirements. Then, based on 67 completed construction projects, a regression model was tested as a prediction tool.

Most studies reduce the large number of cost elements by grouping factors into categories of factors with common attributes. In this study, we regroup the factors identified by earlier studies into 11 categories as shown in Table 2. The factors discussed above are assigned into these categories based on their similarity. The detailed scheme for factors allocation is referred to Table 3. This categorization will be used in the next section in developing the framework for controlling estimation efforts.

Table 2 Summary of literature on factors influencing estimation accuracy

Factor Category	Source										
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
	1978	1988	1992	1994	1994	1997	1998	1999	2000	2001	2003
1. Project Information	★	★	★		★				★	★	
2. Team Experience		★	★	★	★	★		★	★		★
3. Cost Information					★				★	★	★
4. Estimation Process			★			★				★	★
5. Team Alignment	★									★	★
6. Estimation Design								★		★	★
7. Expected accuracy				★		★			★	★	
8. Review and acceptance of estimate										★	★
9. Project Environment Factors	★	★			★	★		★	★		★
10. Project Attribute Factors		★	★			★	★	★	★		
11. Contingent Factor	★		★		★	★	★	★			
Note: [1]. (Koehn, Fallon et al. 1978); [2]. (Skitmore 1988); [3]. (Shash and Al-Khaldi 1992); [4]. (Lowe and Skitmore 1994); [5]. (Al-Harbi, Johnston et al. 1994); [6.] (Kaming, Olomolaiye et al. 1997); [7]. (Hegazy and Ayed 1998); [8]. (Gunner and Skitmore 1999); [9]. (Akintoye 2000); [10]. (Ling and Boo 2001); [11]. (Trost and Oberlender 2003)											

2.2 PROJECT PHASES AND PROCUREMENT SYSTEMS

The conventional procurement system and Design-Build (DB) are two widely-adopted procurement systems in the construction industry. According to Masterman (2002), in 1998, 41% of construction projects in the UK was using the conventional system, compare with 40% of construction project using DB system. Overall, 81% of construction projects in the UK were based on these two systems. Other systems include management-oriented system and discretionary system (Masterman, 2002). For simplicity, the discussion in this paper is limited into the two dominating systems, the conventional and design-build systems.

Under the conventional procurement system, the client contracts separately with designers and contractors and deals directly with most stakeholders involved in the project. In contrast, under a standard DB system, the client usually contracts with a prime contractor to perform both design and construction under a single contract. Typically, the client deals directly mainly with the contractor. The commonly used method is the client starts with own design team to formulate project brief and initial design. Then, prepares either limited documents for a tender or negotiates with a DB contractor. The majority of the design team is then novated to the contractors.

The processes of these two systems in procuring and delivering a typical project are illustrated in Figure 1. As shown in Figure 1, the conventional procurement system can be divided into 5 stages, Conceptual stage, design stage, tender stage, pre-construction stage and build stage.

At the *Conceptual stage*, the typical objective is strategic planning. Estimates are usually prepared as input for feasibility analysis. Relatively little effort is expended carrying out this type of estimate which will be used only as a very coarse screen to gauge the degree of further interest. At this stage, the project scope is not well defined. The typical expected accuracy level at the strategic/conceptual stage is between 30% and 50% (Ashworth and Skitmore, 1982).

At the *Design stage*, cost estimates are continuously adjusted as the design evolves. The typical objective for cost estimation at this stage is evaluating the design feasibility within budget constraint. At this stage, a considerable amount of engineering design work has been completed, and bills of quantities and materials take-offs have been carried out. The availability of detailed design information enables the effective use of traditional estimation method such as detailed break down cost element. Because of increased availability of cost information as design progresses, the expected accuracy level at this stage is around 20% (Morrison, 1984).

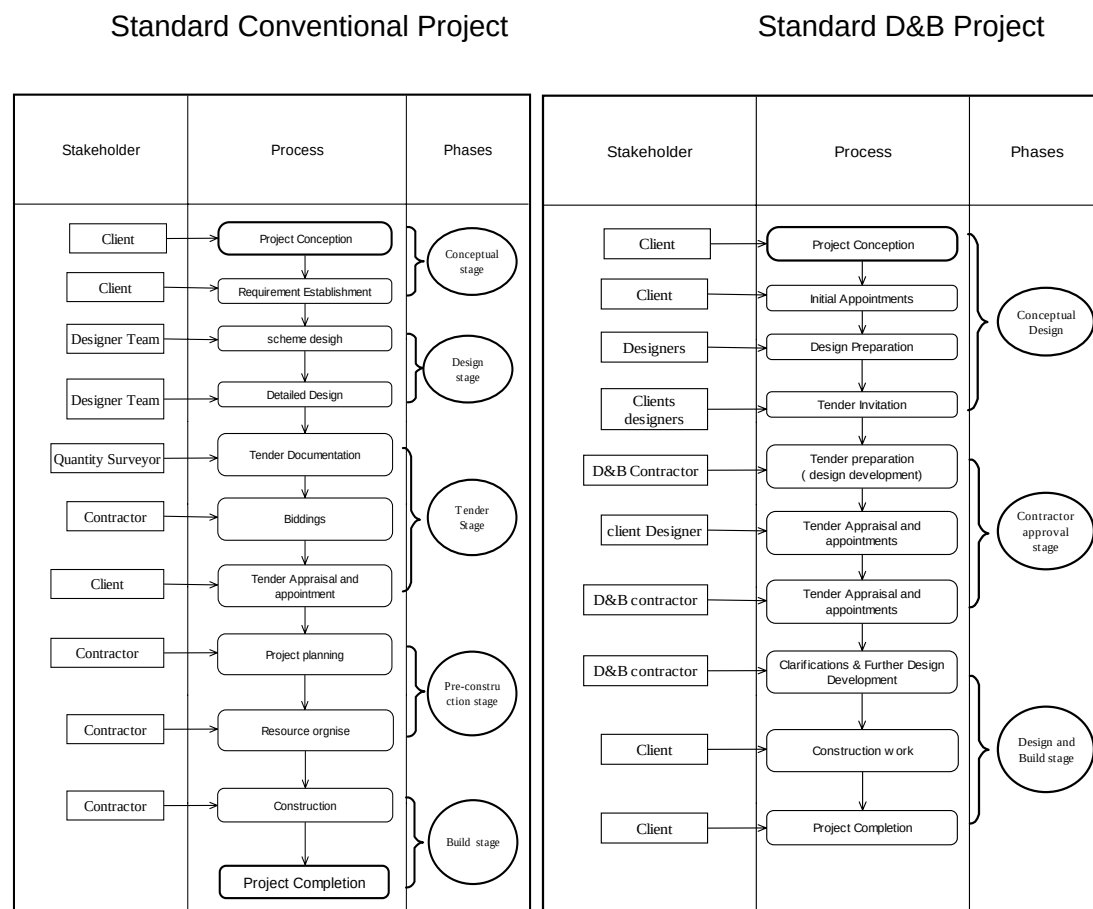
At the *tender stage*, focus is shifted to prepare cost estimates for competitive bidding. Estimates are derived based on subcontractor quotations, quantity takeoffs, construction processes, management overhead and profit markup. The expected level of accuracy typically centers around 10%.

At the *Pre-construction stage*, the main objective shifts to outline cost items for cost control and budget predictions during construction. At this stage, the project scope is

clearly defined. The expected accuracy level is typically around 5% due to the strong focus on cost control (Ferry and Brandon, 1991).

Finally at build stage, the focus here is firmly on cost control. The cost accuracy improves as project moves closer to completion. Since this paper deals with cost estimation whereas the emphasis of this stage is on cost control, the discussion below will focus on the stages from conceptual to pre-construction

Figure 1



The project under DB system as shown in Figure 1 is typically divided into three distinct phases, conceptual design, contractor approval, and design and build.

The conceptual design stage of the DB project is to develop a project plan that outlines the basic requirements for the project. Compared to the conceptual stage of traditional Design/Bid/Build projects, the project plan includes more detailed design specification and construction process definition. Historically, the conceptual phase has the most significant impact on the cost of DB projects (Stillman, 2002). It is the sole responsibility of the client to make sure that the project plan is built on sound business case.

The contractor approval stage is identified as a critical stage for the success of a DB

project and probably a stage where most problems are likely to be encountered. Difficulty of communicating detailed requirements through briefing without the aid of drawings or bill of quantities is a major concern. At this stage, cost estimation is the primary concern of contractors. Contractors need to have confidence in the accuracy of their estimates of the fixed-price lump sum based on client's basic performance requirement. The contractor needs to make a bid based on limited requirement information from the client. Estimation accuracy at this stage is crucial to the contractor's return/loss from the project. Contractors often employ multiple estimation methods rather than relying on any single approach (Crockett, 2001). Since detailed design such as floor drawings has not been drawn up at this stage, it is essential that the estimator is experienced in estimating similar projects. For the clients, effort is concentrated on selecting the contractor with appropriate skill sets, experience and good reputation.

Once the contract has been entered into, the contractor will take the responsibility of obtaining necessary planning, building regulation and any other statutory approval to carry out the design. During this stage, the design process is typically fully integrated with cost estimation to meet budget constraint and client approval for design specification. It is therefore possible to evaluate the constructability and cost impacts of particular designs. As a result, the estimates produced at this stage tend to be more accurate than those produced at the design stage of conventional design/bid/build projects. This ability to more accurately predict costs contributed to the ability of contractors to manage down project costs.

2.3 ORGANIZATIONAL CONTROL THEORY

In this study, organizational control theory is adopted as the theoretical basis for constructing a stage-by-stage estimation framework. This section introduces the organizational control theory. Control is conceptualized in this paper as influences exerted by an organization using various mechanisms that help align the actions of its employees with the interests of the organization (Tannenbaum, 1967). Organizational control theory identifies three types or modes of control that can be directed at achieving the behavior necessary to secure desired performance: behavior control, output control and input control (Snell, 1992). They differ in the ways each influences organizational members' behaviors and performance.

Behavior control seeks to secure a specified type of behavior in the belief that the behavior delivers the right results. Behavior controls are procedures that lay down a sequence of operations that must be followed. Cost estimation methods exemplify this form of control.

Output control specifies the schedule of outputs desired. The assumption is that people, who know what their targets are, adopt appropriate behaviors to achieve them. E.g. specifying expected estimation accuracy is a form of output control. Another

example of output control is to link performance (output) to promotion.

Input control regulates the input into the transformation processes. In the case of cost estimation, input includes historical estimation, design information, experience of the estimators and material price. This may be achieved through mechanisms such as selecting the right people, improving data quality and integrating design with cost estimation. Input control may also be implemented by developing relevant knowledge, skills and values in existing organizational members.

Figure 2 presents Ouchi's control framework (Ouchi, 1979) which subsequently forms the basis for many empirical studies using control theory (Snell, 1992; Kirsch, 1996; Kirsch, 1997; Eisenhardt, 1985; Govindarajan and Fisher, 1990; Henderson and Lee, 1992). In Figure 2, task programmability is defined as the degree to which appropriate behaviors can be specified in advance (Eisenhardt, 1985) and output measurability is defined as the degree to which output can be reliably and accurately measured (Ouchi, 1979). The framework (Ouchi, 1979) shows that when task programmability is high, it is possible to specify the behaviors necessary to achieve a desired result so behavior control is appropriate. When output measurability is high, then output control can be monitored to achieve the desired result. If neither of these conditions applies, then, following Snell (1992), input control is the appropriate control mode to deliver high performance.

Figure 2 Origination control Model (adapted from (Ouchi, 1979))

	Task programmability	
	High	Low
High output measurability	Cell 1 Output and/or Behaviour Control	Cell 3 Output Control
Low output measurability	Cell 2 Behavior Control	Cell 4 Input Control

3. THE FRAMEWORK

Based on the control framework presented in Figure 2, the key input, output and process factors for cost estimation at each project stage are identified for construction projects under the conventional and DB systems respectively. We argue that the levels of task programmability and output measurability change with project stage. Therefore, the locus of controlling estimation task at different stages should be dependent on the level of task programmability and output measurability. Below, we develop a stage-by-stage framework that outlines the appropriate controls for each stage. Then, the key input, output and behavioral factors that could be controlled for estimating task at each project stage are identified.

3.1 PROJECT STAGES AND CONTROL MODES

Under the conventional procurement system, the task programmability and output measurability of cost estimation increase as a project progresses through stages as more information about project design, specification and construction methodology become available. At the conceptual stage, the project scope is not well defined and the design has not yet been undertaken. The only information available for cost estimation is owner requirements and historical project data. Output measurability is likely to be low at this stage because the estimation is based on inaccurate data. The typical level of cost estimation accuracy at this stage is around 30-50% for construction projects (Ashworth and Skitmore, 1982). Estimation at this stage heavily relies upon estimator's experience to make subjective judgment about the magnitudes of key cost factors (Skitmore, 1988) suggesting task programmability is low. Estimating method or process (behavior control) at this stage appears to have limited effect on estimation effectiveness. Therefore, output and behavior control have little impact on the estimation effectiveness at this stage. According to control theory (see Figure 2), control effort should focus on input control.

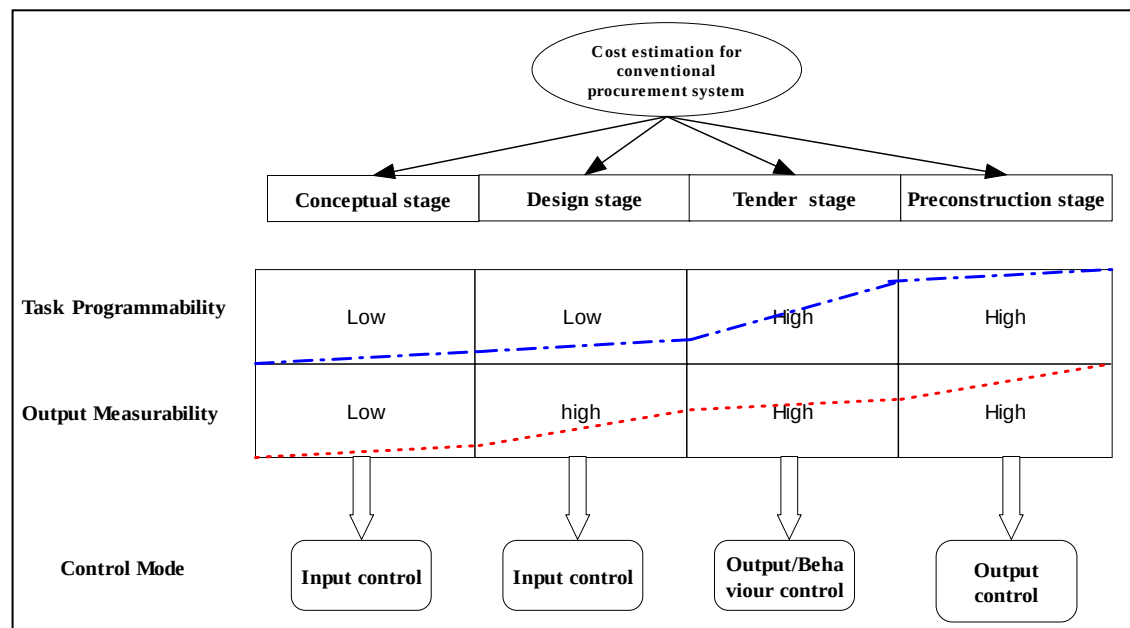
Then at the design stage, a considerable amount of engineering design work has been undertaken, and bills of quantities and materials take-offs have been produced. Output measurability increases as detailed drawings and specification become available to the estimator. Typical estimation accuracy at this stage is around 20% (Morrison, 1984). Since detailed design provides a more objective basis for cost estimation, more elaborate estimation methods and procedures can be used to aid cost estimation--task programmability increases. At this stage, although the reliance on behavior and output control increases, input control is likely to be the dominant control mode because limited improvement in task programmability and output measurability constraints the effect of output and behavior controls. Estimator's experiences still plays an important role in estimating effectiveness.

Next at tender stage, the focus is on producing an estimate that provides the basis for competitive bidding. It is crucial to the contractor that the estimate is accurate in order to make a reasonable return on investment. Output measurability is likely to be increased because the contractor will be able to factor in its construction process cost more accurately. Typical estimation accuracy at this stage is about 10% (Flanagan and Norman, 1983). Task programmability is likely to be improved since more sophisticated estimation methods and processes are justified to be used at this stage. Subjective judgment from human is likely to be minimized at this stage. The locus of control shifts from input control to output and behavior controls.

Finally at the pre-construction stage, the focus shifts to project cost control. Task programmability remains unchanged since estimation methods usually do not change at this stage. Output measurability increases as requirements are crystallized, the construction processes specified and project plan agreed upon. The strong focus at this stage is typically placed on controlling output while behavior control and input control plays enabling roles.

The relationship among control modes, task programmability, output measurability and project stages discussed above are replicated in Figure 3.

Figure 3 Control Model for conventional system cost estimation



The relationships among control modes, task programmability, output measurability and project stages for a DB project is different from that for a conventional design/bid/build project depicted in Figure 3. At each stage of a DB project, there are iterations in design and build. A unique feature of this type of projects is that detailed drawings and specifications are not fully developed upfront. Instead, they are developed as the construction is in progress. It is not unusual that the floor-drawings for the next level are completed the same time when the construction of the level below is completed. The main benefit from this procurement method is the time advantage it may have over other types of procurement methods.

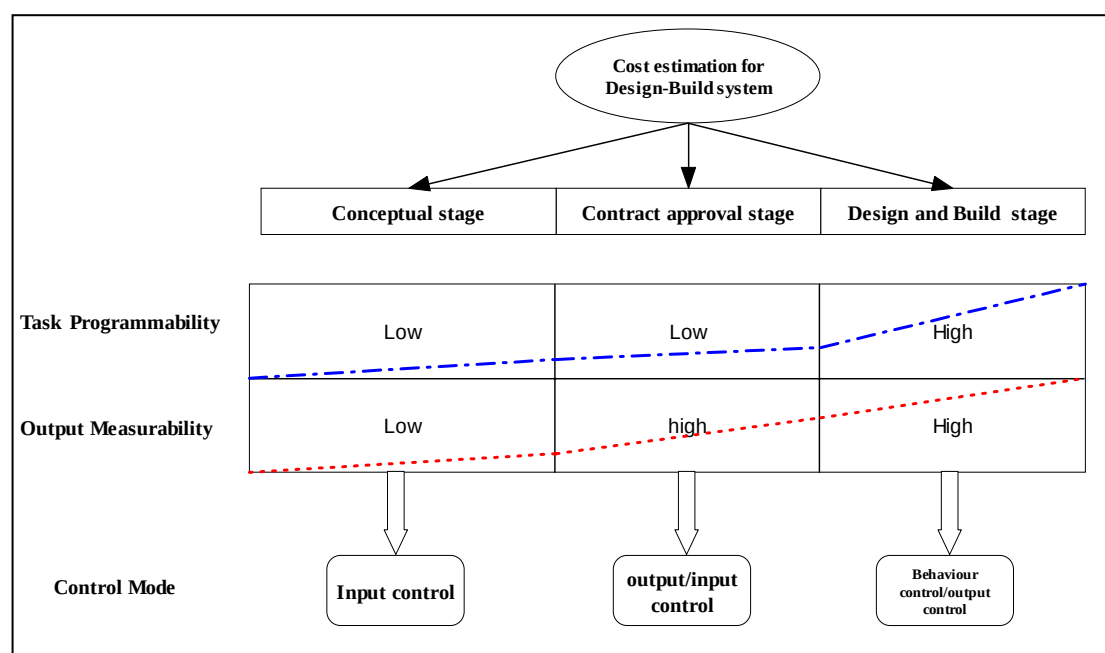
At the conceptual stage of a DB project, the estimator still faces the same difficulties as in the same stage of a conventional design/bid/build project. The dominant control mode at this stage is input control (See Figure 4).

Next at contract approval stage, estimation accuracy becomes the focus of the contractor. Based on cost estimates, the contractor makes a bid for constructing the project (Akintoye, 1994; Molenaar and D.Songer, 1998). Compared with the conceptual stage, output measurability improves as some design details become available. Task programmability is likely to be increased as more elaborate estimating method and processes can be used in this stage thus reducing the solely reliance on expert judgement in the conceptual stage. For conventional design stage cost estimation, the outcome is based on detailed design document. In contrast, for a DB project; the outcome is based on close communication with client about project

requirements (Stillman, 2002). Therefore, Input control still plays a vital role at this stage. The dominant control modes at this stage are likely to be a mix of input and output control with behaviour control plays an enabling role.

Finally at the design and build stage, design specifications are gradually being crystallized, construction processes have been tested and possibly adjusted, and the completed portion of the facility is available for visual inspection. These contribute to the gradual improvements in output measurability. Repeated estimating cycles will lead to improved task programmability levels. Therefore, the dominant control modes here are likely to be output control and behaviour control.

Figure 4 Control Model for DB system cost estimation



3.2 INFLUENCE FACTORS

Having identified the factors influencing cost estimation and the control modes for each of the project stages, we here further group influence factors into two categories, control factors and idiosyncratic factors. Control factors are the factors that can be controlled by estimators to improve the performance of estimation, which are sub-divided into input, output, and behavioural control factors. Idiosyncratic factors are factors outside the control of the estimator that influence cost estimation. This category includes three subcategories, project environment, project nature and contingency factors. The classification scheme is presented in Table 3. Since idiosyncratic factors, which have same impact on the estimation effectiveness regardless of project stage, have been studied by many earlier studies, they will not be discussed here. Their inclusion in Table 3 is for completeness.

Table 3 Influence factors

Control Factors									
FI-Input Control Factor			FB- Behavior Control Factor				FO- Output Control Factor		
Project Information	Project scope definition	FI_1	Estimating Process	Schedule control	FB_1	Expected	accuracy	Level	
	Estimation assumption accuracy	FI_2		Increasing cost planning and control activity	FB_2	FO_1			
	Owners requirements clarity	FI_3		Formal defined estimating work process	FB_3	Review and acceptance of estimate	FO_2		
	Completeness of project Design	FI_4							
Team Experience	Experience in local market	FI_5	Team Alignment	Involvement of resource (Labor, cost) in preparing estimate	FB_4	Benchmarking.....FO_3			
	Experience in similar projects	FI_6		Level of team integration and alignment	FB_5				
	Experience in similar contract type	FI_7		Level of involvement of project manager	FB_6				
Cost Information	Historical data for similar job	FI_8	Estimation Design	Effective communication	FB_7				
	Historical data quality (relative and accurate)	FI_9		Formal structure to categorize and prepare cost estimation	FB_8				
				Estimation methodology	FB_9				
				Standard procedure for updating cost information	FB_10				
Idiosyncratic Factors									
FE- Project Environment Factor			FN- Project Attributes				FC- Contingent Factor		
Market condition index		FE_1	Project complexity		FA_1	Weather		FC_1	
Market competition		FE_2	Size of contract		FA_2	Market price fluctuations		FC_2	
Environment restriction		FE_3	Site constrains		FA_3	Sudden material/equipment			
Equipment/Resource availability		FE_4	Procurement system		FA_4	shortage		FC_3	
Site requirement		FE_5	Contract work type		FA_5	Season		FC_3	
Technology requirement		FE_6	Project type		FA_6				

Mapping the control factors in Table 3 to the models for the conventional projects and DB projects as presented in Figures 3 and 4, respectively, we propose two corresponding models in Figure 5 for controlling influence factors during each project stage.

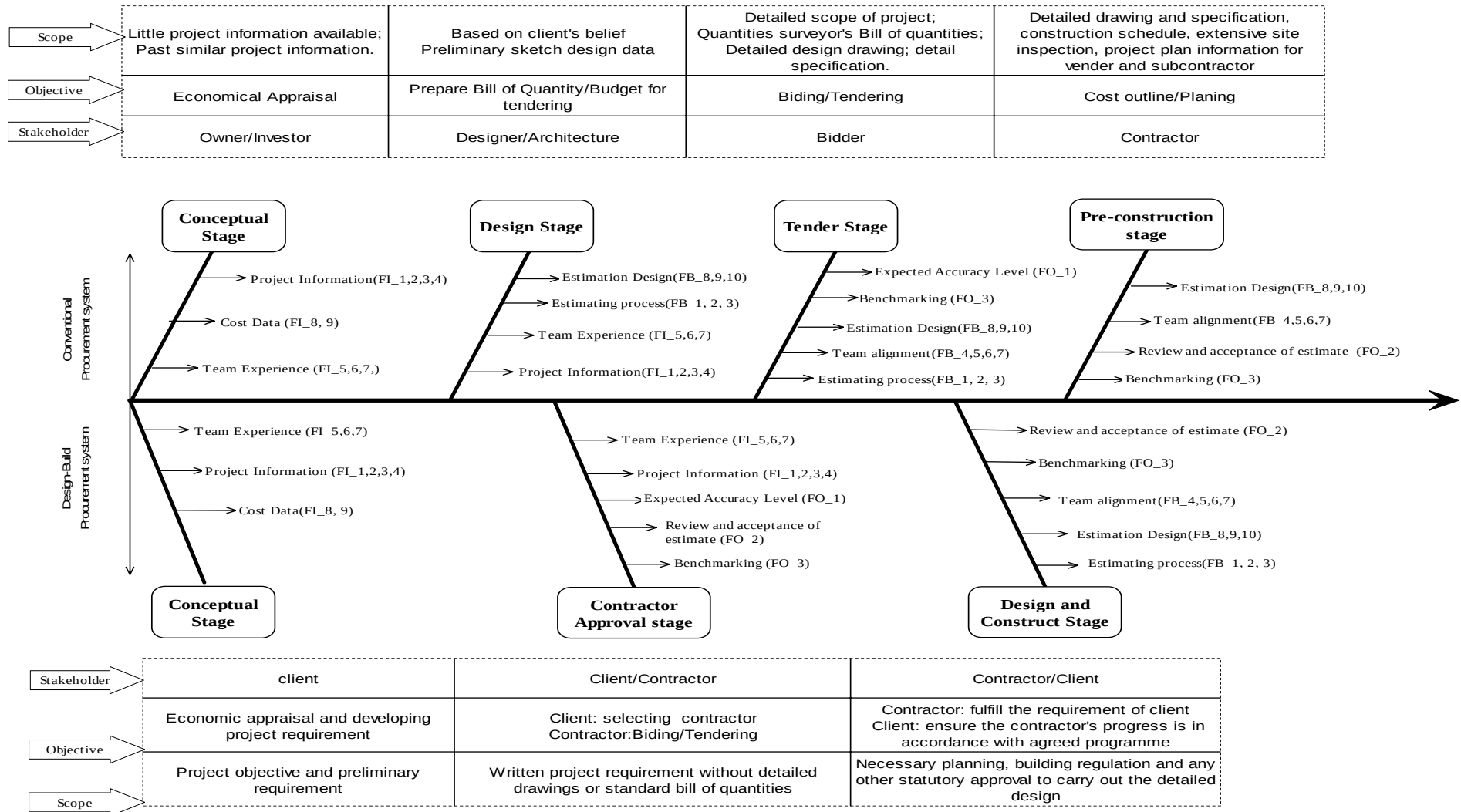
Figure 5 shows that for a conventional project, the emphasis in the conceptual stage should be on input factors such as project information, cost information and team experience. In the design stage, the attention should be shifted to estimation design and estimation process in addition to project information and team experience. Entering the tendering stage, the focus is on expected accuracy level, benchmarking, team alignment in addition to estimation design and estimating process. Finally at the pre-construction stage, the emphasis narrows down to review and acceptance of estimate, estimation design, team alignment and benchmarking.

Similarly, Figure 5 also shows that for a DB project, the emphasis in the conceptual stage is the same as those for the same stage in a conventional project, namely project information, cost information and team experience. Next in the contractor approval stage, since the bidding process is moved earlier than in a conventional approach, the focus on control factors shift to a combination of output and input control factors including project information, team experience, expected accuracy level, review and acceptance of estimate and benchmarking. Finally in the design and construct stage, attention is on output and behavior factors such as estimating design, estimating process, team alignment, review and acceptance of estimate and benchmarking.

4. Conclusion and Discussion

Drawing from organization control theory and cost estimating literature, this paper develops a theoretical framework that identifies the critical factors for effective cost estimation during each of the project phase of a conventional and/or a DB construction project. The underlying logic is that as a cost estimating effort progresses, both task programmability and output measurability improve. As a result, control effort will shift from input-oriented control to a combination of output and behavior control. The validity of this framework needs to be tested in further empirical studies. Eventually, the framework may help construction companies to place their organizational resources on controlling factors that are critical to estimating effectiveness.

Figure 5 Stage-by-Stage Control Factor Framework



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CLIENTS DRIVING INNOVATION

Full Paper

DYNAMIC CAPABILITIES FOR CONSTRUCTION CONTRACTORS

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ABSTRACT

The highly competitive, fragmented and volatile nature of the construction industry has resulted in a number of challenges for construction contractors. Project management capabilities that have evolved in the construction industry over the past few decades, if properly implemented, could effectively address each of these challenges. The project management capabilities identified at project, program, portfolio and enterprise levels include Project Delivery Capability, Benefit Realization Capability, Project Selection & Prioritization Capability, Resource Allocation Capability, Alliance Management Capability and Cross-project Learning Capability. This paper contends that project management capabilities form the core of dynamic capabilities required by construction contractors to effectively compete in this industry. Underpinning dynamic capability is an organizational learning process that continuously strives to improve and adapt its operating routines and processes.

Keywords: Program Management, Construction Contractor, Portfolio Management, Project Management, Dynamic Capability, Project Delivery.

INTRODUCTION

The construction industry is highly competitive, diversified and disaggregated. It requires a unique combination of labour and material inputs, on-site coordination and a large number of specialized trades (Eccles 1981). Work is typically organised into small and often isolated packages that are performed by predominantly small and medium enterprises offering a narrow range of specialist expertise. In Australia, 95% of all businesses in the building and construction industry employ fewer than 5 people while less than 1% has 20 or more employees (Calver & McLaughlin 2003). 75-85% of the value of the industry's production is delivered by subcontractor enterprises (CPSC 1998) and small businesses make up 96% of businesses in the construction industry (LC 1999).

The intense competition, heavy regulations, sensitivity to economical cycles, and fragmented industry structure pose the main challenges to managing construction projects. An organization's capabilities to effectively deal with these challenges could lead to competitive advantage. Construction contractors are typically at the centre of managing complex project deliveries. It is important to understand what constitute their capabilities in effectively dealing with these dynamic challenges.

This paper starts with an analysis of the dynamic challenges facing construction contractors. Literature on project, program and portfolio management, alliance management and project learning are reviewed to identify the core capabilities for successful construction project delivery. We then draw from strategy literature on dynamic capability and contend that the core project management capabilities form the core dynamic capabilities for construction contractors that may lead to competitive advantage.

CHALLENGES FACED BY CONSTRUCTION CONTRACTORS

The construction industry is heavily regulated by a range of legislations, regulations and standards such as the Building Codes of Australia, Australian Standards, Environmental Planning and Assessment act, Occupational Health and Safety Act. Construction contractors need to deliver quality projects within these constraints. For example, the Building Code of Australia and the Australian Standards provide the minimum regulatory requirements for the design and construction of buildings and other structures in Australia and covers matters such as structure, fire resistance, access and egress, fire-fighting equipment, mechanical ventilation, lift installation, and certain aspects of health and amenity. Although it is compulsory to meet the minimum standard requirements, it does not appear to be a major concern for large contractors. Instead, competition seems to be primarily focused on cost (Calver & McLaughlin 2003). Because construction projects are financially susceptible to project delays and the resulting liquidated damages, project delivery time is critical to their success (Walker & Sidwell 1998). Many construction contracts have incentives for on-time or early delivery.

The demand in the construction industry is very sensitive to national economic cycle and the movement of interest rates on economic activity (CPA 2004). Construction activities typically fluctuate widely around its average growth rate (Calver & McLaughlin 2003). The highly competitive, heavily regulated and fragmented nature of the construction industry coupled with the volatility of market conditions subject construction contractors to fluctuating demand levels. As a result, the industry

structure consists of many specialized firms and very lean structures in most large construction contractors. Typically, construction firms have no more than two levels separating top business unit level executives from project managers (Sauer, Liu & Johnston 2001). Moreover, most large contractors specialize in project management while sub-contracting most construction activities. Should an economic downturn occur, it allows them to survive without resorting to substantial organizational restructuring (Eccles 1981).

Typically, projects are acquired through competitive bidding. Since bidding for large projects are time-consuming and resource intensive, it is important that in the process of bidding contractors are able to identify the projects that it has a good chance to acquire and deliver with justifiable level of return. In addition, strategic prioritization and resource utilization are crucial to this process and should be factored in when selecting potential projects as it enables the organization to effectively plan the use of its limited organizational resources. Choosing the wrong projects could result in reduced economic returns or even loss. For example, Kangari (1988) found that 50% of construction business failures recorded in 1986 were due to low profit margins.

Once a project has been acquired, the contractor needs to quickly and effectively put together its resources to carry out the project. Since construction work is typically outsourced (Sullivan 1996), the contractor's capability to manage large number of subcontractors and partners is important to the successful delivery of the project.

Because of intense competition, delivering construction projects according to the conventional iron triangle (time, cost and quality) still remains to be the fundamental capabilities of construction contractors. Most construction contracts have penalties for exceeding the budget, late delivery and substandard quality.

More recently, there is also a shift in the construction clients' preferences for construction solutions. A growing number of clients are now looking for single solutions for complex problems. They prefer contractors to provide a total solution covering pre-construction to post-construction services instead of only project delivery. The former will comprise multiple service providers forming partnerships to supply packages solutions that extend beyond the typical range of construction services supplied by the industry (Calver & McLaughlin 2003; CPSC 1998), while in the latter the client has to incrementally acquire land, organize finances, develop services, build and manage the facilities. The client may prefer the contractor to provide the whole range of pre-construction services (which includes viewing and acquiring of land, organizing finances, developing services and design) and post-construction services (which includes maintaining, operating, sale or lease of project asset) while the client focus their attention on core business issues such as business development and total asset management. These capabilities that are required for construction contractors to deliver a total solution differ from project delivery in that the former address strategic needs (that of providing a total solution that addresses client's problems and realizing strategic benefits from the project assets) while the latter focuses on meeting the well-defined time, cost and quality requirements.

As the competition level increases, many large construction contractors are moving away from the traditional inwardly focused and adversarial method of procurement to an integrated partnering or strategic alliancing approach (Black, Akintoye & Fitzgerald 2000; Bresnen & Marshall 2000; Miozzo & Ivory 2000; Holt, Love & Li 2000) in construction contracting as a way of dealing with the fragmented and

disintegrated nature of the industry (Bresnen & Marshall 2000). The conventional adversarial approach to contracting often results in loss of productivity, increase in costs (Vaaland 2004), poor cooperation, confrontations (Latham 1994; ACTIVE 1996), and mistrust (Hawke 1994; Wong 2004)

For instance, under a traditional approach, subcontractors and suppliers are only brought into the project at a later stage and have a limited role at the design stage, resulting in the lack of the constructability input and maximisation of value engineering. This subsequently disrupts the program timetable and threatens variations due to aborted design work. By establishing trust-based, value-added and collaborative working relationship with the subcontractors, suppliers and other partners, contractors are able to enhance their ability to meet the client's program, quality, flexibility and cost requirements (Black, Akintoye & Fitzgerald 2000) through combining resources and expertise, deploying resources more effectively, better responses to changing market conditions, sharing of risks and the reduction of the learning curve (Bresnen & Marshall 2000; Black, Akintoye & Fitzgerald 2000). Therefore, there is a need to adopt a partnering approach in the industry, especially for large and complex projects. The ability to manage partnering relationship is critical to realize strategic benefits.

Another challenge facing the construction contractors is that of organizational learning. Projects are unique and temporary. Tacit knowledge gained during a project resides in the heads of team members. Once the project is completed, team members are often assigned to different projects and knowledge disappears with them. It is therefore critical for construction contractors to find ways to retain and improve working knowledge, routines and processes (Carrillo *et al.* 2004; Love & Huang 2004).

In summary, the key dynamic challenges facing construction contractors include:

- o Choosing and acquiring the right projects
- o Prioritisation of projects
- o Allocate resources effectively and efficiently to projects
- o Mobilize resources quickly and effectively
- o Deliver projects successfully within constraints
- o Managing alliance to deliver total solutions and realizing strategic benefits
- o Effective cross-project learning

CORE PROJECT MANAGEMENT CAPABILITIES

In this section, we review project management related literature to identify core capabilities that are needed by the construction contractors to deal with the dynamic challenges facing them. Since most work in the construction industry is organized in the form of projects and that the construction industry is the first commercial industry to widely apply project management techniques (Morris 1994), our review starts with project management theory. Subsequently, literature on alliance management and project learning in the context of construction project management are reviewed.

Project management refers to efforts designed to provide a sustained, intensified and integrated management of complex ventures, and to direct and coordinate human and non-human resources into a temporary organization to achieve clear, well-defined and predetermined objectives as well as deliverables of scope, cost, time, quality and participation satisfaction (Wideman 1986; Adams, 1988).

Projects have fixed beginnings and ends and are managed within a set of constraints. The body of knowledge on project management covers a wide range of topics such as procurement, contract management, project planning and control, etc. Project Management Body Of Knowledge (PMBOK) developed by PMI (PMI 2000) represents one of the most comprehensive compilation of knowledge related to project management which has become the de-facto standard for project management practitioners, especially in the construction industry. Our focus here is on identifying the key organizational capabilities that are enabled by project management approach.

Traditionally, the main focus of project management has been on delivering projects within constraints (Morris 1994). The typical project constraints are often referred to as the iron triangle of time, cost and quality. Our contention here is that project management enables an organization to deliver projects within constraints consistently. We call this capability Project Delivery Capability.

More recently, project management theory has been criticized for narrowly emphasizing on satisfying project constraints and not on actively pursuing business benefits. Research has since been extended to program management, project portfolio management and organizational-level management (Morris 1994; Thiry 2002). For instance, PMI's (2003) new organizational project management maturity model, OPM3, has reflected the concept of combining the 'Best Practices' of the three separate domains of project, program and portfolio management.

As opposed to delivering a project to clearly defined targets and constraints, program management focuses on the realization of strategic benefits (Thiry 2002). The expected strategic benefits are often ambiguous and require strategic planning and management efforts to realize the benefits (Remenyi 1998). Typically, a program involves management of a group of inter-related projects and program management frequently extends beyond the traditional project delivery cycle from winning a contract to project handover (Lycett, Rassau & Danson 2004). For example, the governments in UK and Australia are increasingly adopting the privately financed project (PFP) form of delivery for infrastructure projects. In this type of arrangement, the private party is required to arrange financing for the project, planning of the business operation, delivery of the project, operate and maintain the project for a certain period of time. It is up to the private party to make a reasonable return on the program (strategic benefit). The distinct capability enabled by program management is the ability to realize strategic benefits. We call this capability Benefit Realization Capability.

Another critical capability for effective program management is the ability to manage alliance partners. Strategic partnership or alliances refers to "long-term agreements between companies to cooperate to an unusually high degree to achieve separate yet complementary objectives" (CII 1991, p. iv). Such long-term partnerships, if developed and maintained into working relationships, could bestow construction contractors with the capability to mobilise resources efficiently and agilely. Despite the potential benefits, alliances are hard to manage and half of those formed end up in failures (Bleeke & Ernst 1993) suggesting that alliance management capability is a critical capability. Since most programs are large and complex undertakings that typically involve many parties, the ability to effectively manage the collaborations between the parties is critical to program success (Black, Akintoye & Fitzgerald 2000; Bresnen & Marshall 2000). As more and more construction contractors adopt the strategic alliance approach on large and complex projects, there is a compelling need

for Alliance Management Capability. Hence, we contend that these two capabilities inherent in program management enable an organization to deliver solutions, and realize its strategic benefits through the appropriate development and management of its alliances.

Portfolio management was developed in recent years to address the need for project selection and prioritization, and resource allocation among multiple project/programs (Dye & Pennypackers 1999; Artto, Martinsuo & Aalto 2001). In the selection and prioritization process, project objectives are evaluated against corporate objectives, total risk profile and resource commitment with a goal to achieve broader corporate strategies (Dye & Pennypackers 1999; Artto, Martinsuo & Aalto 2001). Once the project/program mix has been decided, and projects prioritized, projects are selected, accelerated, killed or de-prioritised in the resource allocation processes (Artto, Martinsuo & Aalto 2001). The primary purpose of portfolio management is to enable firms to select and acquire the right projects, and prioritize them. We call this capability Project Selection and Prioritization Capability. Without it, projects compete with one another to secure scarce organizational resources. Resources may not be fairly allocated and dissension between projects and its members result in conflicts. Studies have shown that competition between projects is not in the best interests of the organization as a whole (Lord 1993) and that competition creates anxiety that interferes with performance (Moss-Kanter 1989).

After the selection decision has been made, the organization needs to spread its limited resources to the portfolio of projects according to its strategic priorities. It is important to avoid both over-commitment and inadequate utilization of resources. Over-commitment could have disastrous results for the organization (Turner 1999) whereby important projects are starved of critical resources while less important ones compete fiercely for the scarce resources. Similarly, under-utilization of available resources leads to resources being idled away. Portfolio management offers construction contractors a capability known as Resource Allocation Capability. We contend that this capability enables a contractor to allocate its scarce resources appropriately and adequately to the projects in accordance with their strategic priorities. Furthermore, such a capability coupled with strong partnership relations (developed and managed appropriately via Alliance Management Capability), will enable firms to mobilize their resources quickly and effectively. For instance, contractors that have had strong, cooperative and long-term partnership arrangements with their subcontractors would be able to mobilize their resources more quickly, efficiently and effectively as compared with their competitors who do not.

The other important capability in portfolio management is the construction contractors' ability to learn across its projects. Cross-project learning enables an organization to have a bird's-eye-view of all its projects/programs, and for it to be able to systematically assess and review lessons learnt from one project/program and apply it to another, through its organizational routines and processes. This allows valuable information and knowledge that is accumulated to be articulated and codified between projects; thereby preventing knowledge from disappearing with its project members at the end of a project and from being gained in a 'hit and miss' fashion (Frame 1995). This is much more valuable than learning from past projects where knowledge and experience are oftentimes not recorded or not transferred to other projects (Lycett, Rassau & Danson 2004).

Hence, it is pertinent that construction contractors establish, maintain and enhance their learning capability as it is one of the key factors leading to consistently successful projects (Cooke 2002). We call this capability Cross-Project Learning Capability and contend that this capability enables effective cross-project learning to occur.

Table 1 summarizes the PM core capabilities in the construction industry. Alliance Management Capability and Cross-project Learning Capability are categorised under Enterprise-level Management because they can be implemented at all levels although Program Management and Portfolio Management are the most relevant areas.

Table 1 Project Management Capabilities

Relevant Management Theory	Core Capabilities
Project Management	<i>Project Delivery Capability: The ability to deliver projects successfully and consistently within constraints.</i>
Program Management	<i>Benefit Realization Capability: The ability to realize strategic benefits.</i>
Portfolio Management	<i>Project Selection & Prioritization Capability: The ability to identify and acquire 'right' projects/programs.</i>
	<i>Resource Allocation Capability: The ability to dynamically allocate limited resources to projects/programs according to strategic priorities.</i>
Enterprise-level Management	<i>Alliance Management Capability: The ability to develop and manage long-term, co-operative and value-adding partnership relations.</i>
	<i>Cross-project Learning Capability: The ability to learn from previous projects, and utilise accumulated knowledge, experience and expertise in forthcoming projects or/and learn between projects that are running concurrently.</i>

Alliance Management, for instance, is often practiced at the program level where performance risk is typically high, and where full-cooperation and expertise of project partners are required. At the project level, where scope and objectives can be clearly defined and articulated, the approach to managing project partners is still largely based on traditional adversarial contracting approach. In addition, top management is often actively involved in developing and maintaining long-term relationships with value-adding strategic partners. Identifying and developing strategic partnership is a strategic issue that requires the attention of executives at the portfolio and program levels.

Similarly, learning can be achieved during a project or a program through means such as project reviews, prototyping and mentoring. Nevertheless, intervention from top management is needed to ensure effective cross-project learning. For example, enterprise project office is a mechanism widely used to facilitate cross-project learning.

DYNAMIC CAPABILITIES FOR CONSTRUCTION CONTRACTORS

In this section, drawing from literature on dynamic capability, we argue that the core capabilities discussed above form the core dynamic capabilities required to effectively deal with the challenges facing construction contractors. Below, we first review the concept of dynamic capability. Then, the links between dynamic capability, project management capability and the challenges facing construction contractors are discussed.

Dynamic capability is defined as “The firm’s processes that use resources—specifically the processes to integrate, reconfigure, gain and release resources—to match and even create market change” (Eisenhardt & Martin 2000). Zollo & Winter (2002) describe dynamic capability as a learned and stable pattern of collective activity through which an organization systematically generates and modifies its operating routines in pursuit of improved effectiveness. Some authors further posit that dynamic capability arise from the learning mechanisms of organizational routines, knowledge accumulation, articulation and codification which constitute the firms’ systematic methods of modifying routines (Zollo & Winter 2002; Marsh & Stock 2003).

Dynamic capability can be characterized by its reliance on organizational routines and processes (Winter 2003). In other words, dynamic capability is the capability that is derived systematically from routines and processes rather than ad-hoc decision making. For example, improvisation by a senior executive to resolve an unforeseen crisis is not considered dynamic capability.

The pattern of effective dynamic capabilities depends on market dynamism (Eisenhardt & Martin 2000). In a moderately dynamic market like the construction industry, the industry structure as being relatively stable where the key players in the industry are well known, changes are frequent but roughly predictable, and the emphasis of managing projects is planning (Williams 2004). Here, effective dynamic capabilities rely much on existing knowledge typically in the form of routines and business processes (Eisenhardt & Martin 2000). In contrast, in a highly dynamic market such as the IT suppliers market, successful business models are unclear, market players are ambiguous and shifting, changes are difficult to predict, and the dominant management logic is on exploring and experimenting with opportunities (Eisenhardt & Martin 2000). Effective dynamic capabilities in such markets rely heavily on newly generated, situation-specific knowledge and less on existing knowledge (Eisenhardt & Martin 2000).

A necessary attribute of dynamic capability is its continuous learning and improvement efforts in adapting its underlying routines and processes (Zollo & Winter 2002). For instance, a static operating procedure that does not require continuous improvement and adaptation is not dynamic capability. Examples of dynamic capability include product development routines, alliancing routines, exit routines and knowledge management routines (Eisenhardt & Martin 2000).

The core project management capabilities for construction contractors identified in Table 1 are very much process-driven (Sauer, Liu & Johnston 2001), requires tailoring to an organization’s specific circumstances (OGC 2002) and needs continuous improvement efforts (Cooke 2002). PRINCE2 (OGC 2002) is one of the

most widely adopted project management methodology which is heavily process-driven. It covers project, program, portfolio and enterprise level management. Implementing PRINCE2 in any organization requires significant tailoring effort (OGC 2002). The roles and mechanisms for continuous learning across projects are built into the processes (OGC 2002). Similarly, other project management related frameworks such as the capability maturity models (CMM) from Software Engineering Institute (SEI) and LogFrame by USAid, are also process-driven and require tailoring efforts and continuous improvement efforts.

Since projects are unique and their management is process-driven, adapting project management processes to individual projects and changing business environment could be a major source of competitive advantage for construction contractors.

On the business-environment side, the construction industry is heavily regulated where these regulations are subject to frequent changes (LC 1999). The competition is intense in this industry both on project costs and delivery time. The demand of the industry is volatile and depends on macro-economic cycles. As discussed earlier, these competitive forces result in a number of challenges to the construction contractors. To effectively deal with these challenges, a construction contractor needs to improve its ability to identify, acquire and deliver projects, mobilizing and allocating resources, realizing strategic benefits, managing alliance and learning across projects. One of the recommended improvement mechanisms in project methodologies such as PRINCE2 is a dedicated office with responsibilities for process improvement. Project management capabilities identified in Table 1 addresses each of these challenges. Since project management capabilities are process-based, addresses dynamic competitive forces, and the routines as well as processes are subject to continuous improvement efforts, they are the core dynamic capabilities for construction contractors.

It needs to be emphasized that project management efforts at the four different levels form a coherent set of capabilities. The level of capabilities in each area depends on the organization's needs and existing capabilities. For example, an organization may choose to focus on enterprise-level, portfolio and program level capabilities while outsourcing project delivery capability. Nevertheless, all capabilities identified in Table 1 are needed for a construction contractor to succeed in the long-term whether it resides outside the firm or within the firm.

DISCUSSIONS

The purpose of this paper is to outline the core processes and routines that form the core of the dynamic capabilities for construction contractors. Understanding the composition and characteristics of effective dynamic capabilities, construction contractors will be able to develop and deploy effective dynamic capabilities over time.

As suggested by Eisenhardt & Martin (2000), dynamic capabilities are a necessary but not sufficient condition for sustained competitive advantage. At least some of the dynamic capabilities can be imitated by competitors. For example, assigning mentors to project managers and establishing the role of project director for overseeing construction projects are common among leading Australian construction contractors (Sauer, Liu & Johnston 2001). Therefore dynamic capabilities themselves cannot be a source for long-term competitive advantage. Sustained competitive advantage is

likely to lie in the resource configurations which contractors created through applying dynamic capabilities (Eisenhardt & Martin 2000). The implication for construction contractors is that the advantage created by PM capabilities is likely to be short-term and it therefore makes sense to create a series of temporary advantages through reconfiguring resources. For example, strong alliance management capability may enable a contractor to create an advantage in acquiring and delivering complex projects by teaming up with organisations with complementary skills quickly and efficiently. A contractor may choose to focus on developing some PM capabilities and select long-term partner organisations with complementary PM capabilities.

Dynamic capability cannot be assembled through the market Teece (1982; 1986). It requires continuous learning and improvement efforts (Zollo & Winter 2002). It is therefore critical for construction contractors to develop project management routines and processes through persistent process improvement initiatives. Generic project management methodologies that are implemented without tailoring and subsequent improvement efforts to an organization are likely to result in failures.

CONCLUSION

The competitive forces in the construction industry result in 8 specific challenges for construction contractors. Project management capabilities that evolved in the construction industry over the past few decades, if properly implemented, could effectively address each of these challenges. The project management capabilities identified at project, program, portfolio and enterprise levels include Project Delivery Capability, Benefit Realization Capability, Project Selection & Prioritization Capability, Resource Allocation Capability, Alliance Management Capability and Cross-project Learning Capability. This paper contends that project management capabilities form the core of dynamic capabilities required by construction contractors to effectively compete in this industry. Underpinning dynamic capability is an organizational learning process that continuously strives to improve and adapt its operating routines and processes.

The unbundled PM capabilities help construction contractors to choose and focus on developing core capabilities and form alliances with partners with complementary capabilities to effectively compete in the market place. We hope this paper provides useful guidance for future empirical research on the link between dynamic capability and project management, and on the core capabilities for construction contractors.

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INNOVATIVE ASSET MANAGEMENT

Full Paper

RELIABILITY BASED OPTIMAL SOLUTION FOR REHABILITATION OF EXISTING BRIDGE STRUCTURES

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ABSTRACT

Many countries are experiencing problems in management of rehabilitation of aged concrete bridges due to increasing demand on load-carrying capacity combined with fast rate of deterioration and limited budgets for rehabilitation and strengthening of older bridges. The strengthening, rehabilitation or retrofitting of an existing structure can be accomplished using different materials and construction techniques, which often lead to a situation where officials are faced with a decision to select an optimum solution. Decisions are typically made based on a cost basis analysis. However, determination of the cost of each alternative is not straightforward simply because of uncertain nature of the future of most repair schemes and risks involved. Probabilistic time-dependant analyses can be used to evaluate and optimize life-cycle costs associated with each strengthening or rehabilitation alternative. This is often referred to as risk-cost benefit analysis or whole-life costing. By incorporating risk information into the cost benefit analysis, a bridge rehabilitation decision can be made on the basis of comparison of risks against benefits. The optimal strengthening/rehabilitation solution, chosen from multiple options, can then be found by minimizing life cycle costs. This paper describes a methodology for development of a decision support tool that relies on the life cycle cost analysis.

Keywords: Bridges, rehabilitation, strengthening, risks, life cycle cost and probabilistic time dependent analysis.

1 INTRODUCTION

In Australia, over 60% of bridges for local roads are over 50 years old and approximately 55% of highway bridges are over 20 years old (Stewart 2001). Structural deterioration increases with the age of the bridge structure due to corrosion, fatigue, wear and tear and other causes of material deterioration. At the same time, loads, vehicles and legal load limits for bridges have been increasing. When the ageing bridge structures are subjected to these kinds of excessive loads, then the structural capability of it reduces. Therefore keeping bridges in a good operation condition is a continuous challenge faced by transportation agencies. Fast rate of deterioration and the high cost of repair, rehabilitation and replacement of bridge structures have become major issues in road asset management. Even when the resources have been allocated, completing rehabilitation tasks with minimal interruptions to traffic flow and inconvenience to the public has been a major issue in identifying a given method of rehabilitation. This paper presents a decision support methodology developed for selecting the optimal rehabilitation method for a deteriorated bridge using the whole life cost analysis of each potential treatment option.

2 DECISION SUPPORT FRAMEWORK

Almost every organization faces the need to evaluate several program proposals or projects competing for scarce resources. Most of the time, the decision maker is trying to satisfy conflicting objectives or cater for opposing group interests. The challenges faced in developing an integrated decision making framework are both procedural and conceptual. In operational terms, the framework should be easy to be understood and employed.

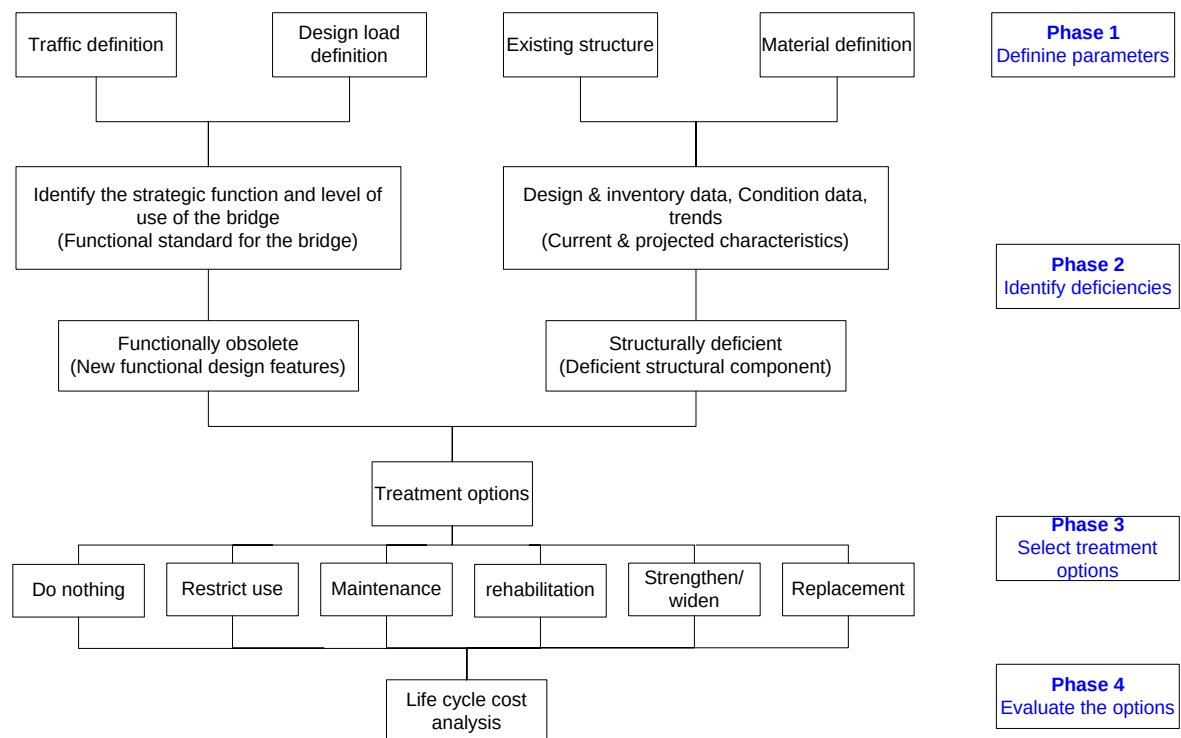


Figure 1: Proposed decision making framework for rehabilitation of bridges

In philosophical terms, the framework should be able to deal with challenging issues, such as uncertainty, time frame, network effects, model changes, while integrating cost and non-cost values into the evaluation. The choice of evaluation techniques depends on the feature of the problem at hand, on the aims of the analysis, and on the underlying information base (Nezamian & Setunge 2004). A decision support framework was developed after identifying the most important factors to be covered (Figure 1). The framework was developed around three key tasks: Identification of deficiencies, establishing available treatment options and then conducting a life cycle cost analysis for each of the options. These tasks were identified through industry consultation

3 IDENTIFICATION OF THE DEFICIENCIES

Identification of the deficiencies of the bridge structure is the first step in addressing the issue of rehabilitation. This requires clear identification of performance requirements of the bridge structure and then evaluating the performance based on existing information of the bridge.

Condition assessment of the structure is the first step in determining the rehabilitation methodology. Clear identification of the performance level needed and deficiencies requires design load definition, definition of traffic, material properties and design documentation of the existing structure. Project specifications and identified strategic function and level of use of the route can be used to establish some of the above information. Evaluation of the structure should commence by conducting a systematic field assessment and recording details of previous repair or rehabilitation task undertaken and accident and traffic overloading data if available. This would be followed by a structural analysis and design calculations complying with the recommendations of the relevant codes and standards. At the end of this phase, the bridge structure can be categorised as “Structurally Deficient” or “Functionally Obsolete”, with a clear understanding of the deficiency. Structures can also be considered “adequate for current use” and simply kept under surveillance.

4 TREATMENT OPTIONS

This is an extremely important component of the framework. Options available to the authorities have been expanded over the years with new developments in materials and structural technology. However, a lack of availability of complete information, which facilitates a fair comparison, makes it difficult for the decision maker to make an informed decision. The broad range of higher-level options identified by the authorities is given below.

- Do nothing
- Restrict use
- Maintain and monitor
- Rehabilitate
- Strengthen/widen
- Replace super-structure
- Replace entire bridge

Recent developments related to materials, methods and techniques for structural strengthening and rehabilitation of the deteriorated bridges have been significant. In addition to well established and proven technologies such as steel plate bonding, external post tensioning, concrete encasing, etc., innovative technologies such as use of fibre reinforced polymer composites are appearing in the market place.

Evaluation of different options requires the asset manager to find a basis for comparison of the options. Evaluation process needs to include uncertainties associated with the innovative methods as opposed to well-understood and established methods.

5 EVALUATION OF THE OPTIONS

Presenting clear and concise information to the decision maker regarding the available options will enable him/her to make a higher level decision from the list identified above. Detailed discussions with the industry revealed that the “cost” is the prime deciding factor in making a decision in selecting a particular strengthening scheme. Authorities prefer to be presented with the whole of life cost of a selected treatment option and incorporate other factors through their own judgement using a broader framework covering social and environmental issues.

6 LIFE CYCLE COST ANALYSIS

Whole of Life cycle cost analysis (WLCCA) is an evaluation method, which uses an economic analysis technique that allows comparison of investment alternatives having different cost streams. WLCCA evaluates each alternative by estimating the costs and timing of the cost over a selected analysis period and converting these costs to economically comparable values considering time-value of money over predicted whole of life cycle. The analysis results can be presented in several different ways, but the most commonly used indicator in road asset management is net present value of the investment option. The net present value of an investment alternative is equal to the sum of all costs and benefits associated with the alternatives discounted to today's values (Darter and Smith 2003).

Making a decision for selection of the rehabilitation method will be done by minimizing the life cycle costs. Such a decision analysis is referred as a whole of life cycle costing, cost-benefit or cost-benefit-risk analysis. Life cycle costs will assess the cost effectiveness of design decisions, quality of construction or inspection, maintenance and repair strategies (Stewart 2001). The costs associated in a rehabilitation project may initially include:

- Initial cost
- Maintenance, monitoring and repair cost
- Costs associated with traffic delays or reduced travel time (Extra user cost)
- Estimated cost of failure

As shown by Austroads (1996), all of these costs are valued in resource cost terms (i.e. Market prices + subsidies - taxes). If monitoring, repair, extra user cost are considered as the maintenance cost then the cash flow for any rehabilitation method can be shown as in Figure 2.

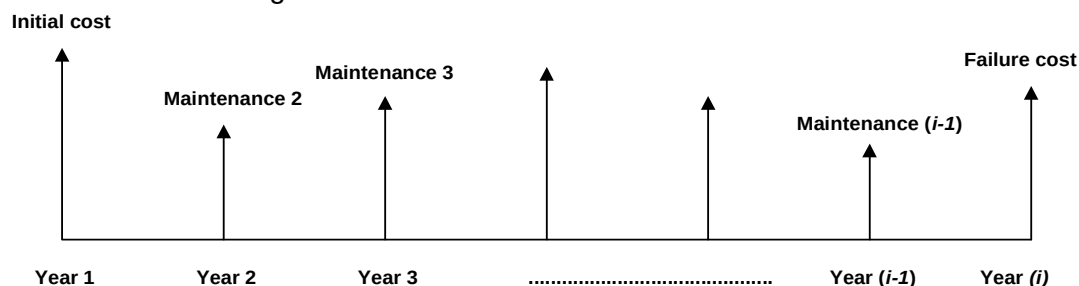


Figure 2: Cash flow for the rehabilitation of bridge

In order to be able to add and compare cash flows, these costs should be made time equivalent. It can be presented in several different ways, but the most commonly used indicator in road asset management is the Net Present Value (NPV). The present value analysis has to be considered together with Internal Rate of Return (IRR).

6.1 STUDY PERIOD

The study period begins with the base date, that is the date to which all cash flows are discounted. Because the cost of each alternative rehabilitation strategy can be compared reasonably only if the benefits gained are the same, the alternatives should be compared over the same operational time period which is known as study period. As a rule of thumb, the analysis period should be long enough to incorporate all or significant component of each alternative's life cycle including one rehabilitation in each alternative. Generally study period or the evaluation period is based on the economic life of major asset in the project. For bridges, the study period is normally longer than the pavements (more than 40 years). Assets with economic life longer than the evaluation period should be given a residual value (resale value).

6.2 DISCOUNT RATE AND INFLATION

The costs are incurred in a project in different times. The interest rate used to discount is a rate that reflects an investor's opportunity cost of money over time. Discount rate is defined as "the rate of interest reflecting the investor's time value of money (Mearig et al. 1999). It is the interest rate that would make an investor feel the same way if he receives a payment now or a large payment at sometime in the future. The LCCA can be performed in constant dollars or current dollars. Constant dollar analyses exclude the rate of general inflation. Current dollar analyses include the rate of general inflation in all costs, discount rates and price escalation rates. Both methods give the identical present value.

It is obvious that the discount rates are normally influenced by the economic, social and political factors. Discount rates used by various countries are different. For example Australia 4%, US 2-3%, UK Department of Transport 8%, Sweden 4% and Finland 6% (Val and Stewart 2003). The discount rates normally are updated and published. Therefore a standard discount rate can be obtained from such published data. For AUSTROADS or national work, the recommended discount rate is 7% (Austroads, 1996). However it is recommended to calculate the NPV based on borrowing rate (bank interest on loans) minus inflation rate.

6.3 FORMULATION OF WHOLE OF LIFE CYCLE COST

Objective function for the optimal bridge rehabilitation can be formulated as the maximization of,

$$W = B_{lifecycle} - C_{lifecycle} \quad \text{Eq. 1}$$

Where $B_{lifecycle}$ is the benefit which can be gained from the existence of the bridge after rehabilitation and $C_{lifecycle}$ is the cost associated with the bridge during its whole life. Since the benefit from the bridge will be the same irrespective of the rehabilitation method considered, it is possible to consider only the cost component. Therefore the new objective function will be the minimization of the total cost during

its whole life cycle subjected to reliability and other constraints. The whole of life cost can be estimated as,

$$C_{lifecycle} = C_{initial} + C_{repair} + C_{user} + C_{failure} \quad \text{Eq. 2}$$

When all these input costs are defined it is straightforward to calculate the present value of them. However all the input costs have a high degree of uncertainty. In order to deal with such uncertainties it is necessary to include the probabilistic behaviour of the input costs.

6.3.1 Modeling of the initial cost

Initial rehabilitation cost will include preliminary design cost, start up, material and labour costs (supervisors, skilled and unskilled). All these costs will incur in the base time of the project.

6.3.2 Modeling of the maintenance (repair) cost

Modelling of the future maintenance cost is complicated. Thoft-Christensen (2000) divided this cost into three categories namely, functional repair cost $C_1(t_{r,i})$, fixed repair cost $C_2(t_{r,i})$, and unit dependent repair cost $C_3(t_{r,i})$, if a repair is to be taken place at the time $t_{r,i}$. r is the discount rate and i is the number of occurrence of repair. Therefore the corresponding maintenance cost may be defined as (Thoft-Christensen 2000),

$$C_{maintenance}(t_{r,i}) = C_1(t_{r,i}) + C_2(t_{r,i}) + C_3(t_{r,i}) \quad \text{Eq. 3}$$

The expected repair cost discounted to the time $t=0$ is the summation of the single repair cost.

$$C_{repair} = \sum_{i=1}^n (1 - P_f(t_{r,i})) C_{maintenance}(t_{r,i}) \frac{1}{(1+r)^{t_{r,i}}} \quad \text{Eq. 4}$$

where n is the number of failures during the life cycle of the bridge and P_f is the updated failure probability at each repair time.

6.3.3 Modeling of user cost

User cost may be of two types, during initial rehabilitation and during the next periodic rehabilitation. User cost may be calculated in terms of costs associated with traffic delay, and in case of using alternate routes wear and tear of user vehicle. The expected user cost may be formulated as,

$$C_{user} = \sum_{i=1}^n C_{user}(t_{r,i}) \frac{1}{(1+r)^{t_{r,i}}} \quad \text{Eq. 5}$$

6.3.4 Modeling of the failure costs

Expected cost of failure (E_c) may be defined as (Stewart et al. 2000),

$$E_c = \sum_{j=1}^M p_{f,j} C_{f,j} \quad \text{Eq. 6}$$

where $p_{f,j}$ is the probability of failure for limit state i and $C_{f,j}$ is the cost associated with occurrence of limit state i . Failure cost will include the damages, injury and loss of life costs.

6.3.5 Life cycle cost

The life cycle cost can be formulated in an excel spreadsheet. All the possible cost components need to be then added to this spreadsheet for each and every rehabilitation option considered. Cash flows can be given as input variables for the respective year and finally the calculation of present value is performed using the built in financial function for NPV.

The probabilistic behaviour (mean and standard deviations) of any of the input cost should be entered to the respective cells of the spreadsheet in terms of the considered distribution function.

In a similar way each cost component can be given as input parameters and include the probabilistic behaviour. Eventually the decision analysis should be subjected to a sensitivity analysis to make sure that the decision is not unreasonably affected due to the uncertainties of the costs associated.

7 SENSITIVITY ANALYSIS

LCCA estimations should be checked for the sensitivity to the uncertain parameters of the analysis such as analysis period, discount rate, traffic growth rates, traffic speeds, capital costs and accident predictions. Austroads (1996) has suggested the variables and ranges for a road project as shown in Table 1.

Table1: Sensitivity tests – variables and ranges (Austroads, 1996)

Variable	Suggested minimum value	Suggested maximum value
Capital cost (final costing)	-10% of estimate	+10 to 20% of estimate
Operating and maintenance cost	-10% of estimate	+10% of estimate
Total traffic volume	-10 to 20% of estimate	+10 to 20% of estimate
Proportion cars in work time	-5 percentage points	+5 percentage points
Average car occupancy	-0.3 from estimate	+0.3 from estimate
Normal traffic growth rate	-2% pa (absolute) of the forecast rate	+2% pa (absolute) of the forecast rate
Traffic generated or diverted by project	-50% of estimate	50% of estimate
Traffic speed changes	-25% of estimated change in speed	+25% of estimated change in speed
Accident changes	-50% of estimated change	+50% of estimated change

@RISK 4.5 for Excel can be used to evaluate the impact of uncertain model parameters on the final result. For assumed values for input costs, the sensitivity of the net present value can be identified using @RISK software. It calculates the NPV for a base input parameter and then for a range of values (base value $\pm$ 10%). Similarly for all the input cost values the sensitivity of the NPV can be determined and compared.

8 RISK RANKING

All the input variables in the LCCA are uncertain for a particular project. For example time to first rehabilitation may occur in a range of years, the bid cost of the materials is not fixed and discount rate can be varying (Darter and Smith, 2003). Therefore the resulting mean LCCA value is always probability based. As a result there is a risk involved in calculating LCCA value for any of the rehabilitation methods. As shown by Darter and Smith, 2003 it is necessary to include a risk analysis or risk ranking in any LCCA calculation.

Risk ranking can be used to compare the relative risks of various alternatives. This can also be used to evaluate effect of the deterioration rates, relative frequency of overload, costs of failure, cost and efficiency of repair strategies etc (Stewart et al. 2000). The traffic delays or the increased travel time depends on the traffic volume. Therefore estimated cost of failure is a more meaningful measure for the risk ranking. Thoft-Christensen (2000) defined the risk for a failure mode as the product of the failure cost and the probability associated with that. Damage cost and costs associated with loss of life and injury can be considered as the cost of failure. Cost of failure must be discounted to a present value. The probability associated with the failure is related to structural reliability. In this approach, the reliabilities for each option of rehabilitation can be ranked from higher risk to lower risk and a decision of selecting the optimal rehabilitation method can be based on both life cycle cost analysis and risk ranking.

It has been proposed by Thoft-Christensen (2000) that for a bridge rehabilitation program a risk based structural optimization is more suitable than reliability based optimization.

9 CONCLUSIONS

Availability of innovative materials and new technologies of structural rehabilitation has opened up opportunities for more efficient structural rehabilitation. However, lack of decision support tools which facilitate comparison of these options has stalled ready application of these technologies in the field. The work reported herein presents a decision-making framework for rehabilitation of reinforced concrete bridge structures. The major components of the framework have been identified as, capacity analysis, identification of treatment options and whole of life cost analysis of each of the options using a reliability-based methodology.

Probabilistic life cycle costing together with the risk ranking offers prominent improvements in selecting the most suitable rehabilitation strategy. This approach is superior to the deterministic approach used in traditional bridge management systems. The basic steps involved in the LCCA estimation are shown in Figure 2.

The mean and standard deviations of the inputs are entered into the spreadsheet for the simulation. Frequency distribution of the predicted LCCAs of each alternative and some LCC statistics (mean, standard deviation, coefficient of variability, range) are illustrated as the outputs. It is then possible to continue the calculations in spreadsheets including a sensitivity analysis using Monte Carlo Simulations with the aid of @RISK 4.5 software Professional version for simulations and risk analysis.

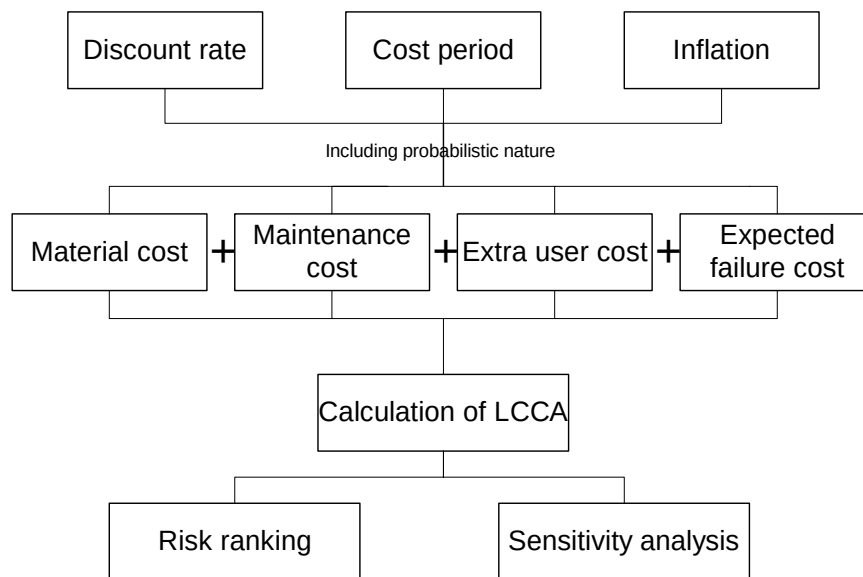


Figure 2: Flow-chart for the LCCA estimation

10 ACKNOWLEDGEMENTS

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STAKEHOLDERS

Full Paper

SOCIAL RESPONSIBILITY, SUSTAINABILITY AND THE TRIPLE BOTTOM LINE: BRINGING BUILDING STAKEHOLDERS BACK IN

The research described in this paper was carried out by the Australian Cooperative Research Centre for Construction Innovation.

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ABSTRACT

This is a brief CRC CI 2001-011-C background paper supporting the project's social and environmental research focus. This paper takes the view that buildings are generally not sustainable – rarely are they built to last or are maintained in a way that reflects the evolving physical and social demands exerted on their sites. To discover why sustainability has not been a high priority in the past, this paper explores the importance of power and the role of the market in the built environment. This bolsters our understanding of the emerging notion of social responsibility in terms of construction, management and usage of buildings, and the increasingly influential role of stakeholders. Essentially what we are starting to see as this new paradigm of social responsibility emerges is power being dispersed. This is establishing beachheads of sustainability, understood as a suite of goals and ideas designed to steer change in a direction that benefits rather than further compromises stakeholders and their built environment both now and in the future.

Identifying and measuring social responsibility and sustainability helps builders and managers accumulate more of it. This is where triple bottom line (TBL) evaluation frameworks based on innovative benchmarking is proving useful. TBL explicitly advance the social and environmental dimensions of an entity, while implicitly asserting that these aspects rank equally with the traditional bottom line – financial profit. If embraced industry-wide and reinforced by regulation, or in Australia's case, by increased self-regulation, a triple bottom line evaluation framework is likely to have profound impacts on the way we construct and use the built environment, empowering stakeholders, and making cities more pleasurable, workable, and durable.

Keywords: buildings; sustainability; social responsibility; triple bottom line; power; stakeholders

INTRODUCTION

Hall and Pfeiffer convincingly argue that the hardware in which we live is increasingly becoming less attuned to our needs, wants and wishes. They observe that:

“[b]uildings in cities are always public because they create the communal environment; they are part of neighbourhoods and the physical basis for social networks. The ‘hardware city’ of infrastructure and buildings is interrelated with the ‘software city’ of habits, traditions, networks, markets and social relationships. Social change therefore cannot but demonstrate itself in a change of the built city.”¹

This conception of the modern city is central to the arguments developed in this paper. Indeed, sustainable cities are all about human compatibility with the built environment. Emerging from the social and environmental sciences, ‘sustainable development’ was one of the most prominent buzzwords of the late 20th C. Many conferences and literally dozens if not hundreds of volumes have been devoted to understanding its meaning and application. I make no attempt to build on this extensive work here, but I would like to use these conceptions in a ‘micro’ approach to urban studies. It is recognised that there has been much valuable work done on developing Sustainability Indicators (SIs) for cities². At a finer scale there has also been significant work done on environmental benchmarking of buildings. However, there has been comparatively less research undertaken on measuring the social dimensions of buildings, notwithstanding the existence of statistically-based social databanks for buildings and the post-occupancy evaluation movement.³ This has stalled the development of sustainable buildings, or at best deflected the importance of social criteria by privileging economic and environmental concerns. As this paper points out at some length, it makes little sense to talk about sustainable cities if we have no agenda in place to build, manage and invest in socially as well as environmentally sustainable buildings.

Achieving sustainable buildings is a complex, multi-faceted task that relies heavily on the ‘institutional’ environment, or more simply, the ‘rules of the game’. A sustainable urban agenda is *instrumental* in its focus, meaning that distinct outcomes are pursued, essentially by means of a strategy that combines agency and ideas. In more material terms, this strategy is defined by process, policy and practice. Furthermore, the aim of making cities more sustainable is dependant on supporting organisational, regulative, and normative structures. A clear understanding of what these structures look like will help us with our discussions in this paper.

Urban sustainability hinges on organisational structure because it implies the existence of constructs that are inseparable from the institutions that make up society, with some types of arrangements promoting enduring economic, social and environmental well-being better than others.⁴ Organisations populate the terrain and provide the actors that give formal rules and informal constraints meaning and expression. And because there are expectations that organisations will exist and

¹ Peter Hall and Ulrich Pfeiffer (2000) *Urban Future 21: A Global Agenda for Twenty-First Century Cities*, (E & FN Spon: London), p.98.

² See for example the ICLEI website, Global Cities 21 @Indicators, at <http://www.iclei.org/cities21/c21ind.htm>

³ See for example the Probe post-occupancy series of 20 individual building studies carried out from 1997-2002 and available at: www.usablebuildings.co.uk

⁴ Paul Greenfield and Tor Hundloe (2000) ‘The Environmental Bottom Line: A Keynote Address to the QELA Conference’, 11-13 May, in conference proceedings, Sustainability – Reality or Fantasy: the triple bottom line, p.5, 2000.

grow, they provide the important 'organic' basis to human interaction and social inclusiveness.

And it is regulation that provides the framework for civil behaviour. Well-policed regulation maintains standards in the built environment where community pressure is insufficient, non-existent or antagonistic. It is often local authorities who are continually introducing new laws and revising old ones to reflect their various agendas. However, it can also emanate from the very top. The European Energy Performance of Buildings Directive (EPD) for instance requires all member states to legislate national laws by the beginning of 2006, with regulations to be tightened at least every five years thereafter. The EPD has been drafted to meet Europe's Kyoto commitment to reduce greenhouse gas emissions, and buildings have been singled out because it is the largest source of CO₂ emissions, accounting for more than 40% of energy consumption. Moreover, the EPD covers new as well as existing buildings, and in part stipulates the compulsory designation and display of an energy label. This is likely to impact the property market in a similar way to the labeling of energy ratings on white goods.⁵

While regulation is disciplinary in nature, relies on surveillance techniques, and is instigated from the top-down, self-regulation more strongly reflects the normative structures of society. These structures are arguably the more important vehicle of sustainability, particularly in Australia's case. The emergence of 'green building' performance codes for instance are a clear indication that self-regulation has an important role to play in the built environment – sustainable development agenda. While green codes target environmental criteria, they also implicitly raise broader questions about social responsibility. This paves the way for the 'socialising' of economics and the modification of corporate behaviour through institutional pressure and the locking in of informal constraints. We will explore these ideas in more detail shortly. For now though, it is important to emphasise that greater self-regulation obliges developers and investors to compete for the 'moral high-ground', and thereby avoid unwanted transaction costs associated with social irresponsibility.

A TRIPLE BOTTOM LINE FOR BUILDINGS

There are few frameworks for implementing and controlling self-regulation in the property and construction industries. Highly regulated building codes abound, but these have a limited reach in terms of social and environmental criteria. They specify acceptable standards and take accessibility and certain safety issues fairly seriously, but there're limited by the universal and minimalist approaches used to draft them. On the other hand, 'triple bottom line' (TBL) reporting is aimed at achieving best practice targets, which to date are seldom extended beyond corporate activities. And just as indicators for sustainable cities have little meaning for individual buildings, measures used in the business context fail to translate to the built environment. This is not to say that broad-brushed attempts have not been made at the neighbourhood and city levels.⁶ Nevertheless, the obvious hesitancy in embracing TBL frameworks

⁵ Robert Cohen and Bill Bordass (2003) 'Property needs sustainability', *Building Services Journal*, Sept. Available at: www.usablebuildings.co.uk

⁶ A lot of this work has been carried out in Europe and particularly the UK. See for example New Economics Foundation (1998) *Communities Count! A step-by-step guide to community sustainability indicators*, (New Economics Foundation: London); and London First Sustainability Unit (2001) *A 'Triple Bottom Line' for London: An index of London's Sustainability*, (London First Sustainability Unit: London).

for buildings highlights the need to develop indicator sets tailored specifically to property.⁷

The major obstacle to selecting for social responsibility in new or existing buildings is the widespread expectation amongst investors of acquiring the highest possible capital growth and returns potential. The problem is that there is an enduring perception that social responsibility comes at a greater cost and a lesser return. However, new evidence suggests that socially responsible properties can yield higher capital growth returns than the competition, especially over the longer term. For instance, research undertaken at the Rocky Mountain Institute and the U.S. Department of Energy shows that green building designs can result in sustained increased returns of 3 to 15%.⁸

There is no denying that social, and particularly environmental measures often come at an added cost. Nevertheless, these can be recovered in commercial buildings once rents are adjusted to account for savings on capital expenses, increased productivity and improved employee recruitment and retention. Usually this will be a delayed recovery in a new building because rents are invariably offered at the market rate. The perceived tenancy benefits of green credentials speed up the leasing period, and rental increases are factored in during the rent review process, once capital expenditure savings and tenancy satisfaction is proven.⁹ This also has implications for the capitalised market value of the property.

Because of its currency as a self-governing strategy for good corporate citizens, many businesses appear to be taking TBL seriously. It is proving to be a flexible tool to build reputations and bolster stocks of goodwill. And it's not all self-indulgent reporting. Research indicates that those that are committed to TBL processes were starting to make changes, even if this was just in the way they thought about their business.¹⁰ However, with the release of an Australian Conservation Foundation corporate report concluding that the country's top 50 companies failed to improve their environmental performance in 2003, the greening of Australian business may have stalled.¹¹

While it is not inconceivable that an adverse TBL report could impact on a firm's stock price, it is highly unlikely that a company will actually cast itself in a bad light by self-reporting negatively about its operations. This underscores the need for objectivity in the TBL process. And this is not a prohibitively expensive thing to do for

⁷ See Philip Kimmet (2003) 'Socially Responsible Public Administration and the CBD', paper presented at the Vision 2020, IPAA conference, Griffith University, Brisbane, November 26, available at http://www.gu.edu.au/school/gbs/ppp/ipaa/ipaa_papers.htm; also Sarah Sayce and Louise Ellison (2003) 'Integrating sustainability into the appraisal of property worth: identifying appropriate indicators of sustainability', paper presented at the ARE and UEA conference, August 21-3, Skye, Scotland.

⁸ Go to <http://www.bsr.org/BSRResources/IssueBriefDetail.cfm?DocumentID=449>

⁹ These assertions were confirmed in personal communication by Chris Kinder of FPD Savills, managing agent of the William Buck Building (120 Edward St.), currently Brisbane's 'greenest' new office high rise. Kinder claims that the building's environmental benefits contributed to a rapid (12 month) lease-up period, and the attraction of high quality tenants. He also claims that energy savings are likely to be factored into the first round of rent reviews. A more detailed discussion of the financial returns of green buildings is undertaken in the paper by Terry Boyd and Philip Kimmet, 'Innovative Benchmarks for Built Asset Performance – The Triple Bottom Line Approach', which is also being presented at this conference. See also Greg Kats et. al. (2003) 'The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force,' unpublished.

¹⁰ C. Deegan, C., M. Rankin and P. Voght (2000) 'Firms' Disclosure Reactions to Major Social Incidents: Australian Evidence', *Accounting Forum*, 2000, 24:1, pp.101-30.

¹¹ ACF (2004) *Corp Rate: An Assessment of Australia's Top 50 Listed Companies in 2003*.

a building. A TBL assessment could actually be added on to a standard property appraisal, which in essence is a single bottom line (economic) assessment.¹² Before we start discussing how it can be done though, let us first position the whole notion of 'socialising' economics in a built, institutionally complex, environment.

A TRIPLE BOTTOM LINE ONTOLOGY

To understand the way things are planned, built and operated, we must first realise the pivotal nature of power and how it is distributed. Or more plainly, we must view the built environment as a political construct, and as an expression of prestige and advantage. As power has a tendency to concentrate, so development left to itself increasingly reflects the 'profit-making' desires of the few who control it. In order to socialise development then and make it responsible to those who are affected by it – the stakeholders – it is necessary to redistribute power.¹³ We conclude from this assertion that "it is the mitigation of power that is central to the idea of being held publicly accountable or socially responsible".¹⁴

Organisations, regulations and norms, the same structures responsible for sustainability, are also the agents of power redistribution. Principal institutions illustrating a supportive organisational structure include a rigorous and independent media, freedom to organise, and a representative, open and transparent system of government. A regulative structure that can facilitate power redistribution depends on an independent judiciary supported by appropriate and effective law enforcement agencies. Finally, the normative environment must promote a respect for the rule of law, and sensitivity to economic, cultural, religious, ethnic, gender and age differences. These structures do not enshrine the principles of social responsibility or sustainability, but they do provide the right conditions for progressive learning, and the development of a pluralist, dynamic, cosmopolitan, well-educated, enabled and participative society.

In advanced democratically governed economies we see much evidence of power leaking to the community. The growth and sophistication of civil society is a clear demonstration of this. Nevertheless, there is more that can be done to siphon power from profit-centred developers and managers for the social responsibility cause. The attempt here to articulate a clear and well thought through analysis of social responsibility in the context of power in the city is as good a place as any to start. What's needed though are institutions that build social responsibility by doing what institutions do best – mobilising "collective action in control, liberation, and expansion of individual action".¹⁵ And the types of institutions that appear to be most effective in doing this are normatively supported, narrowly defined 'carrot and stick' rules disseminated and administrated by industry-backed bodies working within well-defined frameworks. Such industry generated guidelines, which are increasingly being developed by organisations ranging from stock exchanges to many types of

¹² See Philip Kimmert and Terry Boyd (2004) 'An Institutional Understanding of Triple Bottom Line Evaluations and the use of Social and Environmental Metrics', paper presented at the PRRES conference, Bangkok, January 25-8.

¹³ A.G. Papandreu (1972) *Paternalistic Capitalism*, (The University of Minnesota Press: Minnesota), cited in Frank Stilwell (1974) *Australian Urban and Regional Development*, (Australian and New Zealand Book Co: Brookvale, NSW), p.194.

¹⁴ P. Kimmert (2003) 'Socially Responsible Commercial Property Entities and the Allocation of Cultural Space', paper presented at paper presented at the International Association for the Study of Common Property 2nd Pacific Regional Meeting, Brisbane, September 7-9, p.2. To be posted at <http://www.iascp.org>

¹⁵ John R. Commons (1959) *Institutional Economics: Its Place in Political Economy*, University of Wisconsin Press: Madison, p.5.

professional guilds and councils, has the potential to significantly reform thinking about the way buildings are conceived, built and used.

Assuming that social planning is an outcome of power redistribution, and that this has traditionally been the vestige of the state, how then are we to understand the apparent emergence of corporations as exemplars of the 'social conscience'? According to Rhodes what we are seeing is the "hollowing out of the state", with corporations taking over many of the roles of government.¹⁶ In practice, this equates to the maintenance of state structure, while civil society increasingly takes on the activities traditionally carried out by the state.¹⁷ And this is fuelling the 'competition state', as 'distributive states' are losing their autonomous policy-making capacity.¹⁸

What we appear to be seeing then in the modern industrial complex is the increasing domination of corporate-sponsored utilitarianism within a context of robust civil society. This perspective casts doubt on ideas that corporations are instigating the move to prioritise people over profits, and points out that the reach of the community is invading the corporate arena in ways that the state is no longer able to do. It holds to Adam Smith's 'self-interested' precepts in the suggestion that the corporate world is proselytising the existence of more than one – financial – bottom line, because it is in the best interests of business to do so. And it is in the corporate interest because the market, which is the centre of its universe, is firmly situated within the domain of civil society. So from this view, TBL is very much a market construct, and any attempt to understand the contemporary market in advanced Western economies should therefore include a TBL component.

Having established the need for TBL, we can now try to single out the factors shaping what the framework looks like with a view to tailoring a package specifically for the built environment. If TBL is geared toward the market as I have suggested, then we can assume that the market determines the form that it takes. However, the market doesn't do this directly, but through its emerging institutional agents. Historically, government articulated the rules governing corporate behaviour, but with the growth of institutions, industry representative bodies have increasingly taken on that role. This self-censorship is punctuated by talk about the need for good corporate governance, up-to-date social policy, and environmental sensitivity. Such rules, which in essence embody institutions, are being mutually reinforced by community expectation and expressed by an increasing number of stakeholders. So in fact what we are seeing along with the proliferation of property institutions is an increasing recognition of stakeholders who are actively seeking to reduce impacts on their own interests. Acting on stakeholder input is in this sense the essence of social responsibility demonstrated in the built environment. And a TBL framework for built assets driven by property institutions is arguably providing a way forward for systematically building social responsibility in the broader community.

CONCLUSION

This paper has not set out to discuss what is and isn't sustainable in the built environment, nor has it attempted to blueprint a method for measuring sustainability. What it has done instead is explored the increasing interest in achieving sustainability in buildings, and tracked the changes that have taken place that has

¹⁶ R.A.W. Rhodes (1994) 'The hollowing-out of the state: the changing nature of public service in Britain', *Political Quarterly* 65, No.2, pp.138-51.

¹⁷ Ibid.

¹⁸ Philip G. Cerny (1990) 'Globalization and other stories: the search for a new paradigm for international relations', *International Journal* 51, No.4, p.635. See also Cerny (1990) *The Changing Architecture of Politics: Structure, Agency and the Future of the State* (London: Sage), chap. 8.

brought us to this point. The market traditionally has functioned as a profit-maximising mechanism, so mapping a possible transformation to a multiple objective property exchange system is arguably a worthwhile thing to do. While it's clearly early days, and it's possible that this transition may begin to stall or even reverse, investors and assessors should heed the message that there are new demands being exerted on property in terms of social responsibility performance expectations. And it appears inevitable that these essentially social and environmental demands will increasingly influence the financial aspects of owning and operating buildings.

Understanding who is pushing the property sustainability agenda and why, and the broader implications for appraisals, is essential background to benchmark development discussed elsewhere. Such benchmarks can encourage best practice performance, leading to buildings becoming more socially and environmentally responsible. In the UK and elsewhere, these positive changes in the built environment are being reinforced by regulation. In Australia, the agenda appears to be driven by the property industry's own market-sensitive institutions. Either way, the triple bottom line approach to measuring buildings is likely to have a profound impact on the way we construct and manage the built environment, bringing stakeholders back in to built environment thinking.

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VISUALISATION AND INFORMATION

Full Paper

MAPPING PLANNERS' INFORMATION-VISUALISATION REQUIREMENTS FOR 4D CAD DEVELOPMENTS

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ABSTRACT

This paper reports investigations into the needs and requirements of information visualisation for designers and building planners. The study firstly discusses current CAD visualisation approaches for planning. Current user preferences are established and measured from interviews with eleven construction professionals including planners, designers and contract managers. The resulting model predicts planners' requirements for information visualisation. The underpinning research method is that of Ethnographic research. The tools used allow qualitative attributes of data-display formats to be established. Interview transcriptions were coded and structured in grids containing 'hierarchy trees' and cluster 'diagrams' to identify relationships between participants and the topics of discussion. Planners' specific priorities and requirements for future software development are presented as principal components. The paper concludes with recommendations on two areas being firstly, directions for further developments in visualisation and secondly, implementation and consolidation of new planning tools.

Keywords: 4CAD, planning workbench, decision-making,

1. INTRODUCTION

This CRC Construction Innovation (CRC CI) “Contract Planning Workbench” project, on which this paper is based, is in Program C (Delivery and Management of Built Assets) of CRC CI. The main aim of the project is to demonstrate the feasibility of deriving draft construction schedules from IFC data generated from 3D CAD models. The project also investigates methodologies for automatically linking construction schedules with 3D CAD models to allow users to visualise and simulate construction schedules.

The project is a collaborative effort between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Manufacturing and Infrastructure Technology and the School of Architecture and Built Environment at the University of Newcastle (UN), together with two industry partners. CSIRO's contribution focuses on software development whereas UN's is that of providing underpinning knowledge, as well as data capture and analysis.

The first industry partner, [Company x](#), is an Australian design consultant, founded over 100 years ago. This organisation has grown into an international design practice with 12 offices worldwide and over 300 staff. The company specialises in the design of facilities for health, education, transport, retail, residential, hospitality, sport and leisure, defence and commercial clients in the private and public sectors.

The second industry partner, [Company y](#), is an international construction contractor founded over 50 years ago. It is a diversified contractor and a provider of operations and maintenance services to the rail, telecommunications, building and heavy engineering sectors.

This paper investigates the use and implementation of 4D CAD software and the working practices of our industry partners. 4D CAD refers to the dimension of ‘time’ added to more traditional bi- (2D) and tri-dimensional (3D) building and construction representation techniques. The paper adopts a qualitative research approach and provides insights into the views of individual professionals from the consulting and contracting sectors. Results identify current needs and expectations for visual aspects of planning.

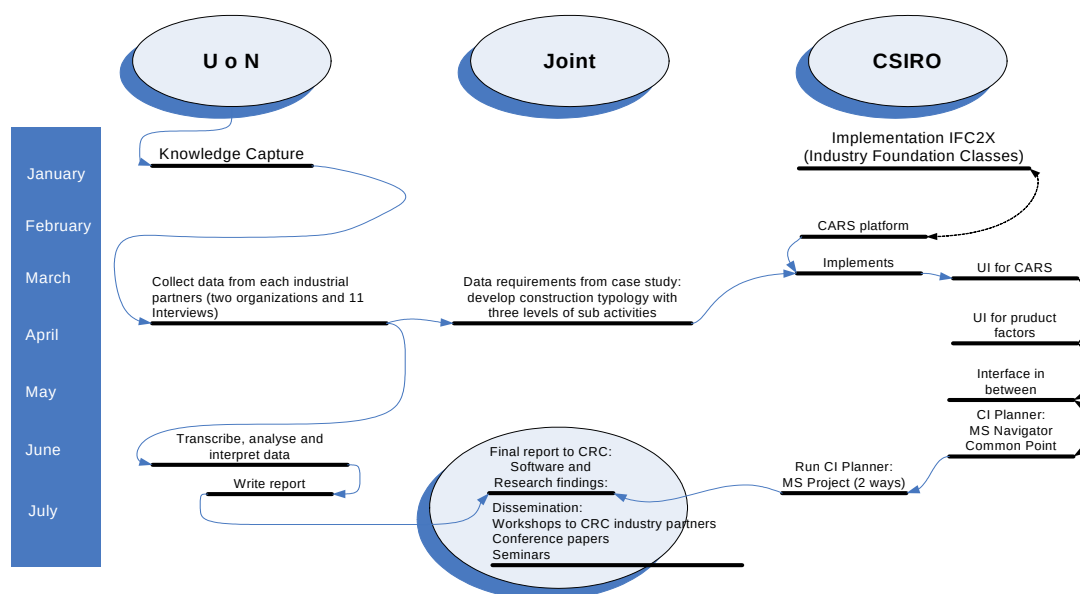


Figure 1 R&D workflow: construction planning workbench (CPW)

Figure 1 illustrates workflow and collaboration between the two research institutions. This paper focuses on UN activities and reports our findings. A description of the work of CSIRO is provided elsewhere in these conference proceedings. This paper reviews and investigates current 4D applications in the construction industry. It takes a pragmatic approach and identifies key factors which contribute to the commercial success of 4D systems in the Architecture, Engineering and Construction industries (AEC).

2. VISUALISING THE TIME DIMENSION

Planning is defined by Uher (2004 p.9) as *“a disciplined effort to produce fundamental decisions and actions that shape and guide what an organisation is, what it does, and why it does it”*. This definition includes organisations with a limited time span, such as project-based organisations.

4D visualization techniques allow users to observe construction sequences in 3D environments. The logic of these sequences is based on conventional construction programming techniques such as Gantt charts and critical path analysis. The AEC industry is expected to derive real benefit from visualizing construction processes in a timeline (Rodgers, 2002 and Issa et al. 2003). Planning occurs at all stages of the design and construction process but emphases differ from stage to stage. At the highest level 'strategic planning' determines an overall project strategy. In later stages, 'operational' and 'coordinative' planning activities occur.

Hassan (1996) found that the application of such tools improved the management of processes on confined construction sites and facilitated precise co-ordination of activities. These results provide a strong incentive to use such systems.

- Schedule creation: 4D models help visualize schedule constraints and opportunities for schedule improvements through re-sequencing of activities or reallocation of workspace.
- Schedule analysis: 4D models help analyse schedules and visualize conflicts that are not apparent in Gantt charts and CPM diagrams.
- Communication: Many participants join projects midstream, and it is critical to induct new participants quickly. 4D models help facilitate such activities.
- Team building: A shared, visual model, capable of externalizing and sharing project issues is believed to be a valuable team-building tool.

In using 4D modelling for design Wong, (1997), and Schwegler, (1999) found that the technologies:

- Increase and improve information available for early project decision-making through pre-visualization or “3D sketching”
- Plan site and space use better
- Improve design quality
- Speed up evaluation of design
- Reduce time needed to model alternatives
- Improve co-ordination between design disciplines
- Share real-time work around the world

- Reduce design production work as fewer construction documents are needed

Designers can control the generation of information and this allows them to reap these benefits. According to (Schwegler, 1999) other benefits may accrue, such as reduced re-work, more productive field crews, and less wasted materials. In essence, these systems benefit all areas that require co-ordination, team-building and communication across current organizational and project phase boundaries.

Regarding added benefits, Fischer (2000) argued that 3D CAD should be a preferred way to document a design rather than an extra task to complete at a client's request. Several design / build firms reported that they were able to eliminate traditional 2D construction documents because these were produced directly from 3D models.

According to (Haymaker, 2001) other benefits of 4D CAD include:

- Planning to shorten construction period
- Improved evaluation of schedules
- Improved constructability and site constraints
- Avoidance of interferences on site
- Increased site safety
- Shortening site layout / surveying time
- Improved site layout accuracy
- Improved learning and feedback from project to project
- Improved effectiveness of communication.

Heesom et. al. (2004) found that 4D CAD models have proven to be particularly helpful in projects that involve many stakeholders, in projects undergoing renovation during operation such as hospitals, and in projects with tight, urban site conditions.

Schwegler et.al. (1999) discussed the advantages of 4D modelling for design and construction and concluded that, by explicitly modelling the relationships between design, cost and schedule information, designers, planners and managers could automatically disseminate design and planning changes, whilst ensuring that a project's design, cost estimate, and construction schedule remained aligned.

Tarandi (2003) noted some advantages of 4D models produced by object oriented databases (e.g. Industry Foundation Classes). These included data originating from CAD models, such as bill of quantities, spaces, time and costs. These observations highlight data constructors may wish to exchange, in addition to drawings and 3D models. Tarandi concludes that exchanges are needed, not only between applications of the same type, e.g. CAD to CAD, but also between heterogeneous applications like CAD and cost estimation. Some examples of these desirable exchanges are (Tarandi, 2003):

- Building elements between two different CAD systems in one project
- Building elements from a CAD system to an analysis tool e.g. for structural analysis
- Bills of quantities from a CAD system to a cost estimation application
- Products / articles from catalogues / databases into CAD systems.

The following section introduces and discusses various commercial CAD and modeling products, emphasising visualization of timelines.

Haymaker (2000) concluded that the main contribution of using a 4D prototype tool included assistance in co-ordinating the activities of subcontractors, studying the construction of design, and verifying the executability of construction schedules.

Yerrapathruni (2003) reported case studies that use virtual immersive environments for design and programming various industrial facilities. For example, Cave™ (Automatic Virtual Environment) is a projection room with advanced visualization that combines high-resolution, stereoscopic projection and 3-D computer graphics to create the illusion of a complete sense of presence in a virtual environment for multiple users.

2.1 MIXED REALITY

Other areas of design and visualization now include the representation of objects in real space (Dias 2003; Salles, 2003). This means that elements of virtual environments are brought to real settings such as during face-to-face meetings. Dias (2003) reported current scientific developments in this field and argued that the breakthrough presented by **augmented representations** is *“the ability to interact with other people as visualising the model at the centre of the conversation”*.

Mixed Reality (MR) is formally defined by Milgram et al. (1994, 1999) as a special class of Virtual Reality (VR) related technologies for creating environments where real world and virtual world objects are presented together in a single display.

An example of a current project using mixed reality technologies is ARTHUR™ (Romell 2001). ARTHUR is an acronym for “augmented round table for architecture and urban planning”. The aim of this project is to bring elements of VR to traditional ways of practicing design and architecture. In addition, real-life, industrial experiments are currently being undertaken by well known practices such as Foster and Partners Architects (Foster and Partners, 2004; and Linie 4 Architekten, 2004).

Such technologies provide cohesive team-building opportunities as they facilitate interaction between participants during the briefing and programming stage. They are currently seen as a significant breakthrough in promoting collaboration and teambuilding (Wythe, 2004). According Dias-Salles (2003) these human-computer interfaces provide new and exciting opportunities to improve the way construction projects are planned, constructed and concluded. Although technology-related limitations have prevented these MR systems from maturing beyond the prototype stage, rapid technological improvements and capabilities are likely to make these feasible (Dias, M.J.S., et.al., 2003).



Figure 2 Mixed Reality Systems

Integrating MR with time enables different specialised integration. Heesom (2004) found that a valuable contribution of the 4D modelling process is that the process makes it very clear where complete scope and schedule information exists and where

additional thinking is needed. Such systems provide highly collaborative multi-user environments and users are linked to mobile users by means of wireless networking (Hessom, 2004). The latter are equipped with electronic agendas and wearable systems. Mixed Reality systems provide a new, highly innovative medium for design and planning.

3. FIELD STUDY: MAPPING PLANERS' INFORMATION VISUALIZATION REQUIREMENTS

This section describes investigations to elicit the views of experienced practitioners about their needs and expectations in reading and interpreting planning data. The study adopted a qualitative and consultative approach, using semi-structured interviews with 11 key design and construction professionals. These individuals held different roles within their organisations, and had different levels of experience. The two participating companies from which interviewees were recruited have been described in Section 1.

3.1 QUALITATIVE DATA ANALYSIS

Research approach and method

The interview methodology and procedures reported here were approved by the University of Newcastle, Human Research Ethics Committee (Approval No. H-767-0204).

The study assessed participants' responses to concepts of 4D CAD and information display and representation. Fieldwork was undertaken with planning professionals from partner organizations, and results were documented and compared across individuals and organisations. The approach underpinning the study is that of Qualitative Data Analysis (QDA) (Seidel, J., 1998).

QDA provides insights into theoretical and applied studies of knowledge, perception and cognition (Denicolo and Pope, 2001). Attitudes can be discerned in qualitative studies and these can be measured using a variety of methods. The approaches adopted for this study, called Ethnography (Seidel, 1998) and Repertory Grid analysis (Kelly, 1955; Stewart, 1980), were used to structure and synthesise data for all interviews.

The interview analysis software used includes: Ethnograph® (2000) and GridSuite® (Fromm, 2003) and Adobe Acrobat Professional™ (2004). These packages assisted content analysis and interpretation. They provide useful facilities for interpretative studies, including data coding, structuring and sorting.

Figure 3 Model for interview analysis (Seidel, 1998) describes the *iterative* process of data analysis and interpretation adopted. The first step involved importing and numbering files, followed by coding, searching for segments, and finally identifying new aspects before repeating the process again. The model also shows the software used during the various investigative steps. Aspects of the analytical process and the use of content analysis software follow.

Ethnograph® was used for content analysis and to code text files. Once interviews were transcribed, various emergent themes were identified. Figure 4, which shows some of these themes, is the result of iterative topics of discussion across participants (and records common issues that were noted by all interviewees).

The initial text, coded in Ethnograph, was then imported into Adobe Acrobat Professional™ for *reiterative* cluster identification. The impact of this was that themes were searched for and reviewed using different but similar software. This added *rigour* to the search for segments and assisted in identifying unique aspects. Some advantages of this dual software approach include:

- They are user friendly - especially in the coding of text segments and procedures
- They facilitate the assignment of author, participant, theme and topic
- They provide text highlighter, symbol and colour coding facilities
- They contain search facilities (by key words or key segments, as hypertext relationships)
- They contain facilities to sort codes in a number of ways (such as by theme, author, date, participant, colour and so forth)
- They are able to export relational summaries and reports

At the discovery stage (see Figure 3), cluster themes were identified and derived for the text samples transcribed. Nodes and keywords were then arranged and sorted in clusters and relational tables. Tables in this study were created using GridSuite© (Fromm, 2004). This software assists in summarising and presenting qualitative data. This is made possible by assigning all key themes and words across all respondents. It is then possible to generate a *repertory grid* for each participant. After individual coding all repertory grids were merged, creating a single relational grid of all interviews. The repertory grid thus presents an overview of entire interviews, and includes all participants and their themes. These grids were then scrutinised and interpreted.

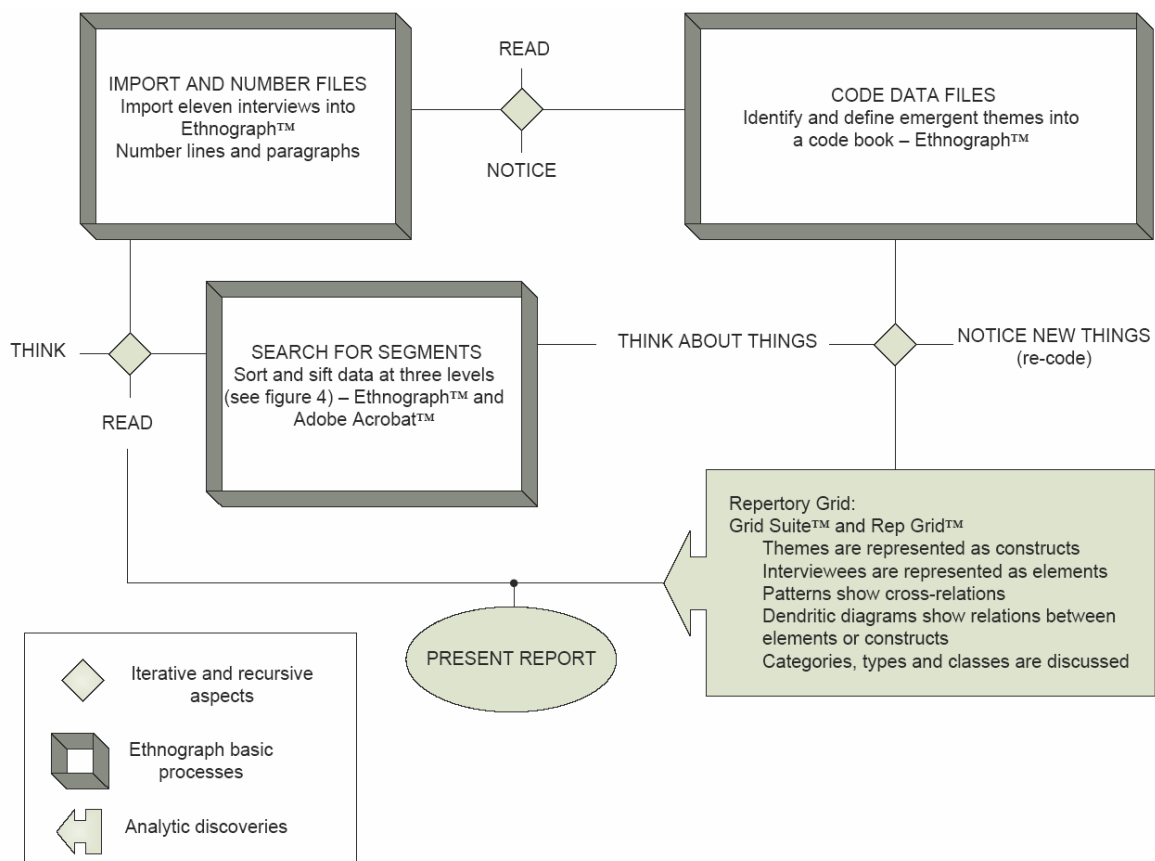


Figure 3 Model for interview analysis (Seidel, 1998)

Interview structure

Interviews were structured in the following six main sections:

- General questions (e.g. participants' position and profession)
- Background information (e.g. experience)
- Case study information
- Programming specific questions
- Information visualization (e.g. data display formats)
- Strategies for Company IT development

Interviews were recorded using digital mini-disks and transcribed in MS Word™. Speech segments were identified and tracks marked to facilitate transcription. Once transcriptions were saved, access to data was restricted to the chief and co-investigators. Recordings were then destroyed and transcripts rendered anonymous.

Transcribed data were imported into Ethnograph™ (Siedel,1998) to facilitate content analysis. A data file containing relational information from the interviews (e.g. common keywords and similar concepts) was named 'the code book' (see Figure 4). The code book also summarises segments identified from the initial interview schedule (level 2 in Figure 4) and key words were then assigned to textual segments (level 3 in Figure 4). Once all transcriptions were coded, comparative sorting occurred. It was then possible to identify a series of "common underlying" themes.

In the context of this study, "themes" represent issues of concern voiced by the interviewees. The activities that identified these themes are shown in are Figure 4. Developing a code book and searching for segments is an iterative process and for this study the first level of the code book was structured as the original interview schedule. An initial search identified relationships between the full interview transcript and the interview schedule (shown at level one). This activity was important because questions were not answered in the same order as the interview schedule. Level 2 refers to the themes identified as main (or cluster) themes. Cluster themes represent key areas of concern as viewed by the interviewees and contain twelve themes and six clusters. Level 3 identifies differing attributes that relate to individual views. It aims to provide a framework to compare and contrast interviewees and their views.

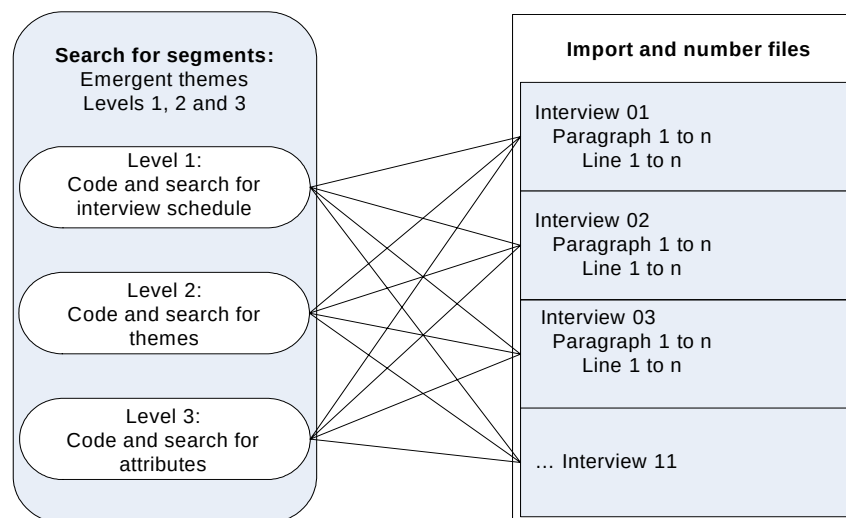


Figure 4 Code book and search for themes

In structuring interview data, all themes were derived from records of discussions. As part of content interpretation, opposites (or *bipolar*) attributes were assigned to participants' responses. These opposites relate to one side of the pole rather than the other.

Content analysis

The initial common themes in the interview data were synthesised into six main 'clusters'. They were then coded and highlighted to assist content analysis. Emergent themes at level two were summarised in *six clusters*, categorised as: *Personal*, *Case study Visualisation*, *Innovation*, *Barriers* and *Benefits*.

All transcribed interviews were coded in Adobe Acrobat Professional™ (2004). Codes were then assigned colours, and colours were also allocated to individual interviewees, researcher's comments and data. Content in the overall interview text refers to any of the six cluster themes which were identified and underlined, as shown in Figure 5.

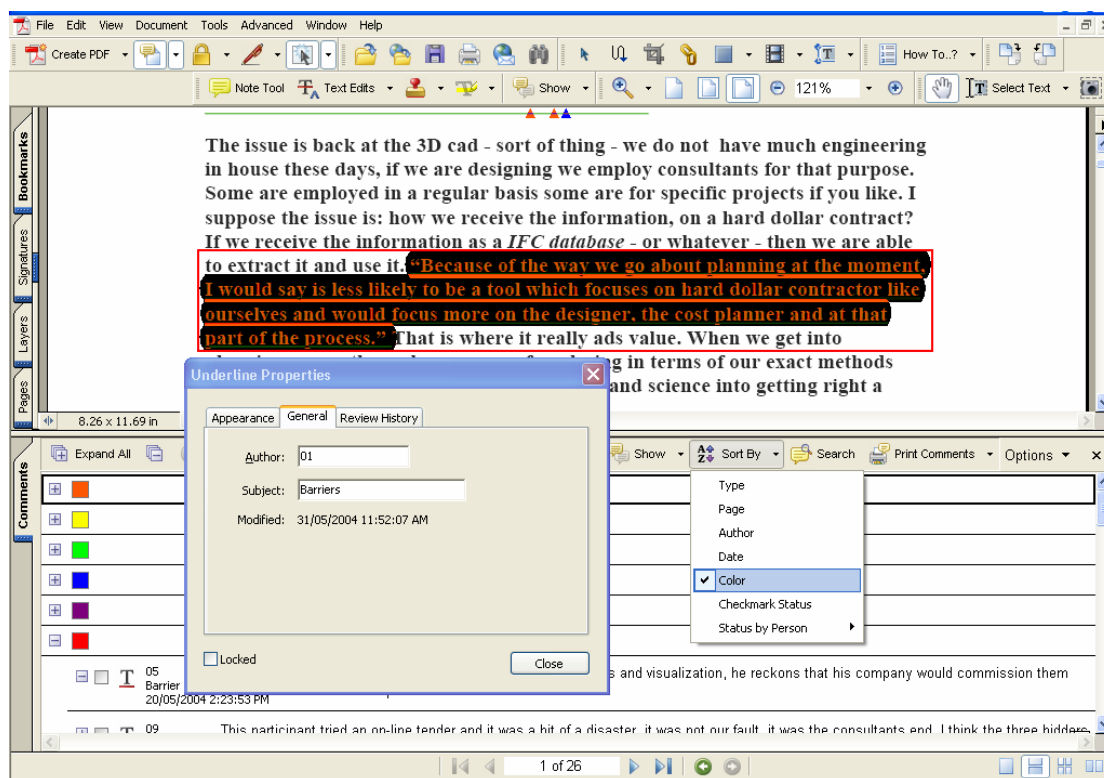


Figure 5 Coding and searching for segments

The interview schedule was structured as follows:

- Background information
- Case study information
- Programming specific questions
- Information visualization
- Data display formats
- Strategies of Company IT development

Comments		
Expand All	Next	Previous
Reply	Set Status	Checkmark
Show	Sort By	Search
Print Comments	Options	
08 Visual 27/05/2004 10:31:03 AM	"We do presentations, but I do not get involved. Most are spread sheets, perhaps cash flow charts to show expenditure across the project. We do lots of diagrams."	
10 Visual 31/05/2004 1:41:30 PM	"What estimators do is not good to me as a planner. I might need each level divided into four functional areas and having a total is of no use to me. If I got four levels, then I got 16 different areas and I need the quantity broken into that data."	
10 Visual 31/05/2004 10:59:11 AM	"Our Gantt charts would include some little diagrams of design within the building or designs within slabs or reports, chart which indicates traffic management of the process, and area of unloading equipment within the project, access to public road systems, for example trucks, side entrance in relation to public roads as we might need to divert when we have to build over something but also indicate where our site offices, our establishment is going to be located."	
10 Visual 27/05/2004 11:51:48 AM	"Planners make the decision that is supported on figures and finance but some other times on improved methods and techniques. Here is when we have to convince the client"	
04 Visual 26/05/2004 7:40:31 PM	In terms of visualisation, this participant makes use of graphics and bar charts, performance curves, progress diagrams, stage diagrams and tables of achievements, and extensive use of hand diagrams too. He only uses line of balance on multistory buildings. "I also use excel, Shorttrack and to a lesser extent, MS Project". He also uses digital photos to overlay and make notes on images. This is generally done with Adobe Photoshop. In terms of drawings, he states: "I don't like Autocad because it is too hard to do anything". I use photo/video only for reporting purposes, either to the client and/or to the office.	
10 Visual 31/05/2004 12:09:20 PM	"We got one which is a bar chart style and Gantt chart style of program but all it does is indicate when we are going to inspect a bit of equipment and when are we going to service it or when are we going to a statutory type of test on test... or do a major overall."	
08	In the bidding they only deal with summary sheets.	
10	Use of diagrams for communicating.	
09	For presentations, is mainly the planner who makes use of visual techniques to assist.	
05 Visual 27/05/2004 9:34:09 AM	"Flow charts to show cash flow, things that help me explain and compare. I also like the use of 3D computer models to improve communication and to make everyone understand things. Although a model is as good as the information is put into it. From 2D or 3D to select and track, paid matter model functions are of great use to us. Tables and matrices are also useful."	
08 Visual 27/05/2004 11:08:31 AM	"I can pull that information from that project on my screen and I can see wether or not we are going on pile with each trade. It is a database where all the staff has access to it. Wether is on site or office, it is updated every 20 minutes, so everything that is done will be updated."	

Figure 6 Cross analysis of 5 interviewees

3.3 ANALYSIS OF RESULTS

Structuring interview data in Repertory Grids has been discussed in detail by Denicolo and Pope (2001), Slater (1977) and Kelly (1955). In this study all interviews were coded as repertory grids using RepGrid™.

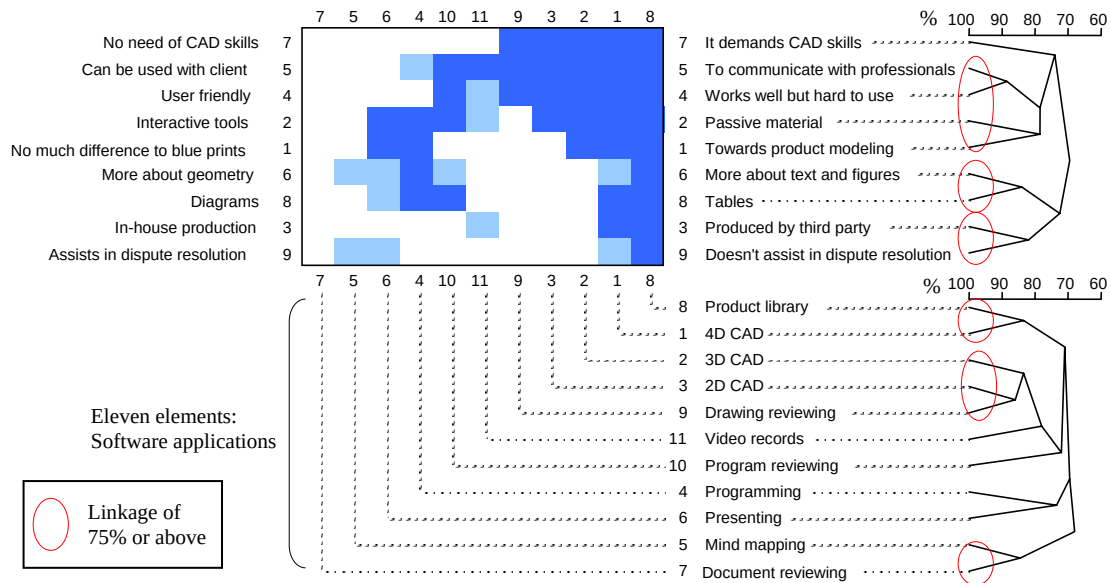
Figure 7 is a relational table of software and attributes as viewed by the participants. Eleven elements represent the various tools and technologies for visualisation. The columns at each side of the table represent the attributes of the constructs.

Figure 7 Attributes Gird

Elements: 11, Constructs: 9, Range: 1 to 9, Context: Information-Visualisation Requirements

Left pole (low ratings – light clusters)

Right pole (high ratings – dark clusters)



The Repertory grid diagram shown in Figure 7 provides a cross comparison of individuals' views about visualisation tools and technologies. It is in the form of a matrix containing elements (software tools) and constructs (identified attributes) themes (or topics under discussion) presented.

For the study 11 participants were interviewed about the use of visual aids in design and construction. The study focussed on the use and implementation of 4D modellers and information visualization techniques.

- Element 1: **4D CAD** - refers to the time dimension added to 2D and 3D CAD drawings or models. Software reviewed includes Archicad™ v7 and Commonpoint™.
- Element 2: **3D CAD** - refers to design tools such as Archicad where design is three-dimensional.
- Element 3: **2D CAD** - refers to the more traditional CAD procedures.
- Element 4: **Programming** - refers to software for planning and scheduling such as Primavera P3™, MS Project™ and others.
- Element 5: **Mind mapping** - refers to tools and software to map such as Mind Manager™.
- Element 6: **Presenting** - refers to the use of tools such as MS Powerpoint™, Adobe Photoshop™ and on the high end Macromedia™ tools.
- Element 7: **Document review** - refers to tools and software packages such as Adobe Acrobat™.
- Element 8: **Product library** - refers to 'database libraries' such as IFC's and STEP.
- Element 9: **Drawing and reviewing** - refers to software packages such as Autodesk Autocad™ and Archicad™.

- Element 10: **Program reviewing** - refers to software tools such as reviewing facilities within Common Point™ or similar programmes.
- Element 11: **Video and photo records** – refers to digital or analogue.

The relationship between the elements involved calculating correlations between the various current and expected visualization techniques, such a 3D CAD display.

Since common elements correspond to semantic differential concepts, common constructs correspond to semantic differential scales, the data analytic problem being equivalent (Bannister 1968). However in semantic differential analyses, attention is generally focussed on either concepts or scales, and is the equivalent of the important relationship of element construct interactions. A way such data can be analysed is through three-mode principal components (Bell 1999) (see Figure 7).

Figure 8 shows that the items were plotted sequentially in a radial pattern, suggesting a qualitative sequence. The variance and coefficient of alienation in the three-dimensional solution was 20, which presents a degree of distortion on the plot. However, the basic configuration suggests a number of patterns, in that four groups of elements (such as 'software tools') are readily identifiable. To aid interpretation, elements related to the regions are coloured differently, indicating the relational calculations for the principal components.

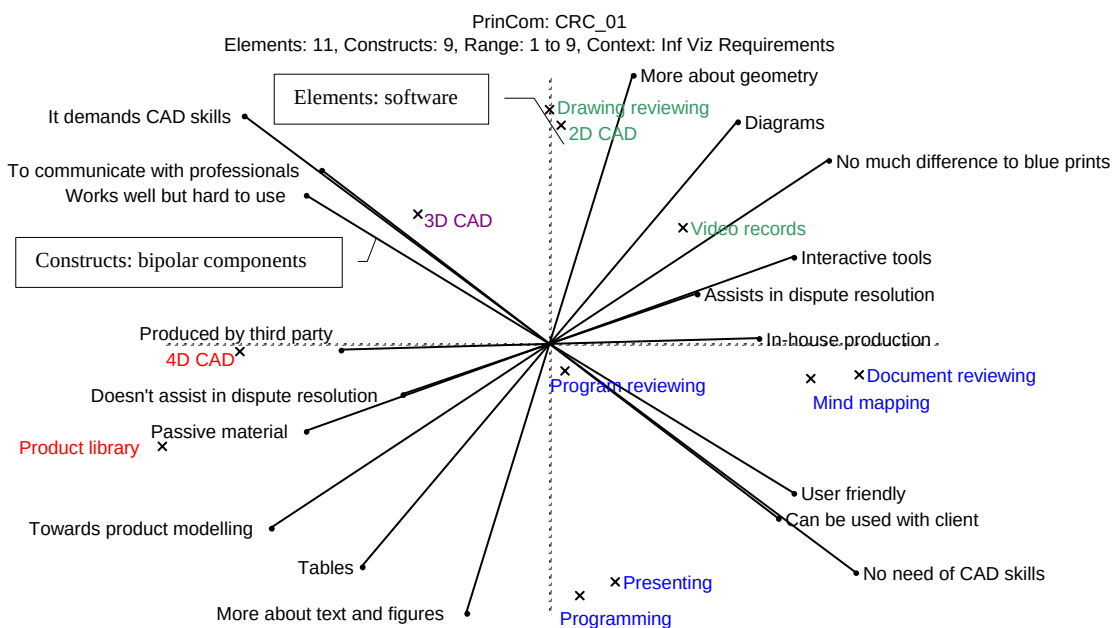


Figure 8 Principal Components: attributes

Figure 7 refers to the arrangement of 9 bipolar constructs and 11 elements. It defines how the elements relate to the constructs. Quadrant top-left 3D CAD and 'programming' relates closely to attributes such as 'works well but hard to use', 'to communicate with professionals', and 'it demands CAD skills'. In the opposite quadrant, (bottom-right), software packages for reviewing (e.g. Adobe Acrobat™) and presenting (such as MS Power Point™) would closely relate to 'user friendly', 'can be used with the client' and 'no need of CAD skills'. '4D CAD' and 'Product Library' are in the lower-left quadrant and relate to the attributes on that side.

Result variation is part of the process of comparing current and future views of visualization requirements. Constructs and elements have been sorted so that those that are more similar in the two grids (present grid and future grid) are the top and on

the right, respectfully. For example element (7) 'document reviewing' tools and procedures are expected to change considerably.

CRC_01+ consensus-with CRC_01. Expected future for information-visualization: darker clusters refer to stronger change expectations (lower left corner).

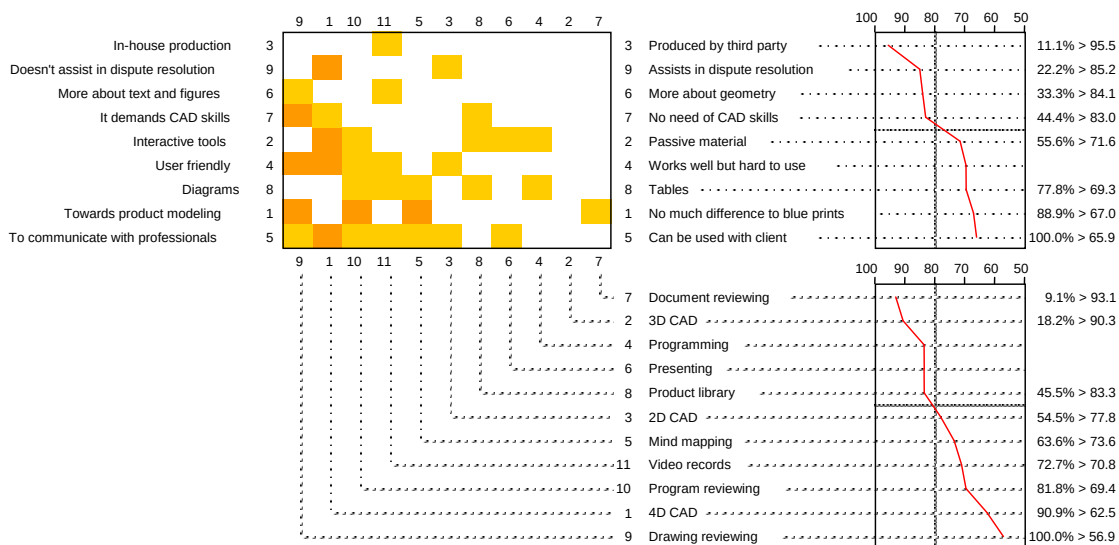


Figure 9 Validation grid

Software for document reviewing (E7), visual aspects of 3D CAD (E2) and programming tools (E4) are expected to function and perform as they currently do. Other tools / elements such as drawing reviewing (E9), 4D CAD (E1) and program reviewing (10) are expected to change and improve the way they currently perform. Architects and planners need more user-friendly project reviewing tools to facilitate interactions with clients. Current tools and approaches are more likely to hinder communication.

The largest change and expectation remains the development of tools 'to communicate with professionals' especially 9, 1, 10, 11, 5, 3 and 6.

All procedures have their limitations. For example Patrick Slater (1976) debated the merits of principal components analysis vs. cluster analysis. Mair (1988) wrote about the problems of correlational approaches, and there has been debate about the different distance measures which are used in cluster and other analyses. These issues need critical consideration in determining how data is to be analysed, especially when comparing multiple participants' responses.

This section has detailed future needs and expectations of planning and visualisation software.

4. Software assessment and future development

Creating a 4D model is generally perceived as highly challenging and labour intensive. Issues confronting users relate to geometry, schedule, and the linking of geometry to schedule.

The model used in this project to interface and communicate 4D CAD is based on Industry Foundation Classes, and was found to perform well. It provided an effective tool to integrate CAD models and planning software but has not been refined to a commercial standard as yet. There is a need to develop an interface for practitioners and a 'light' viewing interface for reviewing and use by non-professionals.

Another reason for these issues is that the construction of a 4D model requires significant project scope and schedule information. Some of this information is precisely the information that project participants want to develop or refine through the 4D modelling process.

The results also revealed the need for “user friendly tools” that can assist at the briefing process.

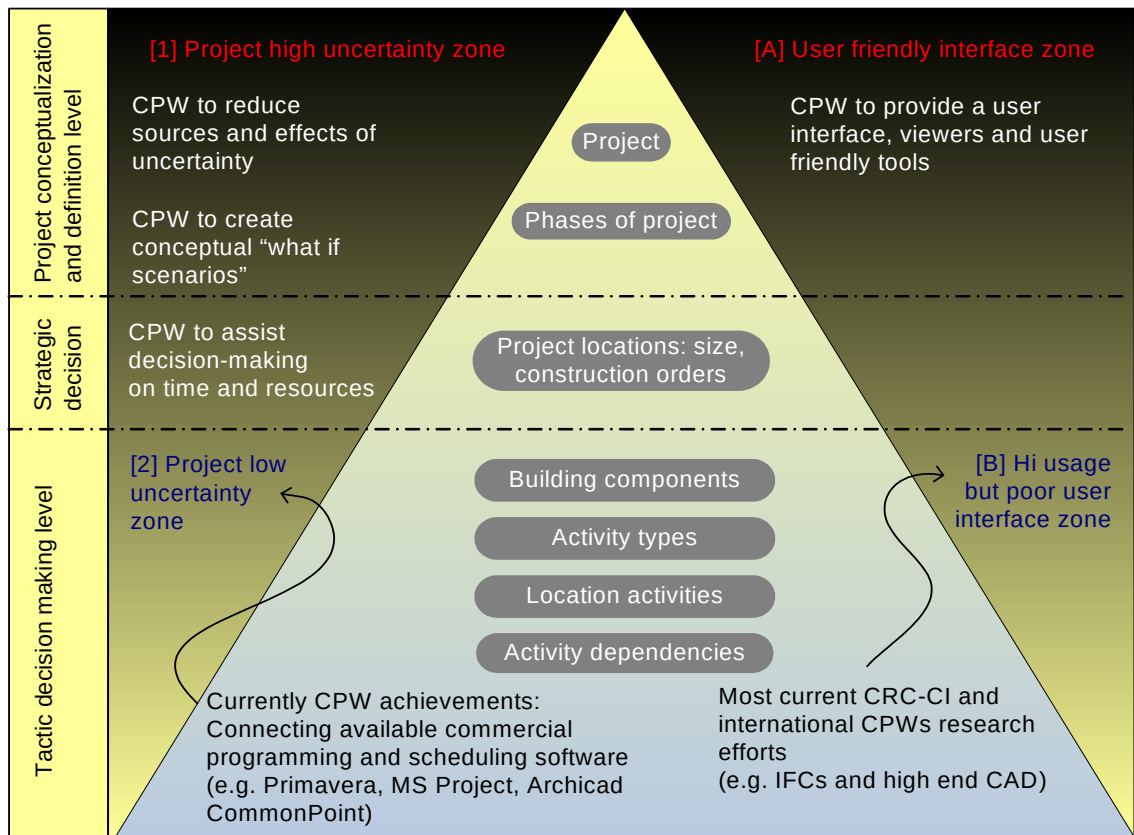


Figure 10 Construction Planning Workbench (CPW) current and future developments

Is CPW satisfying current needs and expectations from industry partners? For CPW to perform well, a second stage is needed to provide a user interface for planners, designers and construction professionals. Figure 10 illustrates current achievements and future directions for CPW.

Currently 4D models are generated by a combination of planners and 3D experts.

Future efforts should also investigate the interface provided by 4D modellers, with a minimum of technical support. Relevant comments by interviewees include:

“With the use of 4D CAD, the relationship between client and designer will improve.”

“With the use of 4D CAD the relationship between contractors, subcontractors and suppliers will improve.”

4D simulation may also be used to plan site logistics and space usage on construction sites, processes that frequently have conflicting requirements. Another area where 4D

would be of value includes detecting potential time-space conflicts that may occur between activities being executed on a construction site.

In summary, 4D CAD provides tools which integrate theoretical frameworks to predict engineering behaviour. This allows for projects to be systematically managed using predictions and observed data to achieve measurable business objectives.

Discussion: Visualisation in dispute resolution

Dispute resolution is an area where 4D technology could be developed and applied. Take for example, a typical claim for an extension of time. To effectively prove an entitlement to an extension of time, a claimant needs to:

- Establish that the contract allows an extension of time for the delaying event in question;
- Comply with the procedural requirements of the contract with regard to notices and notification of the party's intention to make a claim;
- Prove that the claimed event was the cause of the delay;
- Quantify the period of delay; and
- If the contract allows, establish and quantify the costs of the damages suffered as a result of the delaying event for the period of the delay.

The provisions of the contracts determine if a party is entitled to make a claim under the contract and outline the notification procedures and time in which the relevant notices must be given. Establishing that the delay was the result of a specific event or events on large complex projects can be difficult and argumentative. Agreement of the actual events that took place has to be reached prior to determining the effects of those events on the project programme. Determining the effects typically involves the calculation of the amount of time the project has been delayed by way of a critical path analysis, comparing the original 'as planned' project duration with the resultant 'as built' project duration. The difference between the durations is perceived to be the effects of the delaying events and is estimated to be the period of the extension of time. This process is not without argument in itself. A number of delay analysis techniques are recognised as being suitable for this purpose, such as the global impact, net impact, adjusted as built, "but for" or collapsing, snapshot, and time impact techniques (Pickavance, 2000, Alkass et al, 1996, Wickwire et al, 1991, Reams, 1990, Leary and Bramble, 1988). These provide a means of "accurately" quantifying the time element of the analysis, all requiring agreement as to which method of analysis should be used, which computer software should be applied, and which project programme should be analysed. These issues should be addressed prior to the commencement of the project, but even where this is done, the person determining the period of the extension of time requires detailed knowledge of programming and analysis procedures to ensure meaningful results.

Provided the logic of the 'planned' programme and 'as built' programme are accepted as being correct, and agreement has been reached concerning the delaying events in question, the use of nD modelling would enable a pictorial representation of the 'as built' project to be constructed in real time for comparison with a pictorial representation of the 'as planned' project constructed in real time. The visual aid would enable a non-expert to see the effects of the delaying events by comparing the 'as planned' and 'as built' models over time. This would assist in determining the consequences and true effects of the agreed delaying events without the need for detailed knowledge of programming and analysis techniques by the person responsible for determining the

period of extension. Visibly seeing the effects of the delaying events would help in resolving the issues in conflict and would enable agreement to be reached concerning the period of extension.

5. CONCLUSION

Planners and construction professionals are increasingly finding real value and benefit from the use of 4D technologies. The CRC CI funded 'Construction Planning Workbench' project has shown that IFC's provide an effective vehicle to facilitate the provision of draft construction programs directly from CAD data. However, issues of who should be responsible for developing and maintaining 4D and IFC data remain to be overcome.

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CONFERENCE THEME: VISUALISATION AND INFORMATION

Full Paper

E-TENDERING: BENEFITS, CHALLENGES AND RECOMMENDATIONS FOR PRACTICE

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ABSTRACT

The construction industry is categorised as being an information-intensive industry and described as one of the most important industries in any developed country, facing a period of rapid and unparalleled change (Industry Science Resources 1999) (Love P.E.D., Tucker S.N. et al. 1996). Project communications are becoming increasingly complex, with a growing need and fundamental drive to collaborate electronically at project level and beyond (Olesen K. and Myers M.D. 1999; Thorpe T. and Mead S. 2001; CITE 2003). Yet, the industry is also identified as having a considerable lack of knowledge and awareness about innovative information and communication technology (ICT) and web-based communication processes, systems and solutions which may prove beneficial in the procurement, delivery and life cycle of projects (NSW Government 1998; Kajewski S. and Weippert A. 2000).

The Internet has debatably revolutionised the way in which information is stored, exchanged and viewed, opening new avenues for business, which only a decade ago were deemed almost inconceivable (DCITA 1998; IIB 2002). In an attempt to put these 'new avenues of business' into perspective, this paper provides an overall 'snapshot' of current public and private construction industry sector opportunities and practices in the implementation and application of e-Tendering. This paper identifies the benefits and challenges to the adoption of e-Tender systems and considers future industry trends and recommendations.

Keywords: construction, e-tender, information and communication technology, e-business, e-commerce

1. INTRODUCTION

The construction industry is categorised as being an information-intensive industry and described as one of the most important industries in any developed country, facing a period of rapid and unparalleled change (Industry Science Resources 1999) (Love P.E.D., Tucker S.N. et al. 1996). Efficient information processing is continuously being challenged by the extreme fragmentation of the industry's demand and supply chain - that is, construction work being undertaken by a wide variety of organisations, utilising many different skill sets, processes, and technologies; whilst enduring low profit margins and fierce competition (Pietroforte R. 2003).

Towards the end of the 1980's most disciplines within the industry had access to basic software to assist in carrying out relatively complex designs and calculations. During the 1990's the use of e-mail (as an electronic communication device) and the World Wide Web (as an electronic communication device and source of knowledge) was introduced to the industry. Today's construction industry sectors (both public and private) are following a definite and increasing trend towards adapting traditional business methods and processes to the 'new' electronic ways of doing business (e-Business), resulting in many 'divides' being created: paper to electronic media; local to global commerce; management to a leadership focus; and reactive to a more proactive state (Russell J.S. 2000; NOIE 2002; Murray M. 2003).

International predictions, relating to the amount of business conducted electronically have reached hundreds of billions of dollars, with little doubt that the emergence of the Internet is 'revolutionising' business access to communication and information. Web-based business activities within Australia, for example, are envisaged to increase significantly throughout the decade (NSW Government 2001; Anumba C.J. and Ruikar K. 2002). These 'e-activities' can generally be described as being about eliminating inefficiencies in traditional processes, communications, etc. and finding 'smarter' ways of undertaking these activities in an electronic environment, and generally requires industry organisational commitment, change and investment (NSW Government 2002). Unfortunately, there still exists within today's construction industry a considerable lack of knowledge and awareness about innovative information and communication technology (ICT) and web-based communication processes, systems and solutions, which may prove beneficial in the procurement, delivery and life cycle of projects (NSW Government 1998; Kajewski S. and Weippert A. 2000).

Consequently, through increased knowledge, awareness and successful implementation of innovative systems and processes - such as electronic / internet-based tendering (e-Tendering) - raises great expectations regarding their contribution towards 'stimulating' the globalisation of electronic procurement activities, and improving overall business and project performances throughout the construction industry sectors and overall marketplace (NSW Government 2002; Harty C. 2003; Murray M. 2003; Pietroforte R. 2003). This paper identifies the benefits and challenges to the adoption of e-Tender systems and considers future industry trends and recommendations.

2. E-UPTAKE

The Internet has debatably revolutionised the way in which information is stored, exchanged and viewed, opening new avenues for business, which only a decade ago were deemed almost inconceivable (DCITA 1998) and (IIB 2002). In an attempt to put these 'new avenues of business' into perspective, the following section provides an overall 'snapshot' of current public and private construction industry sector opportunities and practices in the implementation and application of web-based ICT tools, systems and processes (e-Uptake).

2.1 E-COMMERCE

According to 'Information Technology in Construction Best Practice' (ITCBP 2003), online trading (e-Commerce) is forecast to grow rapidly, with the undertaking of business electronically leading to significant improvements in cost, time and quality of business products and services. Rapid developments in ICT, its uptake, and increase in computer-literate customers' expectations, reinforces the need for companies to reconsider their strategy with respect to e-Commerce and e-Business. e-Commerce can be defined as: *'Any value adding business exchange conducted electronically within or between businesses, or between businesses and consumers. It covers all forms of electronic trading including electronic data interchange, electronic banking, electronic mail (email) and other online service and communication tools'* (NSW Government 2002).

The Queensland Government expects the benefits of e-Commerce and its e-Commerce strategies to include lower costs and wider markets for business, cheaper prices and greater choice for consumers, higher productivity for the economy as a whole and greater effectiveness of Government programs (Queensland Government 2001). The (Victoria Government 2000) states that e-Commerce is profoundly transforming the way people and businesses interact, with worldwide predictions of its potential to reach around US\$300 billion in 2003. (Foresight 2000) indicates that the construction industry and its participants need to start realising that:

- e-Commerce is here to stay and that the 'open 'availability of essential information and data is important to facilitate on-line decision-making.
- Technology can bridge the traditional gap between design and production.
- Joined-up manufacturers, suppliers and off-site production can lead to greater resources for research and development into new products and processes.
- Industry standard models may enable automated information sharing across the entire value chain - from products to projects.
- It is essential for the construction industry to play an active part in setting the world standards that everyone will eventually need to use.
- Specialist contractors, suppliers, contractors and the design team will use web-based project portals to manage the project and its associated information.
- For an industry susceptible to adversarial approaches, the issue of trust in the supply chain will be critical.
- Greater operating effectiveness and supply-chain efficiency needs new skills and talent - attracted through better prospects and changed perceptions.

2.2 E-PROCUREMENT

e-Procurement covers a wide range of web-based methods and tools (for obtaining prices, awarding and managing contracts, etc) spanning every stage of the purchase of goods or services. This includes e-Tender (Anumba C.J. and Ruikar K. 2002; ITCBP 2003). e-Procurement can therefore be described as using e-Commerce for procurement: *'A business tool and enabler, involving the use of electronic technologies to automate and streamline the procurement processes of an organisation, improving efficiencies and transparency, and thereby reducing the costs of those processes within and between businesses'* (NSW Government 2002).

The New South Wales (NSW) Department of Public Works and Services, for example, through their *'NSW Government Electronic Procurement Implementation Strategy'*, states a key outcome of the strategy is to maximise consistency in approach in implementing e-Procurement and ICT across government agencies and the construction industry (NSW Government 2003). The primary benefit that government agencies, service providers and industry seek to achieve from implementing e-Procurement is to reduce the cost of doing business. As a result, the key objectives of one of its strategies includes providing better

access to tendering information and streamlining the whole tendering process, by offering electronic access to tender information (e-Tender), thereby providing greater opportunity for business (NSW Government 2002).

Current and future ICT, e-Commerce, e-Procurement and e-Business developments and their applicability and uptake within the public and private sectors of the construction industry, is causing virtually every business sector to shift away from traditional, tried and tested methods of communications, effectively revolutionising the way today's companies trade and conduct business. Even with a reserved uptake, the construction industry and its participating organisations are steadily taking up innovative forms of doing business via the internet, including e-Tendering – making it possible to manage the entire tender letting process electronically and online (Anumba C.J. and Ruikar K. 2002; ITCBP 2003). Today's Government departments / agencies for example, offer a wide range of (current and anticipated) e-facilities / services, including e-Tendering (Ecommerce 2002).

3. E-TENDER BENEFITS & CHALLENGES

3.1 E-TENDER BENEFITS

A significant number, and in many cases similar e-Tender benefits were identified during this investigation, with industry and Government participants generally stating that an e-Tendering process is cheaper and faster than the previous paper-based process (B&C Watch 2001). The primary benefit government agencies, service providers, and industry seek to achieve from implementing electronic procurement (e.g. e-Tender) is to reduce the cost of doing business and to deliver services that are more efficient to the community. e-Tendering is a key strategy in the development of various electronic procurement programs and initiatives, offering additional opportunities for industry businesses, contributing to a globally competitive economy, and helping secure a sustained economic growth.

According to the NSW Government (NSW Government 2002) and Department of Commerce (NSW Government 2003), the construction industry and government agencies / departments can achieve numerous benefits from introducing an e-Tendering system or process, including:

- General:
 - o streamlines the whole tendering process;
 - o provides improved and secure access to tender information;
 - o brings about innovative business processes;
 - o initiates greater opportunities for small and regionally based businesses;
 - o allows downloading of electronically submitted tenders in a form suitable for evaluation purposes without having to manually re-enter data; and
 - o makes it easier for businesses to obtain tender documentation and to submit an offer on time.
- Industry perspective:
 - o provides quick and easy access to public and private tendering information;
 - o increased tender opportunities;
 - o improved access for geographically isolated industry organisations;
 - o increased market share and competitiveness; and
 - o reduces the cost of printing - saving time and resources.
- Government perspective:
 - o best value for taxpayers' money;
 - o increased efficiency and effectiveness;
 - o consistent tendering practice across Government;
 - o promotes overall e-Commerce initiative; and
 - o environmentally friendly due to a predominantly 'paperless' process.

3.2 E-TENDER CHALLENGES

Whilst there are undoubtedly many barriers challenging the successful implementation and adoption of an e-Tendering system or process, researchers have identified the following range of challenges and perceptions that seem to hinder the uptake of this innovative approach to tendering electronically.

3.2.1 General

Whilst the electronic exchange of data within the construction industry is becoming increasingly more common, certain contractors and consultants see the use of an e-Tendering process as 'unfair practice' if they are not in a position to take advantage of receiving or sending tender documents electronically. This issue can easily be resolved by offering tenderers the option of receiving their tender documentation in either paper or electronic format (CITE 2003).

A further two principal barriers to tendering electronically have also been identified (CITE 2003). Firstly, certain consultants perceive e-Tendering as being of more use to contractors than to themselves. Secondly, even though increasing number of contractors are capable of, and encouraged to return their tender bids electronically (even when the initial tender documents were received in paper format) the majority of contractors and consultants have yet to adopt the e-Tendering process. Both these barriers can be overcome through increased efforts in highlighting the potential benefits and opportunities available to contractors, consultants and clients, when adopting an e-Tender process. Therefore, to help achieve this increased knowledge and awareness within the construction industry, researchers suggest the developers, owners and managers of these e-Tendering systems and processes need to hold regular public e-Tender information dissemination programs, which in turn will help fuel their uptake.

3.2.2 Employment

The perceived impact an e-Tendering process may have on existing contractor and consultant employment prospects could raise some level of concern. However, it is believed that the electronic exchange of tender documentation allows staff to use more of their valuable skills on 'profitable' tasks and less time on administration work. This in turn has the effect of 'empowering' employees, providing increased value to their employers and projects, thereby improving the overall service to their clients (CITE 2003).

3.2.3 Security

Research indicates that 43% of Australian government organisations with access to the Internet identify 'security' as a major limitation to the greater use of the Internet (ABS 1999). Yet in reality, according to CITE, the electronic exchange of information and data is probably more secure than the use of paper (CITE 2003). CITE's Legal & Security Issues Group, for example, are currently piloting and evaluating the use of electronic signatures and various data encryption technologies, in an attempt to offer maximum security to project partners when exchanging data electronically. CITE describes an 'electronic signature' as being *'derived from a human signature, which can be generated using data capture via a digitiser or tablet (also known as a biometric token)*. This electronic signature is then *'embedded into a document'*, thereby confirming the 'originator' signed the document and that the content of the document has not altered in any way.

3.2.4 Legal

There also seems to be a growing concern regarding certain formal contracts not making explicit reference to future / ongoing use of electronic data exchange. This is because project

participants (contractors, consultants and clients, etc) still perceive 'important' communications taking place 'in writing', and not having a clear understanding as to whether electronic communications (eg using an e-Tendering system) will 'legally' suffice (CITE 2003).

To help overcome these important legal and contractual issues, the Australian (and Queensland) Electronic Transactions Act's main objective, for example, is to provide a regulatory framework that:

- recognises the importance of the information economy to the future economic and social prosperity of Australia;
- facilitates the use of electronic transactions;
- promotes business and community confidence in the use of electronic transactions; and
- enables business and the community to use electronic communications in their dealings with government (Commonwealth Government 2001; Queensland Government 2001).

Similarly, CITE aims to define a framework for legal conditions and contracts, regarding the use of electronic exchange of information in construction-based e-business. Their goal is to provide a legal framework to regulate the new electronic ways of working for all parties involved in a project (CITE 2003).

3.3 SUMMARY

The efficiency of an e-Tender process seems well supported internationally, with a significant number, yet similar, e-Tender benefits identified during this investigation. Recognised as being in the forefront of e-tender adoption in the UK construction industry, CITE verifies the annual costs to clients, having to produce, copy and distribute tender documents the old fashioned way (that is, on paper), can be cut by as much as 90% using an e-Tender process. Australian construction companies like Thiess have now joined other major contractors and project developers in supporting CITE's e-Commerce initiatives, to help extend the operational use of electronic business and development of electronic structured data standards (including e-Tendering) across the entire construction industry (Thiess 2003).

Both construction industry and Government participants generally agree that the implementation of an automated e-Tendering process or system enhances the overall quality, timeliness and cost-effectiveness of a tender process, and provides a more streamlined method of receiving, managing, and submitting tender documents than the traditional paper-based process.

4. E-TENDER TRENDS AND RECOMMENDATIONS

4.1 RISK

When it comes to industry professionals choosing electronic communications via an e-Tender process or system, the potential legal risks in using such a system or process are directly proportional to the increasing levels of electronic interaction. Three e-Tender risk categories have been identified by (Worthington R. C. 2002), namely:

- Category 1: Where tender information is simply posted on the internet as 'pure information'.
 - Recommendation: Although exposed to minimum levels of risk, attention must be given to its contents – that is, truth, accuracy, not misleading or defamatory, etc.
- Category 2: Where the e-Tender web site claims to have tender related information that tenderers need to rely on and perhaps download.

- o Recommendation: Owners or managers of the e-Tender system are to spend more time ensuring that what is on their site is complete, accurate and true. The inclusion of a 'non-reliance' exclusion clause may also be necessary. Ensure the tender documentation can in fact be successfully downloaded (in its entirety), especially if tenderers are asked to reply in hard copy format.
- Category 3: This is at the top end of the 'risk scale', having a fully interactive internet-based e-Tender system, where tenderers both receive an invitation to tender, and reply with a tender bid electronically – that is, with no option of obtaining a paper copy of the tender documentation (except by printing out the contents of the web site).
 - o Recommendation: Security of information and integrity of the e-Tender system is of paramount importance. Here, legally binding and enforceable contracts are being formed electronically, leaving little room for error in receiving, sending, or storing the information. Furthermore, as owners or managers of the e-Tender system, they are unable to simply exclude all liability for what could happen during an electronic e-Tender process, and will likely have to assume some of the unforeseen risks (especially when an electronic reply is the only option).

4.2 TRAINING & EDUCATION

Whilst this paper is written in 'plain English' and without the use of too many technical terms and phrases, many have become 'buzz-words' in certain industry circles over the past decade (The Construction Confederation 2001). The term e-Tendering, for example, is one of many technical jargons that could act as a deterrent for many when given the opportunity to adopt an electronic tender process, simply due to lack of understanding or misconception.

In an attempt to help increase today's construction industry participant's uptake of innovative technologies, systems and processes (such as e-Tendering), it is strongly recommended that construction organisations become learning organisations. Due to the increasing 'electronic integration' of construction processes, industry participants have no choice but to acquire themselves a complete range of new skill sets, and to 're-think' the way current construction education is organised in delivering these skills, thereby implying a need for 'cross-disciplinary education' (Foresight 2000).

There is also a significant role for tertiary education to develop and support the understanding of how to accept, evaluate and implement technological change and innovation. This provision is required both in undergraduate / postgraduate courses to create a more receptive and able cadre of construction professionals (including the creation of a more common understanding) (CRISP 2000).

4.3 IMPROVED IMPLEMENTATION

When it comes to the implementation of an e-Tender system, 'Information Technology Best Practice' identifies a number of basic recommendations, including:

- Having an extremely robust and secure e-Tender system - by having an enhanced security policy in place and by carrying out regular security 'health checks' on the system itself and its users
- Ensuring confidential information cannot get into the wrong hands – for instance:
 - o Whilst many aspects of an e-Tender process are similar to traditional tender arrangements, there are certain legal issues (possibly contractually binding issues) that need special consideration - for instance, people often let work colleagues check their email inbox, allowing 'unrestricted' access to dedicated e-Tender system usernames and passwords.
- Clarification of certain 'grey areas' regarding timing of electronic tender documents – that is, the need for an e-Tender system to automatically generate and archive dispatch and receipt times of electronically distributed/submitted tender documents.

- Providing accesses to advanced capabilities within the system - for instance, allowing one to compare data from project to project in order to view relative prices and timely decision-making.
- Allowing the reuse of standard information of regular tenderers - for instance, storing the pre-qualification documents and information of a regular pool of tenderers.
- Tender terms, conditions, application forms, and software installation procedures (if applicable) are to be uncomplicated to help 'persuade' certain contractors, consultants, suppliers, etc. to participate in an e-Tendering process.
- Additional e-Tender implementation issues that require consideration include:
 - o liability for lost or corrupted data;
 - o ensuring that the servers are well protected – that is, having 'fallback' plans/procedures in place for when the e-Tender service were unavailable (off-line);
 - o ensuring that firewalls do not restrict the dissemination of supporting tender related documentation (ITCBP 2003).

4.4 LEGAL

Legislatures are identified as typically 'lagging' behind technical innovation and social change (Woulds J. 1997). The successful implementation of an e-Tendering process within the industry, for example, is susceptible to the current legal status regarding electronic transmissions, use of electronic signatures, etc. Furthermore, commitment by both government and industry sectors is required to help develop more innovative strategies to build a stronger and more competitive construction industry. Ongoing legal investigations, aimed at strengthening organisational and individual use of electronic communications on projects must continue, by providing better management of communication risks such as:

- Authenticity: This concerns the source of the communication - does it come from the apparent author?
- Integrity: Whether or not the communication received is the same as that sent - has it been altered either in transmission or in storage?
- Confidentiality: Controlling the disclosure of and access to the information contained in the communication.
- Matters of evidence: This concerns e-communications meeting current evidentiary requirements in a court of law, for example, a handwritten signature.
- Matters of jurisdiction: The electronic environment has no physical boundaries, unlike the physical or geographical boundaries of an individual state or country. This means that it may be uncertain which State's or country's laws will govern legal disputes about information placed on the Internet, or about commercial transactions made over the Internet (Electronic Transactions Act 2001).

5. CONCLUSION

In this uncertain and ever changing world, the construction industry and its participants need to be creative, alert to opportunities, responsive to external stimulus, have a good grasp of the changing environment, and increase existing levels of confidence in its ability to adapt (Banks E. 1999). It is been over 40 years since the introduction of ICT tools and systems into the construction industry, yet organisations are still unable to obtain the many potential benefits of ICT investment - many years after the initial expenditures have been incurred. Furthermore, the industry has been identified as 'slow' in embracing innovative ICT tools and systems such as eCommerce, e-Tendering, etc (Stewart R.A., Mohamed S. et al. 2002). These e-Activities will underpin further growth in the Australian economy, enabling innovation and significant advances in productivity and efficiency within and across industry sectors (APCC 2001).

Sharing project information electronically - from inception, design, through construction, and into building operation – can lead to large efficiency gains for all parties involved. Research suggests the eventual goal of the construction industry should be to better integrate the supply chain and all other business functions, allowing new, more efficient ways of working. The extent to which a construction company adopt these applications will depend on its specific circumstances and decisions made according to normal, sound business and strategic objectives (ITCBP 2003).

Finally, if Australian organisations continue to explore the competitive 'dynamics' of the construction industry, without realising the current and future, trends and benefits of adopting innovative processes, such as e-Tendering, it will limit their globalising opportunities to expand into overseas markets and allow the continuation of international firms successfully entering local markets. The construction industry must take into account that the successful implementation of any electronic tendering system often directly depends on the successful integration of innovative ICT / internet solutions, with traditional and frequently archaic processes. Achieving this integration can be a complex process, and if not done correctly, could lead to failure (Bourn J. 2002).

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VISUALISATION AND INFORMATION

Full Paper

ICT IN THE AUSTRALIAN CONSTRUCTION INDUSTRY: STATUS, TRAINING AND PERSPECTIVES

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ABSTRACT

This paper outlines the results of a survey conducted as a part of the CRC Construction Innovation research project '2001-008-C Project Team Integration: Communication, Coordination and Decision Support'. The survey conducted through this research aimed at investigating the Australian construction industry's current performance in ICT related issues including the current status of ICT, training trends associated with ICT and the perceptions surrounding enablers/drivers and barriers/limitations to the introduction and use of ICT. The survey was implemented on a national (Australia) basis within the construction industry and targeted the non-building, building (commercial/industrial), and residential sub-sectors. The most significant observations from the survey results were:

- *'Annual turnover' has an effect on the uptake of ICT and training performance in ICT for an organisation.*
- *Interoperability issues (incompatibility of ICT systems) and not having an ICT professional on site (or within ready access) were found to be strong influential barriers to the uptake of ICT on projects.*
- *The overriding driver for ICT uptake for respondents was to improve operational performance through improved productivity - at both personal and organisational / team levels.*

Keywords: construction, ICT, information and communication technology, training

1. INTRODUCTION

This paper outlines the results of a survey conducted in November 2003 aimed at investigating the Australian construction industry's current performance in ICT related issues. The survey targeted three broad areas:

- Current ICT status including annual ICT investment, access to and use of ICT devices according to annual turnover;
- ICT training including training participation by individuals, training support within respondent organisations with regards to workload and time flexibility for employees, preferred mode of training for individuals, and level of ICT competence expectations of the various construction project participants of their colleagues; and
- ICT trends and opinions on the Benefits/Drivers and Barrier/limitation to the implementation and use of ICT on construction projects.

The survey was implemented on a National (Australia) basis within the construction industry - including non-building, building (commercial/industrial), and residential sub-sectors - with a view to informing the decision makers within the construction industry on ICT policy relating to:

- The types of ICT being used across the construction industry sub sectors and for various project sizes to enable them to identify possible improvements through ICT uptake;
- The preferred mode of training amongst construction industry employees allowing them to implement suitable ICT training regimes for employees; and
- The Benefits/Drivers and Barrier/limitation to the uptake of ICT on construction projects to enable them to identify suitable ICT implementation strategies within their organisations.

2. SURVEY METHODOLOGY

The survey reported here was carried out using web based survey methodology. An email was sent to potential respondents with a web link embedded enabling respondents to hotlink to the survey web server. Respondents were asked to complete each of the four sections and submit the responses - which were stored in the web server. After the nominated survey closing date, the responses were forwarded for analysis by the project team. Further details on the methodology including the survey development, pilot study, response rates, and general principles are outlined in Kajewski, et. al. (2004).

2.1 SURVEY RESPONDENT PROFILE

Respondents were asked to answer specific questions to enable detailed comparative analysis of the responses. In terms of a general profile, the analysis revealed that:

- 92% of respondents were from the East Coast of Australia;
- 78% of respondents have some form of Tertiary Qualification;
- 71% of respondents were in some form of managerial role within their organisation;
- All respondents had greater than 1 year and 54% had at least 10 years service in their present position;

- 63% of respondents were from a contracting organisation and 29% were from a consultant/specialist organisation with the remaining 12% being spread between Supplier and Client organisations;
- The majority (74% of those who knew the organisation's annual turnover) of respondents organisations had annual turnover's of less than \$5M and 10% of respondents organisations had annual turnover's of \$100M+ or greater; and
- At least 80% of respondents were from the Vertical/Building construction sub-sector.

3. CURRENT ICT STATUS

This section investigates the respondents, and respondent's organisations where appropriate, current ICT status including:

- ICT organisational investment: including further analysis of ICT investment according to sub-sector and annual turnover; and
- ICT device access and use: including use and access for various devices, access and use of emerging/innovative technologies by annual turnover.

3.1 ORGANISATIONAL INVESTMENT

Respondents were asked to specify how much their company currently invests in ICT annually. The amount spent varied considerably from \$500 to \$1,000,000 with the most frequent amount specified being \$2000. The factors expected to be influential on ICT investment included annual turnover and the industry sector. Figure 1 displays the distribution of the respondents' organisations annual ICT investment commitment by turnover category. The categories were arbitrarily set at greater than \$10M, between \$10M and \$1M and less than \$1M. A further category (Don't Know) is provided to cover respondents that did not know their organisations annual turnover.

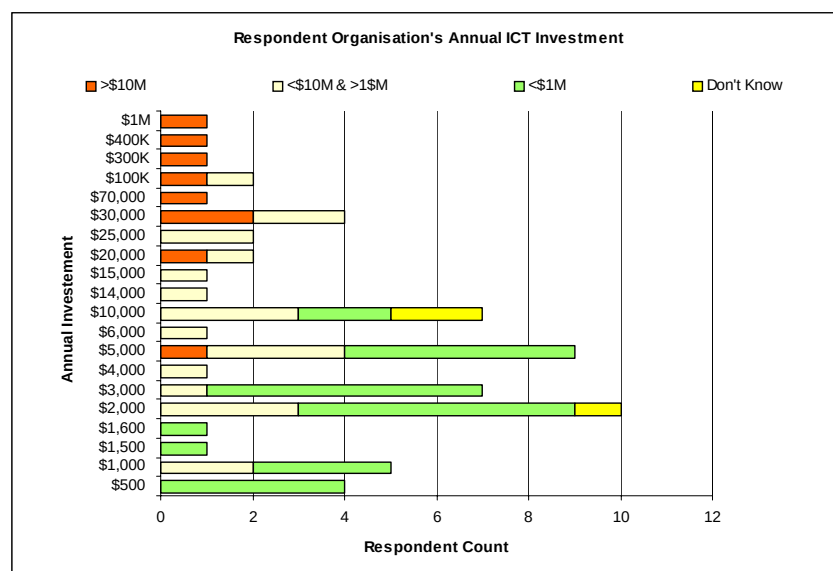


Figure 1 Distribution of ICT Investment Amount by Annual Turnover

To test whether a relationship existed between the annual investment in ICT and annual turnover ranges, a correlation test was performed. The annual turnover responses were coded from 1 to 9 with 1 being the lowest turnover category and 9

being the highest. The correlation statistic used for this test was the Spearman's Rho. The analysis between annual turnover (coded) and ICT investment indicated a positive relationship exists (Spearman's rho 0.51, Correlation is significant at the 0.01 level). It is worth remembering that a proportionally higher number of respondents from the non-building sector were also represented in the higher turnover ranges, which could be confounding the results.

3.2 ICT DEVICE ACCESS AND USE

Respondents were asked to identify which ICT devices, from a specified range, they have access to within their company and subsequent to this, which of these devices they used on a range of project sizes. Details of project size the respondent participates in was not readily obtained, thus the data were pooled and analysed for any project size. Responses for both of these questions are illustrated in

Figure 2.

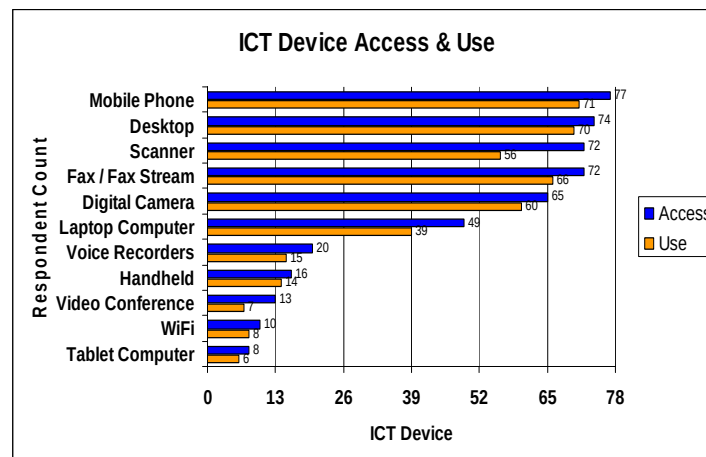


Figure 2 ICT Access and Usage

The list provides a range of ICT technologies. Some ICT technologies such as Desktop computer, Mobile phone, Scanner, Fax and Digital camera are established technologies and according to the responses are accessible by most respondents. Based on the responses, these technologies are widely used on construction projects. When considering emerging technologies such as Wi-Fi, Handheld and Tablet computers, and Video Conference equipment, the analysis revealed that the amount of annual ICT investment of the companies apparently impacts on accessibility. Organisations with higher investment budgets have a higher proportion of these emerging technologies. This is illustrated in Figure 3 which displays the distribution of access to handheld computers according to the ICT investment category. This chart shows that 83% of the respondents with an annual ICT investment budget greater than \$50,000 have access to handheld computers

compared with only 4% of those with an ICT budget of less than \$10,000. A similar pattern emerges when analysing technology usage for other emerging technologies.

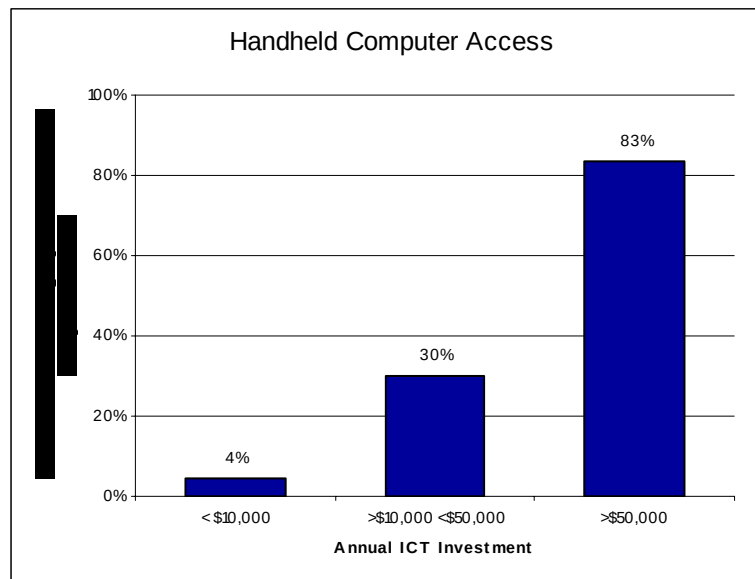


Figure 3 Distribution of Handheld Computer Access

4. ICT TRAINING

This section investigates the ICT training characteristics of the respondents and respondent's organisations including:

- Official ICT training participation – including overall participation, participation considering annual turnover, and participation variability in the sub-sector groups;
- ICT training company support – including whether the respondents were allowed time or workload flexibility to undergo ICT training, sub-sector analysis was also completed;
- ICT training mode preference – including analysis dependent on annual turnover ranges;
- ICT competence expectations – including respondent's expectations dependent on sub-sector group.

4.1 OFFICIAL ICT TRAINING PARTICIPATION

Respondents were asked to indicate whether they had undergone any official ICT training. Almost half (49%, Figure 4) of the respondents indicated they had undergone official training. When comparing responses by the company classification, sub-contractors were more likely to have never undergone official training. Larger (\$100M+ turnover) organisations had a higher proportion of respondents indicating they had undergone official training, as did respondents who indicated their core sector was non-building construction (both 5 out of 7). While worthy of note, these were not statistically significant findings.

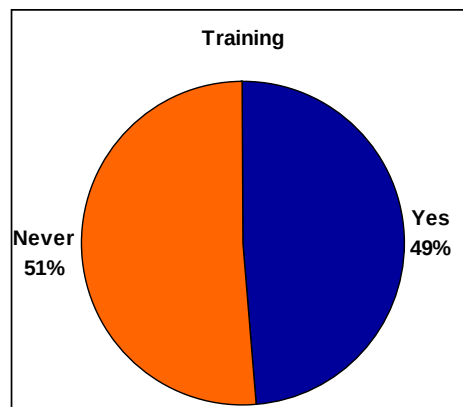


Figure 4 Proportion of Respondents who had undergone Official ICT Training

4.2 ICT TRAINING AND COMPANY SUPPORT

Respondents were asked to indicate whether their company allowed them sufficient time during office hours to undergo ICT training with over half indicating that such time was made available (Figure 5). Although respondents from the residential construction sector were less likely to be provided adequate time for training (13 out of 21), this was not a statistically significant finding. Respondents were also asked whether their company adjusted/reduced their workload to undergo ICT training – with only 10 respondents indicating that such an adjustment had been made. Interestingly, six of those were from companies with a turnover range between \$1M - \$5M.

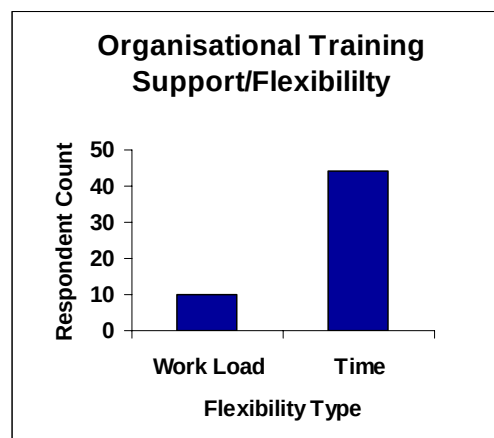


Figure 5 Organisational Training Support

Overall, only two had undergone official ICT training and had been allowed sufficient time and had their workload adjusted to undergo training. Conversely, 18 respondents indicated they had not undergone any official ICT training or received any adjusted workload or time. The residential building sector was heavily represented in this group. Based on the responses, 59 respondents indicated they either, have had either official training or have had their workload reduced, or been allowed sufficient time during work hours to undergo training, implying at least 76% have undergone some kind of training.

4.3 ICT TRAINING MODE PREFERENCE

The respondents were asked to nominate their preferred mode of training from a selected list. As is evident in Figure 6, the preferred training mode was with professional consultants, with 46% of respondents nominating this method.

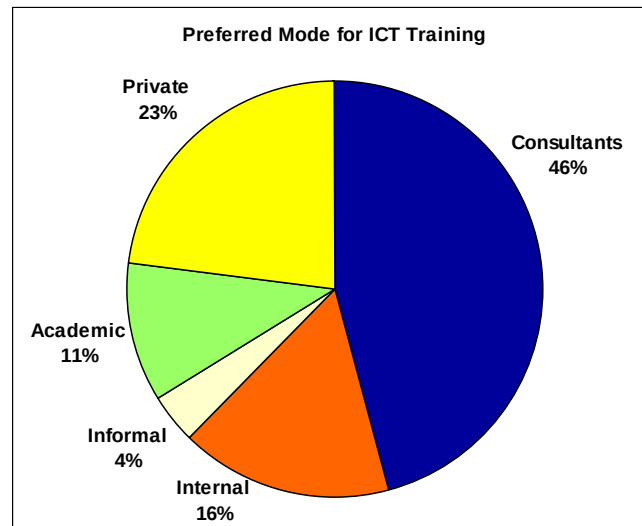


Figure 6 Preferred Mode of Training

The respondents who had undergone official ICT training and had been allowed sufficient time and had their workload adjusted to undergo training, both indicated a preference for training with professional consultants. This preference was supported by the 18 respondents who indicated they had not undergone any official ICT training or received any adjusted workload or time to undergo ICT training.

Figure 7 shows the response trend for preferred mode of training dependent on the respondent's turnover classification. The chart shows an increasing preference for professional consultants as the annual turnover category increased. 86% of respondents from the higher turnover categories indicated a preference for training mode with professional consultants compared with the lower turnover categories, where 52% indicated a preference for private training.

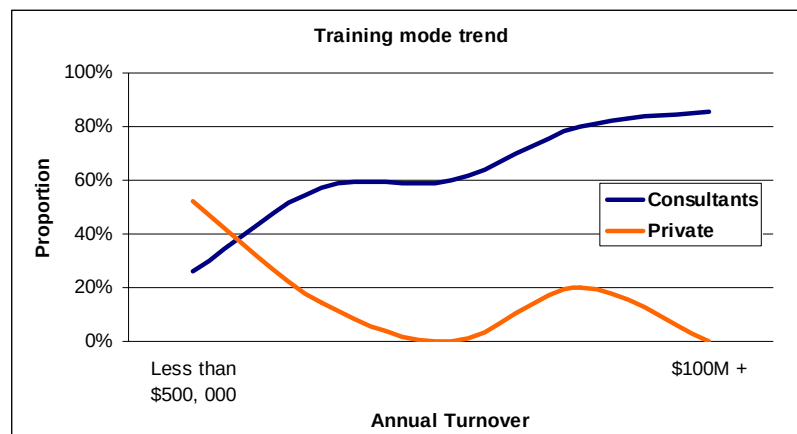


Figure 7 Training Mode Preference Trend

4.4 ICT COMPETENCE EXPECTATIONS

Respondents were asked to indicate what overall level of ICT competence (capabilities, skills, etc) they believed specific team members should have on a project. Overall respondents expect the consultant to have a greater level of ICT competency than all other team members. This result was statistically significant. Contractors and Suppliers were rated next with Clients and Sub-contractors rated lowest however, still expected to have at least average competence.

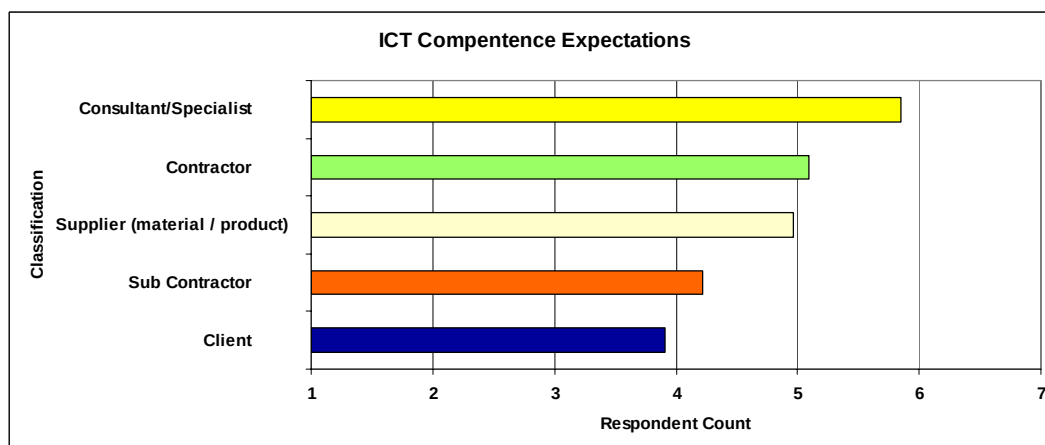


Figure 8 Average Responses for Overall Level of ICT Competence

When comparing the responses dependent on the role of the respondent it was apparent that those in managerial roles tended to expect a higher competency from all team members than did other groups. This was not a statistically significant finding. When comparing responses based on the respondent class, sub-contractors tended to expect a greater level of competency from sub-contractors in general than did other groups. They also expected a higher level of competency from contractors than other groups.

5. ICT PERSPECTIVES

5.1 BENEFITS AND DRIVERS FOR ICT ON PROJECTS

Respondents were asked to indicate what influence a specified range of benefits and drivers has on their decision to implement or use ICT on projects. The issues presented included:

- Benefit 1. To help improve overall team/company efficiency (productivity).
- Benefit 2. To help enable electronic banking etc (eCommerce).
- Benefit 3. To help enable electronic tendering (eTender).
- Benefit 4. To help enable electronic archiving of documentation (eArchive)
- Benefit 5. To help set up a dependable ICT infrastructure within your company.
- Benefit 6. To help become Industry leaders in ICT adoption.
- Benefit 7. To help downsize or become a leaner company/team.
- Benefit 8. To help increase business opportunities.
- Benefit 9. To help gain increased efficiency (improved productivity).
- Benefit 10. To help support industry Research and Development.
- Benefit 11. To help receive tangible rewards (pay/job advancement).
- Benefit 12. To help receive intangible rewards (respect, self-fulfilment).

The response options ranged from no influence at all to highly influential with a total of seven rating options.

The mean response rating for most issues was above average suggesting that most issues were influential in their decision to implement or use ICT on projects. The only issue with a below average mean response was *'to help become industry leaders in ICT adoption'*. The mean response for the issues is displayed in Figure 9.

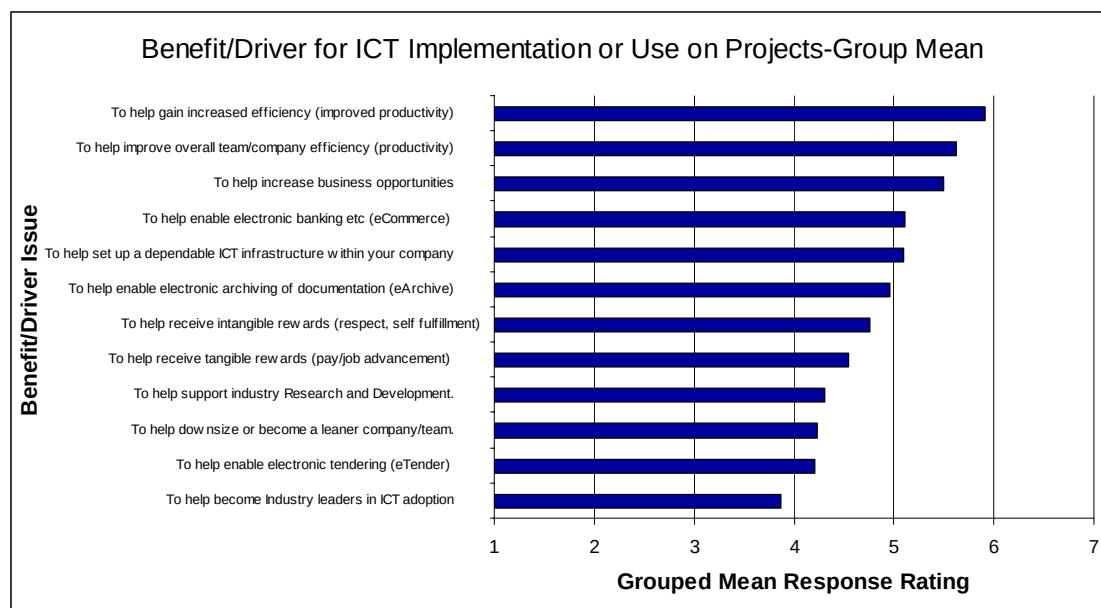


Figure 9 Mean Response for Benefits/Drivers Influencing ICT Implementation

Figure 9 shows the issue with the highest mean rating was *'to help gain increased efficiency (improved productivity)'* followed by *'to help improve overall team/company efficiency (productivity)'* and *'to help increase business opportunities'*.

Based on the sample error the results showed a statistically significant difference in the mean response between issues, with the top three issues being significantly different to the bottom six issues. This result suggests that the top three issues are likely to be the most influential for the population in general.

The issues found to be of least influence, in order of influence include *'to help become industry leaders in ICT adoption'*; *'to help enable electronic tendering (eTender)'*; and *'to help downsize or become a leaner company/team'*.

Essentially, respondents perceive ICT to provide productivity benefits to their project operations, both at the individual and team/company level. They also perceive some strategic benefits in the way of improved business opportunities that the ICT may provide.

When comparing the responses dependent on the analysis factors, there was considerable variability between the core sectors (Figure 10), in particular the responses for the non-building sub-sector. Due to the small number of respondents in this category the differences, in general, were not statistically significant. Figure 10 below displays the results of the core sub-sector analysis. The non-building sub-sector respondents perceived *'to help improve overall team/company efficiency (productivity)'* and *'to help gain increased efficiency (improved productivity)'* as the most influential benefits/drivers respectively to ICT implementation or use on projects. Other issues, which have a strong influence for the non-building sub-sector respondents, in order of influence are *'to help set up a dependable ICT infrastructure within your company'*; *'to help enable electronic archiving of documentation (eArchive)'*; and *'to help increase business opportunities'*.

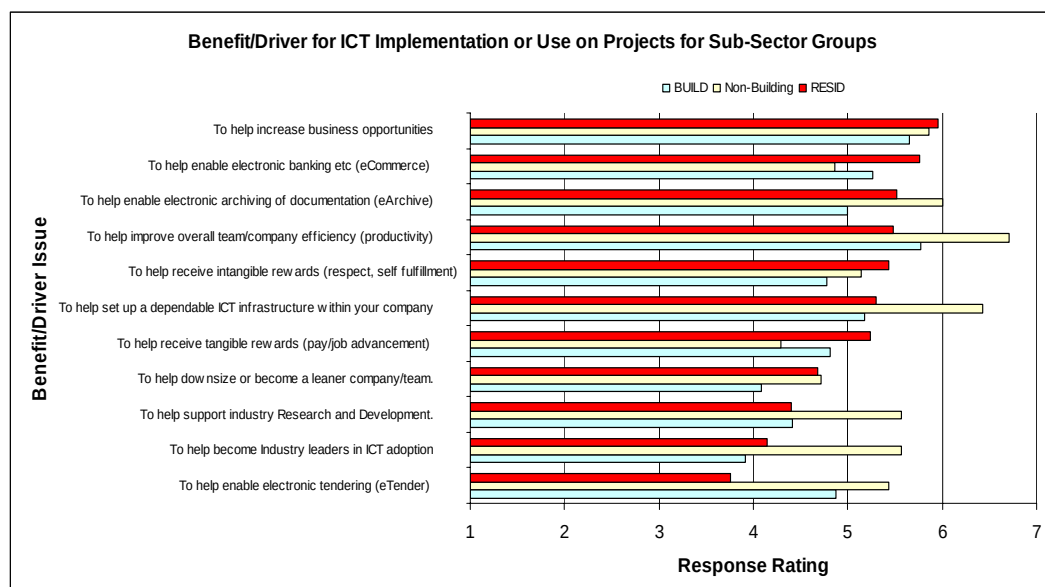


Figure 10 Mean Response for Benefits/Drivers by Core Sector

It is worthy of note that those in the non-building sub-sector indicated that *"to help set up dependable ICT infrastructure"* was more influential than *"to help increase*

business opportunities” where the overall mean response showed a different result. This sub-sector also rated (4th highest) eArchive capability more influential than did the group mean, which gained a ranking of 6th highest overall. In addition, worthy of note was that all issues raised had higher than average influence response for the non-building sub-sector.

Building construction (commercial/industrial) respondents perceived *‘to help gain increased efficiency (improved productivity)’* and *‘to help improve overall team/company efficiency (productivity)’* as being the most influential benefits/drivers respectively to implementing or using ICT on projects. Other issues, which have a strong influence for building construction sub-sector, in order of influence are *‘to help increase business opportunities’*; *‘to enable electronic banking etc (eCommerce)’*; and *‘to help set up a dependable ICT infrastructure within your company’*. These results are in line with the grouped mean response for all sub-sectors where the top 5 issues match in order of influence.

The residential sub-sector respondents perceived *‘to help gain increased efficiency (improved productivity)’* and *‘to help increase business opportunities’* as their most influential benefits/drivers respectively to ICT use and implementation on projects. Other issues, which have a strong influence for the residential sub-sector, in order of influence are *‘to enable electronic banking etc (eCommerce)’*; *‘to help enable electronic archiving of documentation (eArchive)’*; and *‘to help receive intangible rewards (respect, self fulfilment)’*.

It is interesting to note that the residential sub-sector rated the increase in business opportunity benefit/driver as more influential than the other sub-sectors. Another interesting result for residential sub-sector is the relatively high influence rating, compared to the group mean, for the issue *‘to help receive tangible rewards (pay/job advancement)’*. It is also interesting to note that the issue *‘to help enable electronic tendering (eTender)’* had less influence for those in the residential construction sub-sector than the other two.

Figure 11 displays the rating response distribution for the influence the specific benefits/drivers had on their decision to implement or use ICT on projects.

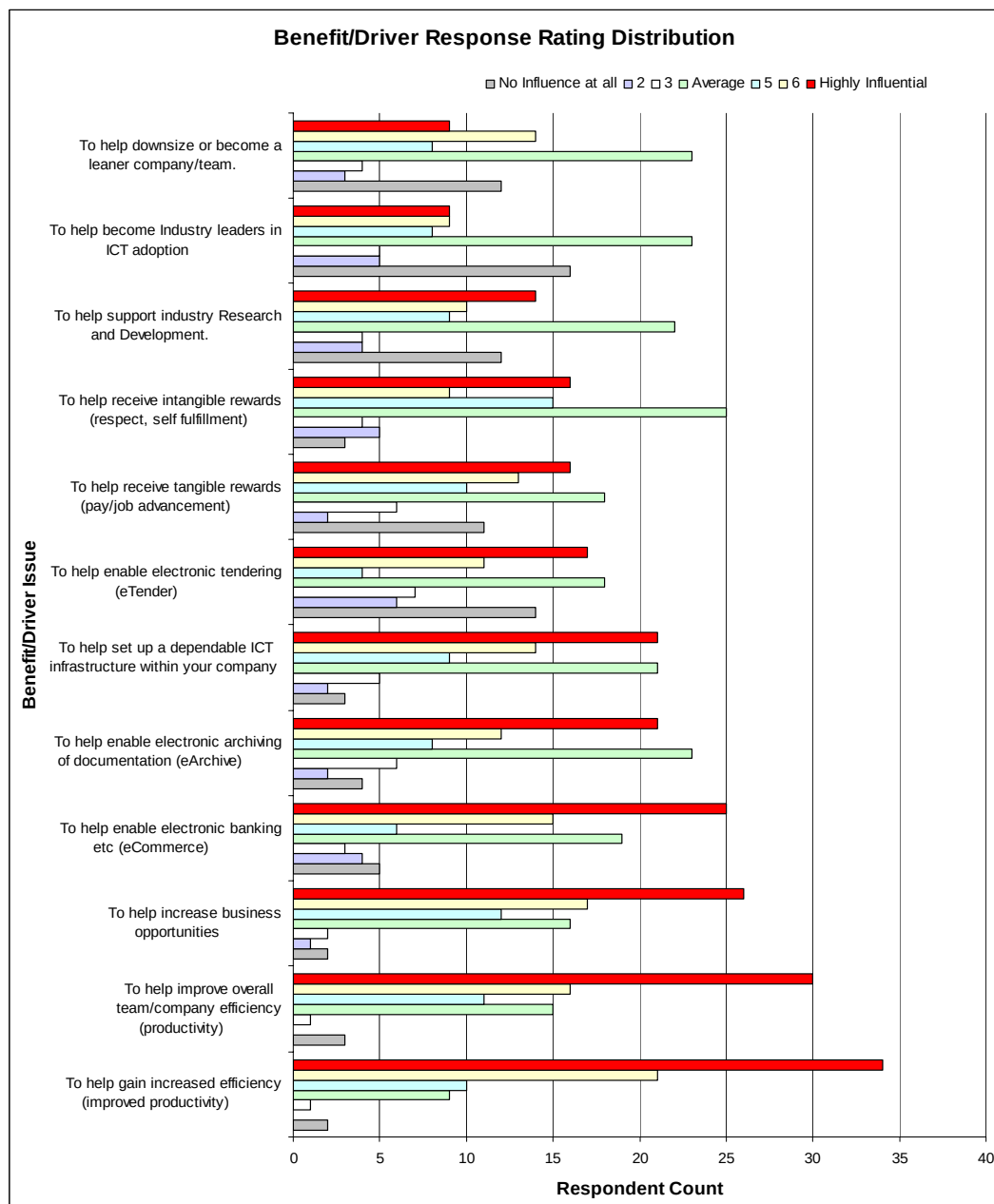


Figure 11 Response Distribution for Benefits/Drivers Influencing ICT Implementation

5.2 BARRIERS AND LIMITATIONS FOR ICT ON PROJECTS

Respondents were asked to indicate what influence a specified range of Barrier/limitation has on their decision to implement or use ICT on projects. The issues presented included:

- Barrier 1. Not having an ICT implementation "Champion" on a project.
- Barrier 2. Existing use of traditional/paper-based documentation.
- Barrier 3. The dispersed nature of the industry/projects & participants.
- Barrier 4. Having limited or no ICT Infrastructure in place.
- Barrier 5. Having limited or no ICT technical support readily available.
- Barrier 6. ICT investment restrictions due to budget constraints.

- Barrier 7. Not being aware of the cost benefits of investing in ICT.
- Barrier 8. The continuous & quick succession of ICT upgrades/advancement.
- Barrier 9. Having to use incompatible ICT hardware/software/systems.
- Barrier 10. Security issues (re project data, access etc).
- Barrier 11. Confidentiality issues (re shared project data).
- Barrier 12. Legislative issues (re contracts, electronic signatures).
- Barrier 13. Having no ICT Strategy Plan (re ICT use).
- Barrier 14. Your company's perception that ICT is not part of its core business.
- Barrier 15. Inconsistent employee requirements on projects.
- Barrier 16. Lack of ICT training & experienced (knowledge, awareness & skills).
- Barrier 17. Demanding & inflexible workload.
- Barrier 18. Having limited or no ICT training opportunities within your company/team.

The response options ranged from no influence at all to highly influential with a total of seven rating options. The mean response for these issues is displayed in Figure 12. The chart shows that all issues are grouped between slightly below to slightly above average influence and that '*ICT investment restrictions due to budget constraints*' was most influential. This result confirms results in previous sections, where in general annual turnover, hence project/organisational budget, has had a great influence on both ICT status and ICT training outcomes.

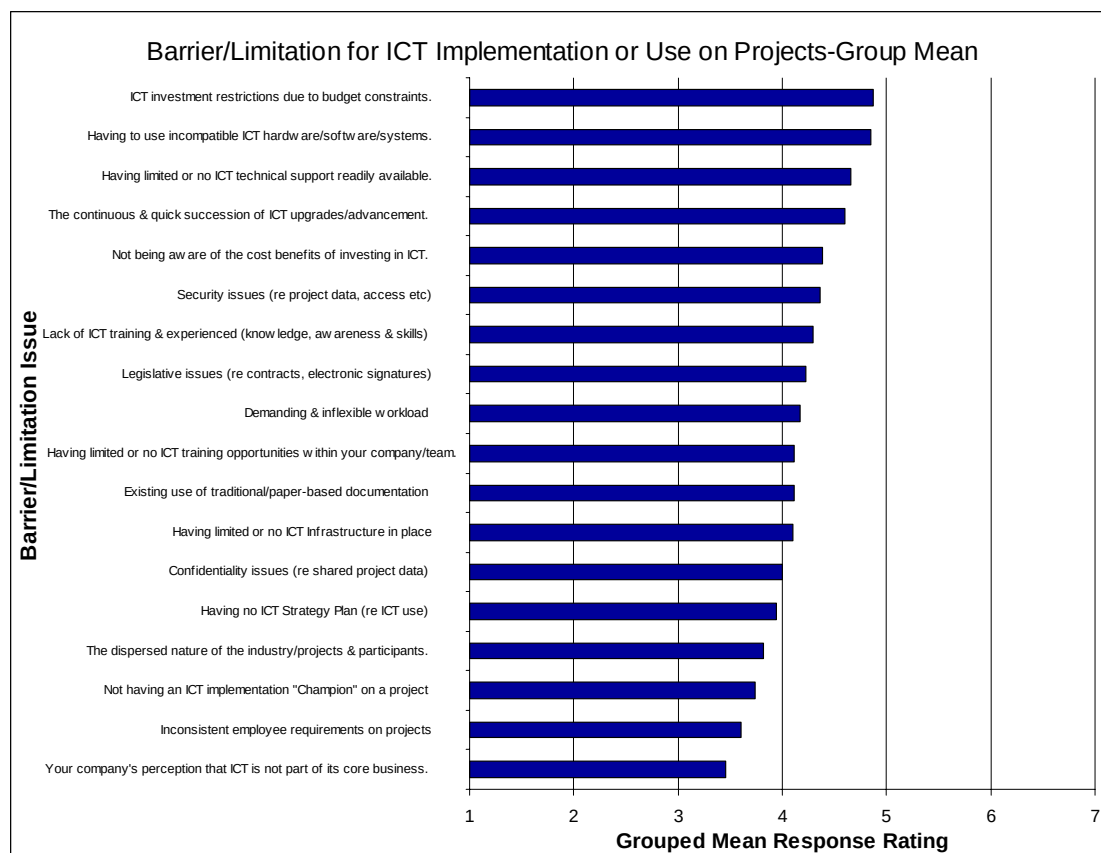


Figure 12 Mean Response for Barrier/limitation Influencing ICT Implementation

Technical issues such as *'having to use incompatible ICT hardware/software/systems'*, *'having limited or no ICT hardware/software support readily available'* and *'the continuous & quick succession of ICT upgrade/advancement'* were the next most influential barrier/limitation issues when considering to implement or use ICT on projects. The issues found to be of least influence, in order of influence include *'your company's perception that ICT is not part of its core business'*; *'inconsistent employee requirements on projects'*; and *'not having an ICT implementation "champion" on a project'*.

Another technology which is allowing interoperability amongst collaborative project members is the Internet, which through networking technologies such as Virtual Private Networks (VPN) and Application Service Providers (ASP), is allowing clients to provide services with minimal technological requirements, only requiring a Web Browser to access the project web site and sophisticated software applications. This leads to another influential (6th highest mean response) issue amongst respondents, the issue *'security issues (re project data, access etc.)'* In an electronic collaborative environment such as construction project websites, data security becomes a major consideration in the implementation and use of ICT for project participants.

Sub-sector groups were analysed to find results of any significance with regard to the barrier/limitation influencing ICT implementation or use on projects (Figure 13). Non-building construction respondents perceived *'having limited or no ICT technical support readily available'* and *'demanding and inflexible workload'* to be equally the greatest barrier/limitation influencing their decision to implement or use ICT on projects. Other issues, which have a strong influence for this sub-sector, in order of influence were *'having limited or no ICT training opportunities within your company/team'*; *'having to use incompatible ICT hardware/software/systems'*; and *'having limited or no ICT infrastructure in place'*.

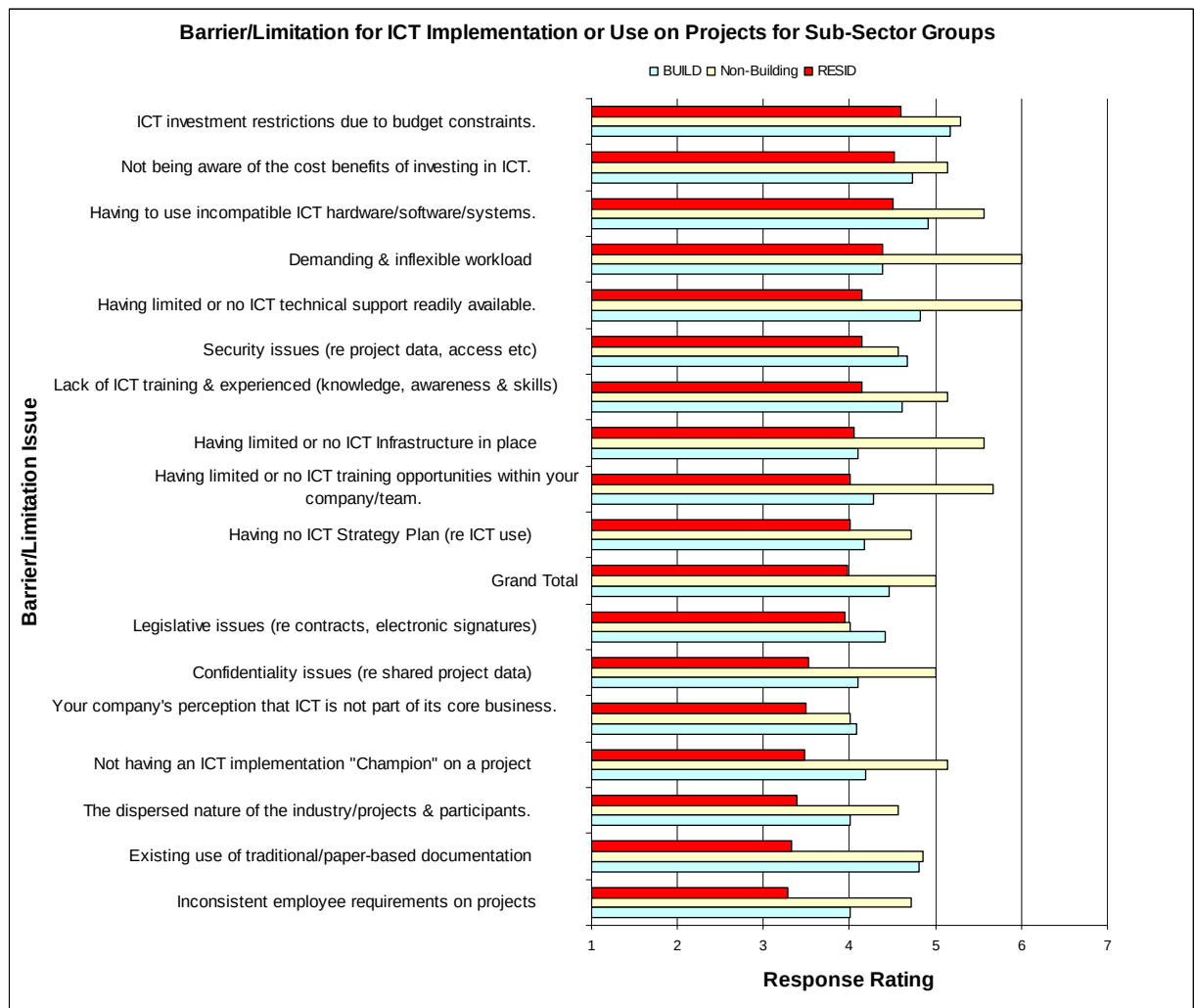


Figure 13 Mean Response for Barrier/limitation by Core Sector

It is interesting to note that '*ICT investment restrictions due to budget constraints*' was not as highly influential for this sub-sector than for the other two. This may be as a result of the relationship between ICT investment and annual turnover, where results indicate that a large percentage (86%) of the non-building sub-sector respondent organisations were in the high (greater than \$5M) annual turnover ranges. It would appear they typically have more money to invest, hence their lower perceived restriction on budgets for ICT, and their tendency to be more innovative. All of the issues presented were perceived by the non-building sub-sector to be at least an average influential barrier/limitation to ICT implementation or use on projects.

The relatively high influence of '*having limited or no ICT training opportunities within your company/team*' is an interesting result due to the fact that all respondents in this sub-sector indicated that they are allowed sufficient time during office hours to undergo official ICT training. However, only one respondent indicated that they are able to adjust or reduce their workload to undergo ICT training, indicating that workload may be a significant determining factor when it comes to ICT training for the non-building sub-sector.

Building construction (commercial/industrial) respondents perceived '*ICT investment restrictions due to budget constraints*' and '*having to use incompatible ICT hardware/software/systems*' as being the most influential barrier/limitation respectively to implementing or using ICT on projects. Other issues, which have a strong influence for this sub-sector, in order of influence were '*having limited or no ICT technical support readily available*'; '*existing use of traditional/paper based documentation*'; and '*the continuous & quick succession of ICT upgrades/advancement*'.

The residential sub-sector respondents perceived '*the continuous & quick succession of ICT upgrades/advancement*' and '*ICT investment restrictions due to budget constraints*' as their most influential barrier/limitation respectively to ICT use and implementation on projects. Other issues, which have a strong influence for this sub-sector, in order of influence were '*not being aware of the benefits of investing in ICT*'; '*having to use incompatible ICT hardware/software/systems*'; and '*demanding and inflexible workload*'.

Figure 14 displays the distribution of responses indicating what influence the range of barrier/limitation had on their decision to implement or use ICT on projects. As is clear many respondents indicated the issues had an average influence on their decision to implement or use ICT on projects.

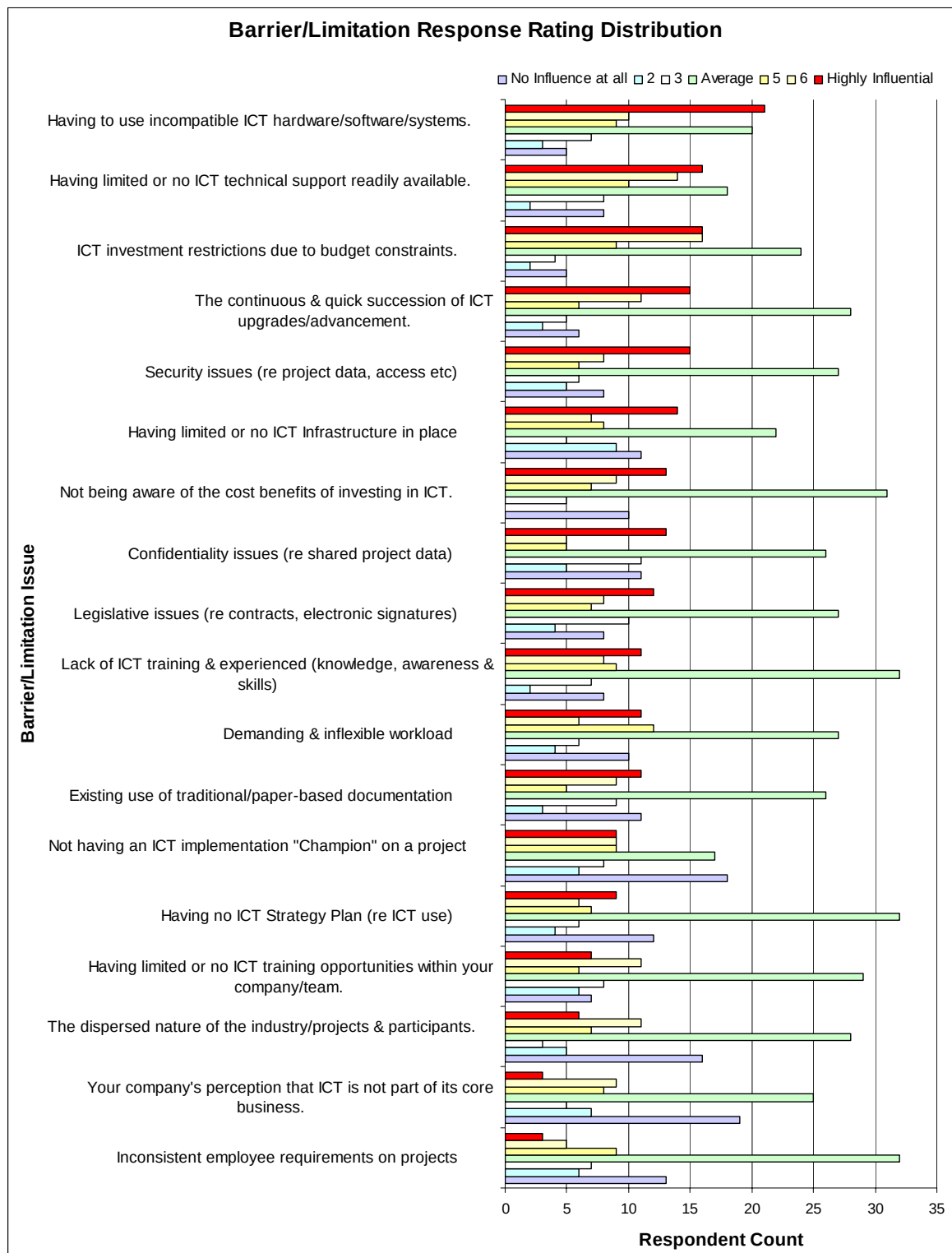


Figure 14 Distribution for Barrier/Limitation Influencing ICT Implementation

5.3 SUMMARY OF ICT PERSPECTIVES

Table 1 summarises the results of the most influential Benefit/Driver issues for respondents.

Table 1 Benefit/Driver Issue Ranking According to Respondent Group

Group	Benefit/Driver Influence Ranking				
	1	2	3	4	5
Total Mean	<i>To help gain increased efficiency (improved productivity)</i>	<i>To help improve over all team/company efficiency (productivity)</i>	<i>To help increase business opportunities</i>	<i>To help enable electronic banking etc (eCommerce)</i>	<i>To help set up a dependable ICT infrastructure within your company</i>
Non-building	<i>To help improve overall team/company efficiency (productivity)</i>	<i>*To help gain increased efficiency (improved productivity); and *To help set up a dependable ICT infrastructure within your company</i>		<i>To help enable electronic archiving of documentation (eArchive)</i>	<i>To help increase business opportunities.</i>
Building	<i>To help gain increased efficiency (improved productivity)</i>	<i>To help improve overall team/company efficiency (productivity)</i>	<i>To help increase business opportunities</i>	<i>To help enable electronic banking etc (eCommerce)</i>	<i>To help set up a dependable ICT infrastructure within your company</i>
Residential	<i>To help gain increased efficiency (improved productivity)</i>	<i>To help increase business opportunities</i>	<i>To enable electronic banking etc (eCommerce)</i>	<i>To help enable electronic archiving of documentation (eArchive)</i>	<i>To help receive intangible rewards (respect, self fulfilment)</i>

* Both had same influence and tied for second.

Table 2 summarises the results of the most influential barrier/limitation issues for respondents.

Table 2 Barrier/Limitation Issue Ranking According to Respondent Group

Sub-sector	Barrier/Limitation Influence Ranking				
	1	2	3	4	5
Total Mean	<i>ICT investment restrictions due to budget constraints</i>	<i>Having to use incompatible ICT hardware/software/systems</i>	<i>Having limited or no ICT technical support readily available</i>	<i>The continuous & quick succession of ICT upgrades/advancement</i>	<i>Not being aware of the cost benefits of investing in ICT</i>
Non-building	<i>*Having limited or no ICT technical support readily available; and *Demanding and inflexible workload</i>		<i>Having limited or no ICT training opportunities within your company/team</i>	<i>Having to use incompatible ICT hardware/software/systems</i>	<i>Having limited or no ICT infrastructure in place</i>
Building	<i>ICT investment restrictions due to budget constraints</i>	<i>Having to use incompatible ICT hardware/software/systems</i>	<i>Having limited or no ICT technical support readily available</i>	<i>Existing use of traditional/paper based documentation</i>	<i>The continuous & quick succession of ICT upgrades/advancement</i>

Residential	<i>The continuous & quick succession of ICT upgrades/advancement</i>	<i>ICT investment restrictions due to budget constraints</i>	<i>Not being aware of the cost benefits of investing in ICT</i>	<i>Having to use incompatible ICT hardware/software/systems</i>	<i>Demanding and inflexible workload</i>

* Both had same influence and tied for first.

6. CONCLUSION

The most significant observations from the survey results were that annual turnover has an effect on the uptake of ICT and training performance in ICT for an organisation.

Identified effects of budget on uptake and/or current ICT status include:

- In general, higher ICT investment was observed for higher annual turnover organisations;
- In general, higher ICT investment, hence annual turnover organisations, had a higher rate of use and access to emerging or innovative ICTs such as Handheld and Tablet computers, Video Conferencing and Wi-Fi devices; and
- The most significant barrier/limitation to the implementation or use of ICT on projects was budget constraints.

Identified effects of budget on ICT training include:

- Lower turnover construction organisation respondents were less likely to have undergone ICT training;
- Lower turnover construction organisations were less supportive of ICT training through flexible workload and time allocation; and
- Higher turnover organisations had a greater preference for the professional consultants mode of training and conversely, lower turnover organisations had a greater preference for self-learning.

Technical issues such as interoperability (incompatibility) and not having an ICT professional on site or within ready access were found to be strong influential barriers to the uptake of ICT on projects for most respondents. When investigating results according to sub-sector, several of the groups were found to rank highly issues that were not in the top five as a sample group. For example, the non-building and residential groups ranked their demanding and inflexible workloads as being in their top five barriers to uptake of ICT for projects.

The overriding driver for ICT uptake for respondents was to improve their operational performance through improved productivity at both the personal level and the organisational /team level. Improved business opportunity was also highly influential for respondents. Similar results to these were found on investigation of results according industry sub-sectors. Interestingly the residential sub-sector rated the driver of improved business opportunities higher than the other two sub-sector groups.

7. REFERENCES

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8. ACKNOWLEDGEMENTS

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PERFORMANCE BASED BUILDING

Full Paper

STAKEHOLDER ENGAGEMENT IN THE PERFORMANCE APPROACH – THE AUSTRALIAN AND EUROPEAN PERFORMANCE BASED BUILDING NETWORKS

Greg Foliente

ABSTRACT

The Performance Based Building (PeBBu) Networks in Europe and Australia have provided an unprecedented opportunity to engage a wide variety of industry stakeholders (on both “supply” and “demand” sides) in advancing the application of the performance approach in building and construction. This paper presents the background development, activities and accomplishments of these Networks. Much has been achieved, even in a short period, and these achievements and those they spawn will likely have lasting contributions and impact beyond Europe, and well beyond the formal period of PeBBu activity and funding. We also identify the primary challenges in practical application and implementation of the performance approach. To effectively engage stakeholders and increase the rate of adoption, the dominant need seems to be clear communication of the meaning, application and benefits of the performance approach, with emphasis on actual benefits and value – that is, a compelling value proposition is more important than technical achievements.

Keywords: performance approach, performance concept, stakeholder engagement, technology diffusion, EU Fifth Framework Programme

INTRODUCTION

The performance concept in building and construction had been practiced in some measure, and in very specific situations, even before it came to be formally known as “the performance approach”. The earliest, and most often repeated, example is the requirement that a house should not collapse and kill anybody in the Hammurabi Code (circa 1950 to 1910 BC). The concept is also reflected in the early architectural philosophy of the Romans, as described in Vitruvius’s (1960) landmark *“The Ten Books of Architecture”*.

Developments in the last century have led to a clearer description of what it means in both concept and practice, and what its potential, benefits and challenges are (Foliente 2000). These developments can be traced through the reports from the US National Bureau of Standards (1925, 1977), the proceedings of the series of joint CIB-ASTM-RILEM conferences on the Performance Concept in Buildings that were held in Philadelphia, USA (Foster 1972a, 1972b), Lisbon, Portugal (LNEC 1982a, 1982b), and Tel Aviv, Israel (Becker and Paciuk 1996a, 1996b) (with ISO as a co-sponsor of the Tel Aviv conference), and various CIB publications (CIB 1982, 1988, 1989, 1993, 1997).

But despite significant progress in some applications such as building regulations (IRCC 1998) and engineering design (BRI 1997, SFPE 1996, 1998, 2000), performance based building has not been applied in its entirety (Becker 1999) – i.e. across performance attributes and systematically throughout the project delivery process – and has not been adopted more widely in the industry. Thus, its full potential and promised benefits remain unrealised. There are technical and non-technical reasons for this (Becker 1999, IRCC 1998). Included in the latter is the lack of committed engagement by critical stakeholders in the full implementation of the performance approach.

In order to progress the technical developments in, and the practical implementation of, performance based building, the CIB Board and Program Committee initiated the Proactive Program on Performance Based Building in the 1998-2001 triennium (Foliente et al. 1998, Foliente 1998). Then with funding from the European Union (EU) Fifth Framework Programme, this was followed by the establishment of the Performance Based Building (PeBBu) Thematic Network, running from October 2001 to September 2005. In 2003, the Australian Performance Based Building (Aus-PeBBu) Network was also established, with funding from an Australian government department, industry partners and the CSIRO, to promote the concept in Australia and to facilitate linkages and exchange of information between the EU-PeBBu Programme/Network and the Aus-PeBBu Network.

Both EU-PeBBu and Aus-PeBBu have provided an unprecedented opportunity to engage a wide variety of stakeholders in moving towards widespread application of the performance approach in building and construction. This paper presents the activities and accomplishments of these Networks, and identifies future development and implementation needs.

KEY STAKEHOLDERS IN THE PERFORMANCE APPROACH

In broad terms, the performance approach is the practice of thinking and working in terms of ends rather than means (CIB 1982). The “ends” usually relate to technical

attributes of a building, whether expressed as a high-level goal (e.g. safety), functional requirement (e.g. structural stability) or specific performance requirement (e.g. the load-carrying capacity of a column should be greater than the vertical load it supports).

Performance based building spans the whole life of the building. It is applicable to cover different levels of the physical elements of a building (from performance of individual products or elements to performance of the whole building) and can accommodate a large set of attributes (limited only by what we can think of). It naturally affects everyone involved in the delivery and management of built assets. The list of important stakeholders include (asterisks indicate relative level of importance in hastening and widening the adoption of the concept):

• Policy makers* • Regulators** (planning, building & occupational health & safety, etc) • Building officials • Investors and financiers** • Developers** • Owners and owner-occupiers** • Architects & designers* • Engineering professionals* • Specialist consultants	• Product manufacturers* • Project managers • Builders/contractors & sub-contractors* • Facilities managers (FM)* • Service providers to FM • Owners, users/tenants** • Software/IT professionals • Researchers* • Teachers/educators*

Since the performance approach is focused on meeting the needs and requirements of those that procure the building and/or will eventually use the building (i.e. the “demand” side), their engagement is considered very critical. And their level of importance is reflected in the list above with double asterisks.

Planning, building and occupational safety regulations specify minimum requirements. When these requirements are given in performance terms, innovative or cost-effective solutions are possible. Building regulations aim to eliminate worst practice and protect building users and owners, and the community. Because of their legal status, in most countries, they can have significant influence in the industry and national economy.

The client/demand side has to know what can be asked beyond minimum requirements, be able to identify their desired building attributes, and communicate these to those who will deliver them (i.e. the “supply” side). The latter needs to be able to translate these attributes into functional or performance requirements. When progressive clients set requirements above and beyond those required in the building code or by regulations, they encourage and promote best practice.

Classification of stakeholders as demand and supply sides is a convenient simplification. In reality, however, the industry cannot be so easily categorised as consisting of these two sides. Some stakeholders, in some instances, can be on both sides (e.g. a developer), and in other instances be on either side. Since the performance approach is mostly about fulfilling the desired “ends” of the demand side, any project that involves educated and innovative stakeholders on the demand side and well-equipped stakeholders on the supply side have a much higher possibility of success.

Researchers and teachers (of tertiary/professional and trade/technical students), who do not fit nicely into the demand and supply classifications, also play crucial roles in advancing knowledge and understanding, developing tools and methods, and educating and equipping the other stakeholders.

THE PeBBu NETWORKS

The main objective of the EU-PeBBu Network is to actively facilitate knowledge dissemination and practical implementation of the performance approach in building and construction practice worldwide. The EU-PeBBu activities were aimed at maximising the contributions to this effort by the international research and development (R&D) community. With the CIB Development Foundation (CIBdf) running the secretariat and programme coordination and management, the natural starting point for stakeholder engagement is the CIB membership and network. The following stakeholder groups are, therefore, well represented in the PeBBu network: R&D agencies, universities, progressive companies and consultants, regulatory and standardisation bodies, and professional organisations and associations.

COMPONENTS OF EU-PeBBu

The current PeBBu programme¹ is presented in Figure 1b. It includes the following “core” components:

- International programming/coordination of research within **6 Scientific Domains**
- Involvement of target groups/stakeholders through **3 User Platforms**: (a) Buildings Owners, Users and Managers, (b) Building and Construction Industry, and (c) International Standardisation and Conformity Community
- **4 Regional Platforms** in Europe to act as the bridge to and the initiator of aligned national activities (Northern, West/Central, East and Mediterranean)
- **Network Management** - through a Network Steering Committee, a Technical Committee and a Network Secretariat
- **Mapping of national and international research** related to various aspects of Performance Based Building.

At the onset of PeBBu, the programme had 9 scientific domains (Figure 1a). These spanned across the various themes and aspects of performance based building. Midway through the project, three of these domains (“Built Environment”, “Organisation & Management” and “Information & Documentation”) were terminated because the scope of these domains was too vast, research was slow or inactive, and/or they overlapped with other domain topics.

Some other relevant topics arose and were developed as new tasks to replace the terminated domains. These are:

1. Performance based building & the EU Construction Products Directive (CPD)
2. Decision making tool-kit for performance based building
3. Sustainability indicators for performance based building.

In addition to the core components, various aligned activities in support of PeBBu have been in operation (Figure 1b). They contribute significantly to the PeBBu Network, but are not directly funded from the EU-PeBBu budget.

¹ More detailed information on the PeBBu Network, its program of activities and its organisation can be found in the PeBBu website <http://www.pebbu.nl>

KEY ACCOMPLISHMENTS OF EU-PeBBu TO DATE

The PeBBu Network has made considerable progress in its few years of operation. Some of the main achievements to June 2004 include:

- o **Expansion of the Network through the Newly Associated States (NAS) and observer-members.** Several Eastern European countries have been added to the Network as Newly Associated States (NAS) and 13 new organisations from these countries are now members of the PeBBu Network. In addition, several observer-members, from non-EU countries, have become a part of the Network.
- o **Establishment of aligned activities such as the PeBBu Compendia.** The Compendium of Performance Based Building Models includes database that at present includes more than 30 different models. The Compendium of Statements of Requirements aims for the development of a consensus derived performance based building conceptual framework and key terminology.
- o **Production of 9 scientific domain reports**, which summarise the main content-based work and results emanating from the domain work and workshops along with 9 international R&D agendas.
- o **Production of the International State of the Art (SotA) Report**, which gives an overview of the status of performance based building in an international context. The International SotA analyses the spread of performance based building principles through many National SotA reports from the European context, and reviews the use of these principles in other parts of the world. The International SotA has been published as a CIB special publication (2003). An East European SotA Report has also been produced.
- o **Establishment of many strategic relationships.** Examples of these are:
 - The relationship between PeBBu Domain 1 and ISO, which has influenced the writing of standards related to the durability of construction materials and components;
 - Co-operation with ISO TAG8 (the ISO Technical Advisory Group that is responsible for building related standards) on a multi-year programme within ISO that aims for the production of performance based standards that are to replace or to be added to the current prescriptive ones;
 - Other strategic relationships including PeBBu and aligned activities have influenced new work in the Indoor Environment area;
 - The relationship that PeBBu has established with the E-CORE projects where performance based building will be one of the main building blocks in a future European Research and Development (R&D) strategy.
 - Co-operation with the Liaison Committee of International Associations of Civil Engineering aiming for the establishment of a joint committee on Performance Based Building and Pre-Standardization in Civil Engineering.
- o **Moving towards a consensus on language, concepts and issues.** This is mainly a result of the performance based building compendium on Statement of Requirements.
- o **Involvement with/and support of several CIB Commissions.** This aspect has been further detailed at a later stage in this paper.

THE AUS-PEBBU NETWORK

An Australian version of the PeBBu Network (or Aus-PeBBu)² was launched in October 2003. With one exception, its program matches the revised scientific domain themes in EU-PeBBu, to provide one-to-one correspondence of efforts and to maximise opportunity for participants in both Networks to discuss similar topics and issues and to cooperate on matters of mutual interest.

The main difference in the program is the inclusion in Aus-PeBBu of a domain “Sustainable Built Environment”. With significant national and international interests, initiatives and investments in sustainable development, this topic provides a great opportunity to introduce the performance approach to a sector of the industry that is progressive, innovative and growing fast. With much dependence on the current use of environmental or “green” rating and assessment tools, and the promotion of demonstration projects, there are indicators that many are implicitly adopting a prescriptive approach.

Australia is one of the leaders in the move from a more prescriptive to a more performance based building code and is actively involved in international and national developments in this area. [The Australian Building Codes Board is involved, for example, with the Inter-jurisdictional Regulatory Collaboration Committee (IRCC)³ and Aus-PeBBu.] But with less funding and much smaller scope than the EU programme, Aus-PeBBu has a relatively stronger focus on facilitating the proactive application of the performance approach through best practice project delivery processes. It aims to contribute to the following areas of long-term development:

1. Establishment of a basic framework (including performance indicators) and clarification of terms and definitions;
2. Establishment of (multi-level) performance criteria for attributes that do not yet have these;
3. Development and publication of a guide on methods of establishing/setting performance; and
4. Expansion and maintenance of the database compendium of performance models, tools or methods that can be used to achieve targets (e.g. during design), and to assess/verify/evaluate performance in-service.

Lack of understanding, relevant information and appropriate tools/methods on the topics listed above hinder the practical implementation of the performance approach.

While addressing these four focus areas assist both the demand and supply sides, the degree of assistance will tend to favour the supply side. To encourage the stakeholders in the demand side, we need to establish the benefits and value of the performance approach. This has previously been identified as a priority area in the CIB’s Proactive Programme on Performance Based Building from 1998-2001 (Foliente 1998) and a CIB report has identified opportunities and challenges (Tempelmans Plat and Hermans 2001). Aus-PeBBu will also initiate a collection of case studies of projects relevant to Australia where the performance approach has been used before and where benefits have been gained.

² More detailed information on the Aus- PeBBu Network can be found in <http://www.auspebbu.org>

³ IRCC is an unaffiliated committee of ten of the leading building regulatory agencies from eight countries; see <http://www.ircc.gov.au/> for further details.

The last area of difference between Aus-PeBBu and EU-PeBBu is the participation of different stakeholders (both demand and supply sides) within each domain in Aus-PeBBu; i.e. there are no separate user platforms. Anyone interested in the technical domains can participate; demand side representatives are actively sought. Communication and social integration of stakeholders are encouraged.

IMPLEMENTATION NEEDS & CHALLENGES

STAKEHOLDER ENGAGEMENT

Within corporate and government client organisations, project decision-makers are often unaware of the concept, application and benefits of the performance approach. Our experiences with the PeBBu Networks confirm that the key to hastening and widening the adoption and implementation of performance based building within a country or region is actively engaging, and then motivating in a sustained way, critical industry stakeholders, especially those on the demand side. Even among these stakeholder groups, we need to identify the key opinion leaders, innovators, connectors and early adopters that can show the way in practical applications, benefit from it and help communicate to others the value of the performance concept. When the “early majority” adopt the approach (Figure 2), reaching an industry tipping point is more likely (Gladwell 2000; Foliente and Boxhall 2002). This is, therefore, one of the big challenges: identifying and demonstrating the value and benefits to these stakeholder groups. This also links the performance based building programme with the CIB proactive programme on Revaluing Construction.

In the international arena, although there is a growing interest in performance based building applications, both concept and language difficulties pose a major barrier to stakeholder engagement. There is fragmentation and divergence in understanding the concept and applications. Many factors affect this issue (Foliente et al. 1998).

In summary, the dominant need in stakeholder engagement seems to be clear communication of meaning, application and benefits of the performance approach, with emphasis on benefits and value. In other words, technical issues should give way to a compelling value proposition.

TECHNICAL CHALLENGES

The broad technical challenges in performance based building have been previously identified in Foliente et al. (1998), IRCC (1998), Becker (1999) and Foliente (2000). The primary technical challenges include the following:

1. *Establishing target performance or outcomes* including objectives, functional attributes and performance requirements – beyond what are covered by building codes – as part of a project brief is currently seen as very onerous, if not very difficult. Both large repeat “clients” and one-time or occasional “clients” would benefit from a broad framework of requirements, which can serve as a checklist or reminder of performance outcomes to consider, and a set of guidelines on how to set these outcomes or targets.
2. *The right tools or methods* to design or deliver solutions to meet target performance or outcomes, *and* to assess/evaluate whether a given design or solution meet these targets need to be provided. The CIB initiative on developing a Compendium of Building Models and Tools (which can be accessed through the Aus-PeBBu website) was an initial attempt to collect and provide a central database of these tools that can be accessed by anyone anywhere. But until this

develops into a critical mass, and tool developers submit information and stakeholders access the information on a routine basis, it will have limited impact. There are a few areas of performance that have lots of tools and there are many that have no available tools. Where tools are available, appropriate guidelines on use, scope and limitations are required. The applicability of some tools is very specific to a country or local environment.

3. *The extent of development and depth of knowledge are very uneven across technical/functional topics (e.g. structural performance vs. indoor environment; fire safety performance vs. sustainability, etc). Multiple levels of quantified performance criteria are possible in one area but only a qualitative statement of requirements is possible in another area. Design tools and methods are available for one but not for another.*
4. *The inter-relationship of performance attributes is not always well established or understood, and requires much further research and development. This inhibits optimum design, considering system performance where competing requirements need to be considered (e.g. structural safety vs fire safety vs sustainability/service life).*

IMPLEMENTATION AND APPLICATION

In regulatory applications, the IRCC has done much in sharing knowledge and experiences in the development and implementation of performance-based building codes in developed countries with strong legal and technological foundations. Other developed countries can obtain much potentially useful information from IRCC reports and publications. But other countries, especially the developing countries, need further materials and guidance on how to implement the performance concept in their own building codes. It is not appropriate for these countries to directly adopt those published in, and for, developed countries. Depending on many local factors – such as original content of building codes, legal status of, and degree of compliance to, local building codes, building approval process, degree of development and practice of quality control, certification and assurance (at both product and building levels), extent of involvement of professionals, etc – the appropriate mix of performance-based and prescriptive provisions in the code will differ. In other words, the entry point into the pathway of performance based building code development will be different for different countries or groups of countries. Guidelines to assist regulatory bodies in these countries will be helpful.

In trade applications, there is still much industry confusion on both requirements and processes for acceptance of products or methods from one country to another, even in a country where a performance-based building code is already in operation. Within Europe, the introduction and implementation of the CPD require supporting documents or guidelines. EU-PeBBu has initiated a new task to provide further practical explanations of what CPD means in the context of performance-based trade. In other countries where local building regulations and standards are unclear about required performance, ISO standards are sometimes accepted. Thus, ISO standards need to be consistently framed in performance terms.

In encouraging best practice in building procurement and production process, there is need for a facilitating platform (Becker 1999) and/or successful example(s) where the performance concept can be or has been used in its entirety from project definition to handover/commissioning and in-service/occupancy stage, and with as wide a set of performance attributes as possible. The process or successful example(s) should be

fully documented to serve as a guide for others to try the *full* application of the performance approach in their projects.

CONCLUDING COMMENTS

The PeBBu Networks have kick-started a range of activities, not only in Europe, but also in other parts of the world that contribute to the engagement of industry stakeholders, the sharing of knowledge and experiences, trade facilitation, establishment of worldwide networks of agencies and professionals, and further development of performance based building. Much has been achieved even in a short period, and these achievements and those they spawn will be likely to have lasting contributions and impact beyond Europe, and well beyond the formal period of PeBBu activity and funding.

To effectively engage stakeholders and increase the rate of adoption of the performance approach, the dominant need seems to be clear communication of the meaning, application and benefits of the performance approach, with emphasis on actual benefits and value. Thus, priority effort is required to: (1) determine the value and benefits of performance based building for different stakeholder groups, underpinned with actual case studies, and (2) package them for a compelling presentation to these stakeholders. This will facilitate client- or demand-driven innovation, made possible by the performance approach.

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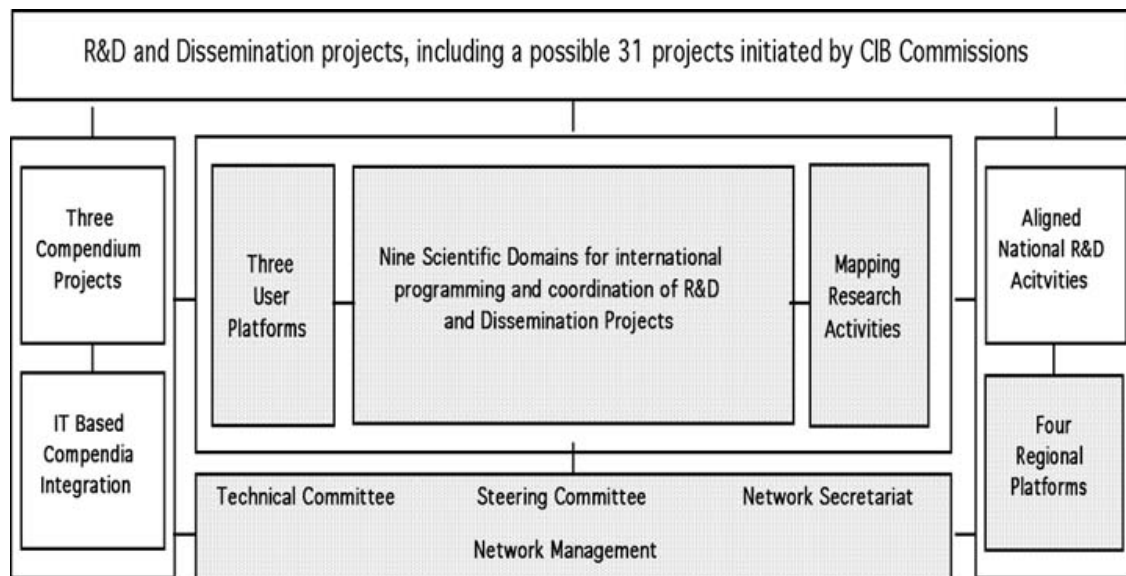
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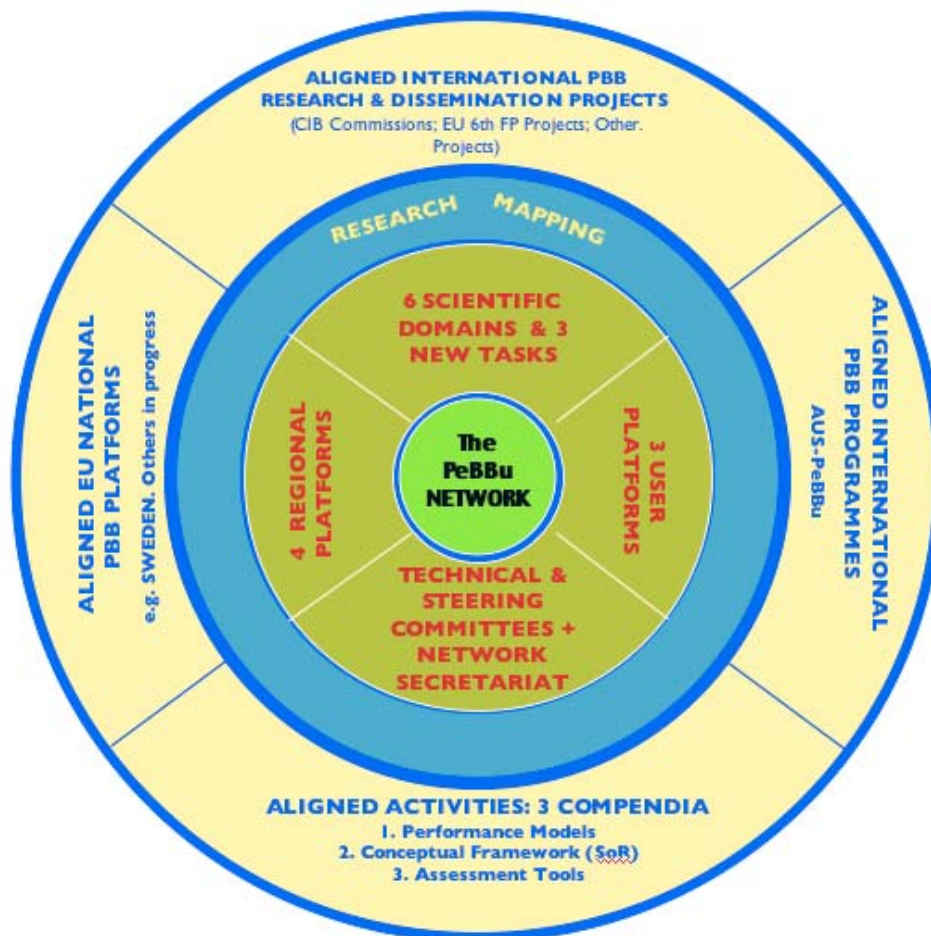
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(a) Original Programme



(b) Revised Programme

Figure 1. The EU-PeBBu Programme

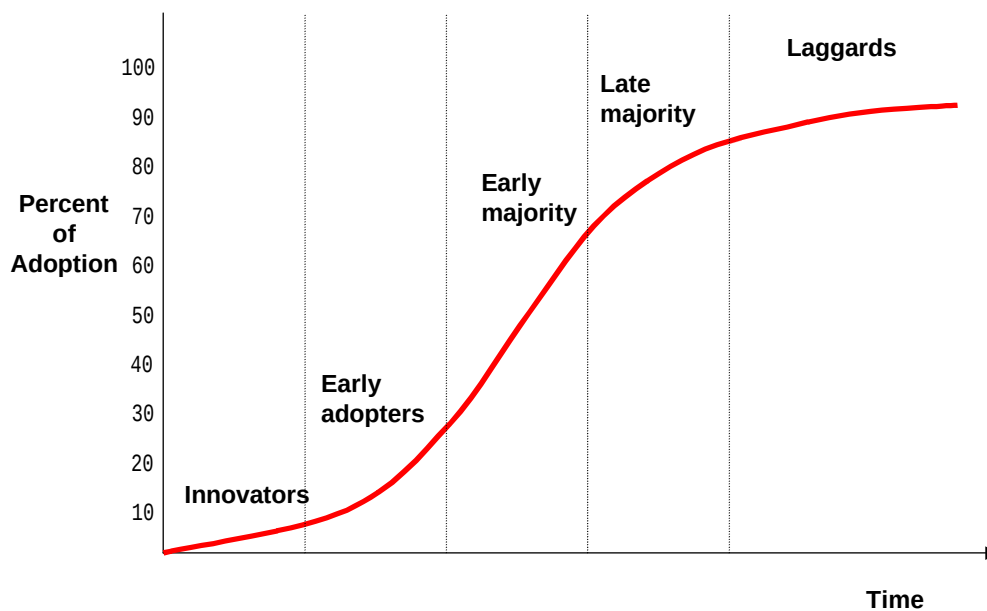


Figure 2. Adopter types in the diffusion process (Smale 1996)

INNOVATIVE ASSET MANAGEMENT

Full Paper

FORECASTING PROPERTY PERFORMANCE

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ABSTRACT

The office construction industry is driven by space supply and demand which are, in turn, driven by the vitality of the commercial property market and the economy. International research has defined the key determinants for propelling new office space supply as: rent levels; vacancy rates; existing stock; office based employment growth; and the level of economic activity. Office markets, internationally, have at times through history experienced the spectre of space oversupply causing financial adversity for construction industries, commercial property markets and economies.

Initially, this paper examines the success, or otherwise, of property market modelling in the international context to determine its potential for mitigating the advent of office space supply shocks. More specifically, the market history and forecasts for the Australian city of Brisbane are examined to explore the financial performance impacts on four individual office towers built in four different decades. Building specific modelling is used to derive evidence of market impacts on property values. The physical attributes of the individual buildings are considered in terms of their past and future contributions or impediments to the overall investment performance of the properties.

The findings illustrate the importance of modelling the functional performance of CBD office buildings with the inclusion of professional capital expenditure projections and plausible property market and economic forecasts. The potential benefits to be derived by property owners and developers include the optimisation of returns and the provision of a decision support tool for astute selection of buy, sell, hold and refurbish options.

Keywords:

Office Buildings, Forecasting, Econometric Modelling, Discounted Cash Flows

1. INTRODUCTION

This research was funded by the Cooperative Research Centre for Construction Innovation, part of the Australian Government's CRC Program.

Property valuers, analysts and fund managers rely on discounted cash flow analysis techniques as a main method of assessing values and investment returns for established commercial buildings and assessing viability measures for proposed commercial developments. Surveys of major property fund managers based in Sydney and Melbourne (Parker, 2003) and of prominent valuation firms in the Brisbane Central Business District (Cowley, 2004) have confirmed the reliance property professionals place on this method. Discounted cash flow analysis requires the forecasting or projection of the net cash flow stream from a building or development and the discounting of this cash flow back to a present value using a market derived discount rate. In the case of a proposed development, the discount rate is the developer's required rate of return and the analysis determines whether the proposal is viable within their required parameters. The analysis also establishes what price a developer can afford to pay for a site while maintaining the viability of the project.

In order to provide some guidance on this assessment process, an extract from a sample cash flow study is inserted below with descriptive annotations.

Total Capital Discounted Cash Flow Analysis											
Annual cash flow forecast for the 10 year period 1 Jul 2003 to 30 Jun 2012											
111 George Street											
Key Assumptions											
Holding Period	10 years										
Assessment Intervals	Monthly										
Discount Rate	10.50%										
Effective Monthly Discount Rate	0.836%										
Terminal Cap Rate	8.25%										
Results											
ESTIMATED PRESENT VALUE 10.5% discount rate 104,646,340											
Less Purchase Costs											
ESTIMATED CURRENT MARKET VALUE 104,646,340											
MARKET VALUE Purchase Price Say 8 \$ 104,650,000											
Annual Term Commencing Period											
	01-Jul-03	01-Jul-04	01-Jul-05	01-Jul-06	01-Jul-07	01-Jul-08	01-Jul-09	01-Jul-10	01-Jul-11	01-Jul-12	01-Jul-13
	0	1	2	3	4	5	6	7	8	9	10
GROSS INCOME											
Retail Rental Income	62,330	62,479	63,697	69,446	78,993	84,996	85,961	85,961	85,961	85,961	85,961
Commercial Rental Income	9,597,595	9,597,595	9,665,901	9,665,901	12,359,571	12,359,571	13,109,498	13,109,498	13,109,498	13,109,498	13,109,498
Car Park Rental Income	440,700	440,700	452,727	452,727	589,188	589,188	637,156	637,156	637,156	637,156	637,156
Naming Right Income	-	-	-	-	-	-	-	-	-	-	-
Communication Income	22,080	22,454	23,123	24,087	24,999	25,666	26,178	26,792	26,792	26,908	26,367
Storage Income	81,317	81,317	93,623	93,623	119,714	119,714	126,978	126,978	126,978	126,978	126,978
Total Gross Income	10,204,022	10,204,545	10,299,071	10,305,784	13,172,465	13,179,135	13,985,771	13,986,385	13,985,863	13,986,501	13,985,960
EXPENSES											
OPEX Inclusive of Land Tax	2,173,504	2,223,599	2,304,428	2,401,734	2,480,959	2,536,313	2,587,792	2,653,261	2,597,707	2,665,592	2,608,017
Bad Debt and Vacancy Allowance	-	-	-	-	-	-	-	-	-	-	-
Incentives and Agents Commission	-	-	-	-	-	-	-	-	-	-	-
Net Income	8,030,518	7,980,946	7,994,642	7,904,050	10,691,505	10,642,823	11,397,979	11,333,124	11,388,156	11,320,910	11,377,944
CAPITAL EXPENDITURE											
Total	393,457	383,917	736,707	504,984	987,217	957,470	979,492	775,801	979,492	775,801	979,492
NET TERMINAL VALUE											
Sale Price	-	-	-	-	-	-	-	-	-	134,485,695	-
Less Sale Costs	-	-	-	-	-	-	-	-	-	2,689,714	-
NET CASH FLOW	7,637,062	7,597,029	7,257,936	7,399,066	9,704,288	9,685,353	10,418,487	10,557,323	10,408,664	142,341,089	10,398,452
Running Yield on Purchase Price											
	7.7%	7.6%	7.6%	7.6%	10.2%	10.2%	10.9%	10.8%	10.9%	10.8%	10.9%

Figure 1 – Sample Discounted Cash Flow Analysis for Office Building – Source – CRC for Construction Innovation (2004)

1	Some key assumptions including the selected discount rate and terminal yield
2	Annual gross rent income figures for the different space categories
3	Line entries for monthly operating expenses, vacancy allowances and incentives
4	Capital expenditure projections
5	Calculated terminal sale price and selling expenses
6	Building's projected net cash flow including net sale proceeds less selling costs
7	Running yield on purchase price giving annual net return on initial investment
8	Cash flow analysis output displaying the property's rounded present value

Without specifying full technical details, brief explanations of some of the terms used in this model include:

- Terminal yield – market derived multiplier used to estimate the value of the property at the end of the study period;
- Vacancy allowance – provision for the loss of future building income due to space becoming vacant and the anticipated time taken to re-let the space;
- Incentives – inducements offered to encourage new or existing tenants to sign new leases; and
- Capital expenditure – projected costs of replacing or upgrading major building services, structural components and finishes.

As can be seen in the structure of this model, the net cash flow stream is determined by deducting projected building operating expenses, capital expenses and various allowances from the building's predicted rental income and sale price over the study period.

The purpose of this introduction to discounted cash flow studies is to emphasise the role forecasts play in determining the value and investment performance of commercial properties as well as the viability of commercial development proposals. The studies are influential in guiding development and, therefore, propelling construction activity in city and urban areas. Additionally, measures of the viability for rural ventures can rely on such studies (McCarthy, 2004).

This leads to the question as to how commercial building rent forecasts are formulated for cash flow studies.

2. LITERATURE REVIEW

2.1 RENT FORECASTING

Research on office rent forecasting has had an intrinsic association with property market modelling involving the development of equations that simulate the markets' responses to changes in various determinants. Correlation analysis using historical data has generally been used to identify the property market and economic variables that influence changes in the levels of office rents. Once the explanatory variables have been established, experimentation and testing is undertaken to estimate an equation with best historical fit. This equation is then

used to “cast” forward rental values based on changes (or forecast changes) in the rent determinants, sometimes referred to as leading indicators (Chaplin, 2000).

Rosen (1984) signalled a problem in forecasting methods stating “*trend-line accounting techniques*” used at the time were inadequate in replicating the supply and demand relationships in the property market. He then proceeded to develop a multiple equation model to represent the relationships in an American office market. The main determinant chosen for the rent equation was the variation between the “optimal” office vacancy rate and the actual prevailing vacancy rate. This concept resurfaced in much of the subsequent American research (such as Wheaton, 1987; Wheaton & Torto, 1988; and Shilling, Sirman & Corgel, 1987). However, the “optimal” vacancy rate received several different names, including “desired”, “structural”, “natural” and “equilibrium” vacancy rate. Generally, the concept considered the office market vacancy rate to be mean reverting and the difference between the prevailing vacancy rate and the long-term average vacancy rate significantly influenced the future direction of rental levels.

During the same era research occurring across the Atlantic (Gardiner and Hennerberry, 1988:36) raised similar concerns about the methods used for forecasting office rents. It was stated that foregoing studies were, “*theoretically weak, methodologically under-developed or of limited practical application*” and the authors set out with an objective of “*constructing a theoretically sound, empirically based, rent prediction model*”. Notably this study commenced a long-term inconsistency between American and British research with the adoption of a demand-side variable (Gross Domestic Product) as the key office rent determinant rather than the US supported vacancy rate variable. In addition, Gardiner and Henneberry argued rent forecast models should be formulated on a “spatially disaggregated” basis rather than on a national basis due to different market influences existing in different localities.

Subsequent research (Clark & Dannis, 1992) suggested rent forecasts should be linked to construction costs and investors’ required rates of return.

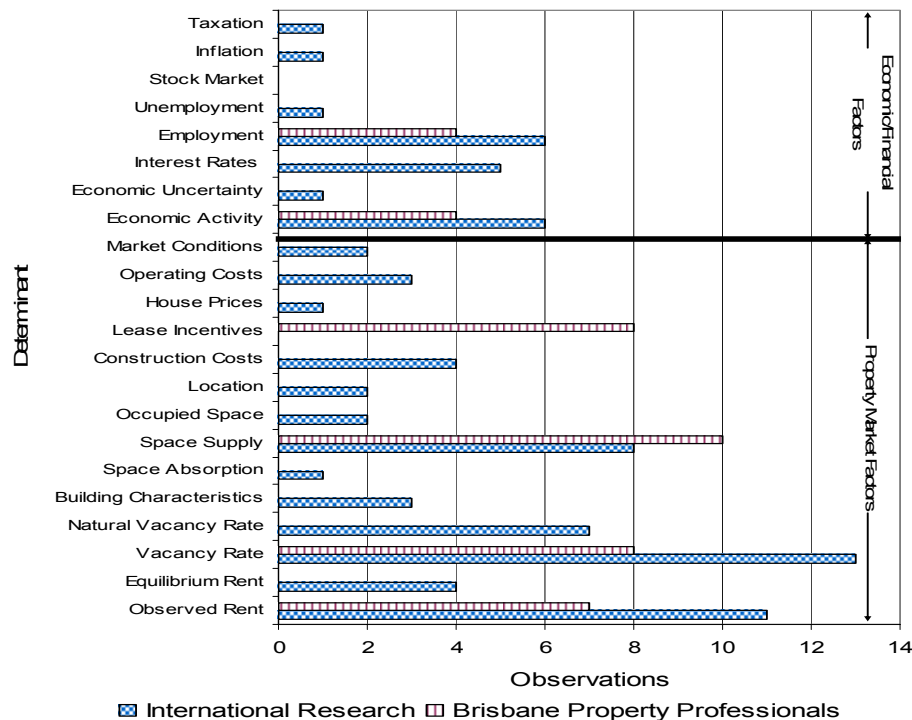
Further English studies (Giussani, Hsia & Tsolacos, 1993 and Giussani & Tsolacos, 1993) examined rent determinants in ten European cities including London. The focus continued on Gross Domestic Product and office based employment as the key drivers of rent levels. Some difficulties were encountered in modelling European city markets aside from London.

Several models have been developed with the aim of forecasting rents at an individual building level based on the physical characteristics of the buildings and their locations within cities (Glascok, Kim & Sirmans, 1993; Dunse & Jones, 1998; and Dunse & Jones, 2002). A notable omission in research to date is the lack of a link between the individual building rent models and the “citywide” rent forecast models.

More recent rent models (DiPasquale & Wheaton, 1996 and Hendershott, Lizieri & Matysiak, 1999) have included an “equilibrium” rent determinant suggesting the level of office rent is mean reverting. However, in terms of previous assumptions that “equilibrium” vacancy rates are constant through time, a recent study has proposed that they are at least partly “time-varying” and models should make allowances for these variations (Tse & Fischer, 2003).

Published Australian research on rent modelling has been very limited. Commercially used models are rarely published for intellectual property reasons and this has been the experience overseas (Mitchell & McNamara, 1997). An attempt was undertaken to adapt the Royal Institute of Chartered Surveyors’ London rent model to the Sydney market with little success due to market and data incompatibilities (MacFarlane, Murray, Parker & Peng, 2002). This trial did, however, find a strong linkage between Sydney’s vacancy rate and the level of office rents prevailing in the city. Murray (2000) had also adopted the vacancy rate with new space supply as the main drivers for her earlier published model for Sydney. Conversely, Higgins (2000) adopted Gross Domestic Product, inflation and interest rates as explanatory variables for Sydney CBD rents, but found the reliability of macroeconomic forecasts needed for the single equation to be a serious handicap to the accuracy of office rent forecasts.

In summary it is interesting to observe a comparison of the relative level of use of different explanatory variables in 22 rent models developed internationally and detailed over time in literature on the subject. The following chart illustrates this analysis as well as superimposing the views of Brisbane property professionals on the city’s office rent drivers established from an interview survey (Cowley, 2004).



This representation clearly shows a research and industry reliance on observed rents, vacancy rates and space supply as the property market drivers in modelling and forecasting office rent. Local property professionals also see lease incentives as a significant influence. A consensus exists on adopting economic activity and office based employment as the key economic explanatory variables.

2.2 SPACE SUPPLY FORECASTING

The literature has nominated office space supply as a significant determinant of office rent levels. There has also been significant research indicating oversupply in office markets has, over time, amplified the cyclical nature of commercial property markets. Office building development lags have been credited with at least partially generating “*powerful, pervasive and self-replicating*” cyclical forces within the commercial property market (Barras, 1994). The periodic historical misallocation of resources to office construction has also been said to have been cause of financial distress in the industry and, on a wider scale, a significant factor in precipitating the last Australian recession (Kummerow, 1997). In referring to the United States office space oversupply event in the late 1980s, Gallagher and Wood (1999) said the market was prone to overbuilding and this was known to cause the poor performance of office property. Mueller (1999) coined the term “hypersupply” of office space and indicated the cause as being the lag between demand growth and supply response.

Thirteen internationally office space supply models were identified through an analysis of literature on the subject. The space supply determinants adopted by the researchers are shown in *Table 1* and *Chart 2*, below, summarises the relative dominance of the adopted variables.

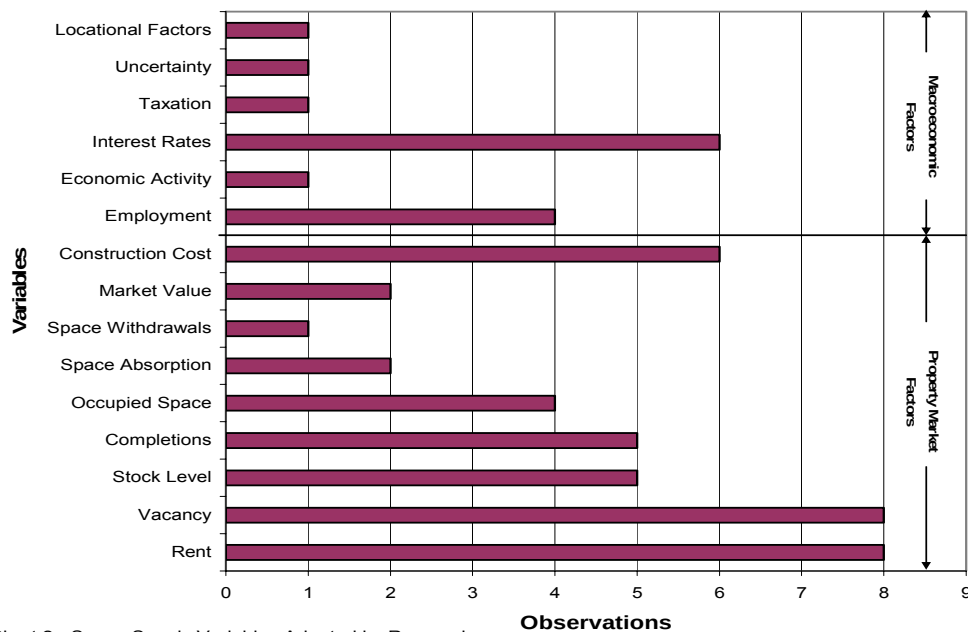


Chart 2 - Space Supply Variables Adopted by Researchers

Researcher(s) / Year	Rent	Vacancy	Stock Level	Completions	Occupied Space	Absorption Space	Space Withdrawal	Market Value	Construction Cost	Employment	Economic Activity	Interest Rates	Taxation	Uncertainty	Locational Factors
Rosen (1984)															
Hekman (1985)															
Wheaton (1987)															
Gardiner & Henneberry (1988)															
Hendershott, Lizieri & Matysiak (1996)															
DiPasquale & Wheaton (1996)															
Wheaton, Torto & Evans (1997)															
Viezer (1999)															
Tsolacos & McGough (1999)															
Sivitanidou & Sivitanides (2000)															
MacFarlane & Moon (2000)															
MacFarlane, Murray, Parker & Peng (2002)															
Tse & Webb (2003)															
Observations	8	8	5	5	4	2	1	2	6	4	1	6	1	1	1

Table 1 – Office Space Supply Explanatory Variables Adopted by Researchers

From this summary it is possible to distinguish rent, vacancy rates, lagged completions and construction costs as the most represented property market variables while employment and interest rates appear as the dominant macroeconomic variables used to model and forecast office space supply.

Despite there being a significant amount of literature on the subject, little evidence of successful out-of-sample space supply forecasting has emerged. A study of office space supply forecasts in Australia (Higgins, 2003) found past short-term forecasts were lacking accuracy, even beyond a period of just 12 months. The difficulties of predicting the levels of refurbished space re-entering the office market was nominated as one cause of the shortcomings.

3. SAMPLE OFFICE MARKET – BRISBANE CBD

3.1 LAND USE PROFILE

Brisbane is the capital of the Australian State of Queensland and is the third largest Australian central business district in terms of office floor area with a total net lettable area of approximately 1.65M square metres.

An analysis undertaken using data collected from the Cityscope (2003) publication, indicates that the total developed lot area in the Central Business District is approximately 74 hectares, including 447 individual properties. After allocating primary land uses to each of these properties, the apportionment of developed land area to each use is represented in the following chart.

Brisbane CBD Land Uses by Area

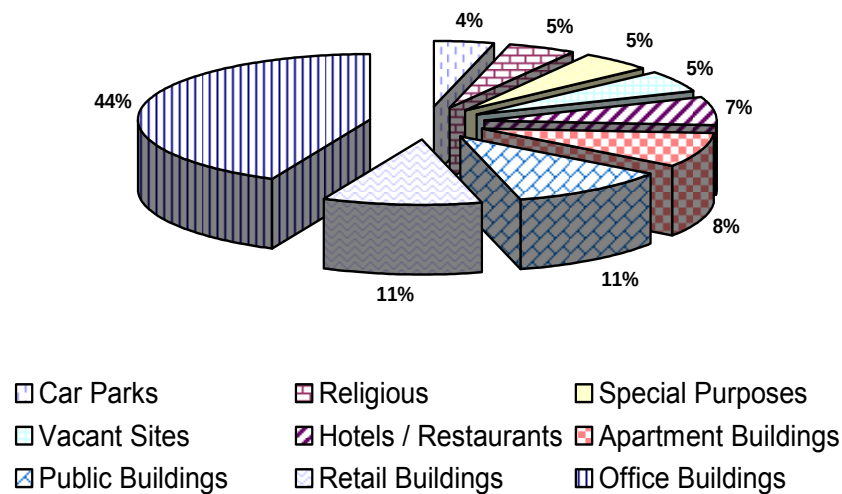


Chart 3 – Brisbane Central Business District Land Use Apportionment Based on Land Area

The dominant land use is office buildings occupying about 44 percent of the city's developed land or nearly 32 hectares. Retail uses occupy about eleven percent and a similar area is used for public buildings, such as, for example, law courts and city hall. Residential apartment buildings, either established or under construction, cover approximately 7.5 hectares or about eight percent of the total land area. At the time of writing this included approximately 4,972 apartments. Eight apartment towers under construction are incorporated in these figures. These new towers are to include 1,356 units and this provides an indication of the current dominance of residential construction activity as opposed to commercial development with only three office towers under construction. Vacant sites only amount to five percent of the CBD or about five hectares in total.

3.2 OFFICE BUILDING PROFILE

Looking more specifically at the office buildings within the confines of the CBD, further analysis of the data derived the following apportionment of building sizes, land area usage and floor areas.

Building Size	Building Number	Land Area Usage	Total Floor Area (NLA)
< 2,000m ²	38	19,701m ²	42,941m ²
>2,000m ² <5,000m ²	38	31,228m ²	132,930m ²
>5,000m ² <10,000m ²	37	43,297m ²	258,716m ²
>10,000m ² <20,000m ²	36	94,230m ²	526,166m ²
>20,000m ² <30,000m ²	19	74,896m ²	476,945m ²
>30,000m ²	7	37,075m ²	286,026m ²

Table 2 – Brisbane Central Business District Building Sizes, Land Area Usage and Floor Areas

This analysis indicates that only 15 percent of the buildings in the CBD have a net lettable area over 20,000 square metres. Approximately 69 percent of the developed land area in the CBD accommodates office buildings with net lettable areas of over 10,000 square metres. Additionally, about 75 percent of the total office floor space is concentrated in the larger buildings over 10,000 square metres. The following chart illustrates these ratios.

Brisbane CBD - Land & Building Area Distribution

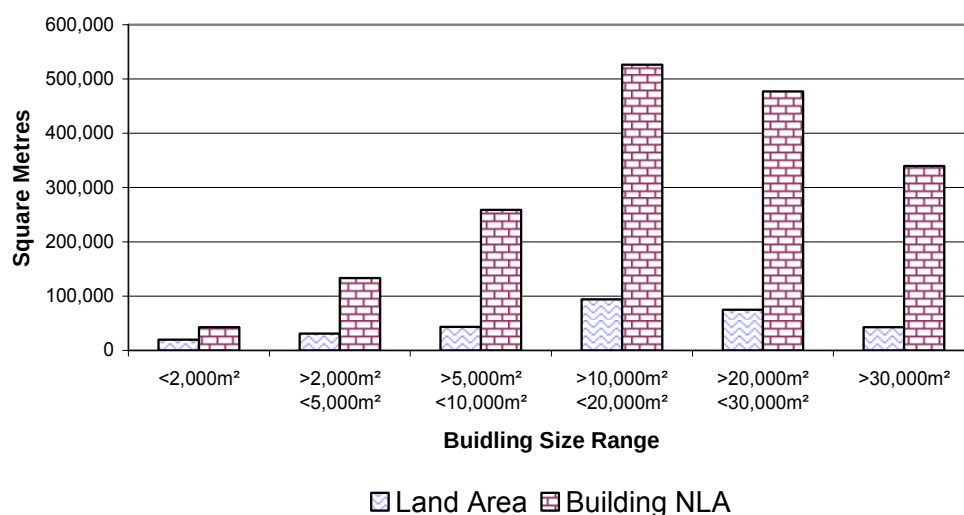


Chart 4 – Brisbane Central Business District Office Building Floor Area and Land Usage Distribution

Further analysis of the Cityscope data was undertaken to establish an age profile of the existing office buildings in the Brisbane CBD. It was not possible to attribute an age to 38 (or 20 percent) of the buildings, but for the balance, the total floor area and building counts falling within seven age ranges are represented in the following chart:

Brisbane CBD - Office Building Age Profile

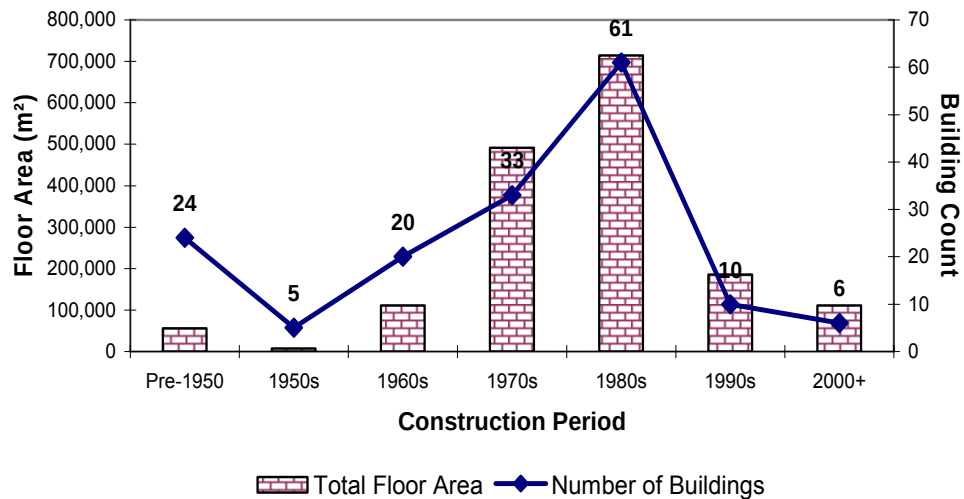


Chart 5 – Brisbane Central Business District Office Building Age Profile

This profile clearly identifies a building activity boom during the 1980s with approximately 41 percent of the city's total floor area being constructed during that decade.

3.3 HISTORICAL OFFICE SPACE SUPPLY AND DEMAND

The Brisbane CBD has experienced similar cyclical space supply and demand volatility as evidenced in published studies for other cities (some of which mentioned under *Section 2.2*). *Chart 6* displays the relationship between space supply, demand and the vacancy rate for Brisbane over the last 23 years and *Table 3*, below, summarises the key space market statistics for the city over the past 32 years.

Variable	Period	Mean	Std Dev	Minimum	Maximum
Vacancy (%)	1972-2003	9.3%	2.7%	3.5%	14.2%
Occupied Space (Δm^2)	1972-2003	38,300m ²	39,300m ²	-33,600m ²	132,000m ²
Net Absorption (Δm^2)	1972-2003	36,900m ²	39,500m ²	-33,600m ²	132,000m ²
Withdrawals (m ²)	1972-2003	11,300m ²	13,400m ²	0m ²	48,300m ²
Completions (m ²)	1972-2003	53,400m ²	40,000m ²	0m ²	142,300m ²

Table 3 – Brisbane Central Business District Space Market Statistics

These figures confirm the relative volatility of the market and *Chart 6* exhibits the strong space supply surge during the late 1980s, coinciding with a fall in net absorption, resulting in a spike in the vacancy rate. Of interest is a comparison with the level of non-residential building across Australia over a period since 1955. *Chart 7* displays this historical data in constant dollars and clearly shows the unprecedented space supply shock during the late 1980s.

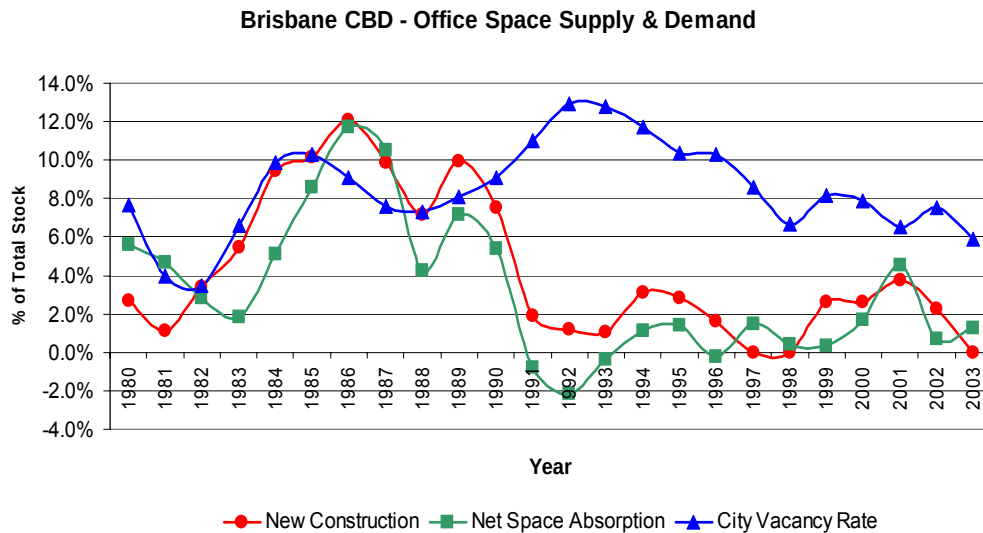
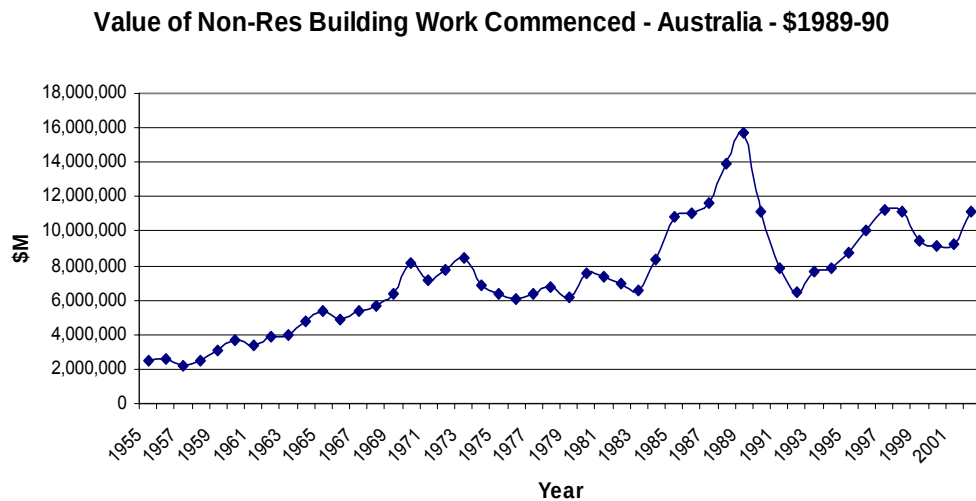


Chart 6 – Brisbane Central Business District – Historical Relationship Among Office Space Supply, Demand and Vacancy Rate



Source - Australian Bureau of Statistics

Chart 7 – Value of Australian Non-Residential Building Work Commenced in Constant Dollars

As discussed in *Section 2.1*, the importance of examining historical space supply relates to its influence on city vacancy levels and, therefore, changes in rent levels.

3.4 HISTORICAL OFFICE RENT TRENDS

Brisbane CBD rent levels have similarly shown considerable volatility. This volatility in office rents is also reflected in property values as the values of

investment properties is inherently linked to their income generating ability. This was demonstrated in the introduction (*Section 1*) dealing with the cash flow method of assessment. *Chart 8*, below, displays the historical change in Brisbane CBD prime office rents since 1980 and a comparison with the corresponding changes in a property value index.

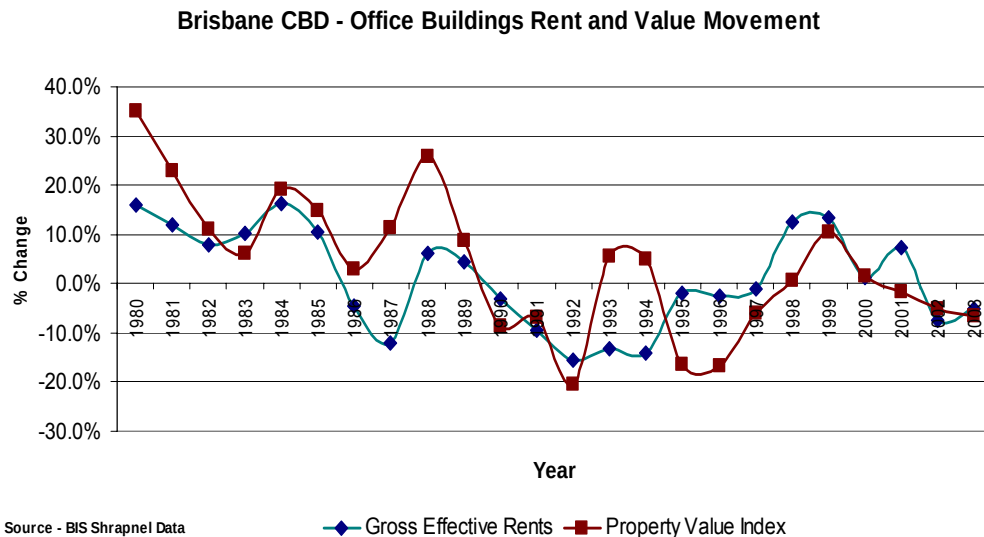


Chart 8 – Brisbane CBD Historical Changes in Prime Rents and Property Values

Prime office rents peaked in 1990 and, during the 14 years since, still have not regained the same levels. The average historical change has been 5.5% and the standard deviation has been \$88 per square metre.

4. FORECASTING

4.1 SPACE SUPPLY FORECASTING

Having regard to the earlier research identifying the most likely drivers for new office construction, analyses were undertaken using historical Brisbane data to identify the space supply determinants for Brisbane. Correlation tests found lagged changes in rents, vacancy rates and property yields to be probable influences. One of the few earlier developed econometric models incorporating an equation for supply and containing the rent and vacancy variables was the Wheaton, Torto and Evans (1997) model developed for the London market. McDonald (2002) and Hendershott, MacGregor and Tse (2002) perceived the Torto Wheaton Research models of this type as being “state of the art”. For these reasons it was decided to assess the fit of an adaptation of this equation to the Brisbane CBD office market for forecasting purposes. The reconfiguration was adopted in this form:

$$C_t = \beta_0 + \beta_1 \Delta R_{t-2} + \beta_2 V_{t-4} + \beta_3 Y_{t-2} + \varepsilon_t$$

Where:

C_t	Office completions in m ² as a % of stock
ΔR_t	% change prime effective office rent rate
V_t	Vacancy rate as a % of total stock
Y_t	Office properties net yields

Using annual data extending from 1978 to 2003, the following results were derived from the regression:

Descriptor	Coefficient	t-statistic
β_0	0.0496	1.804
β_1	0.1334	1.756
β_2	-0.4787	-2.246
β_3	0.6558	1.941
Adjusted $R^2 = 0.51$		Durbin-Watson = 0.73

The variables are all significant in explaining the change in completions at a 90 percent confidence level. The vacancy rate is the only variable significant at a 95 percent confidence level. The coefficient of determination indicates the explanatory power of the equation is not particularly strong and the Durbin-Watson statistic signifies positive autocorrelation in the residuals.

Using the equation to generate a four year out-of-sample forecast resulted in a considerable over-prediction of space supply for the years 1999 to 2003, as illustrated in the following chart.

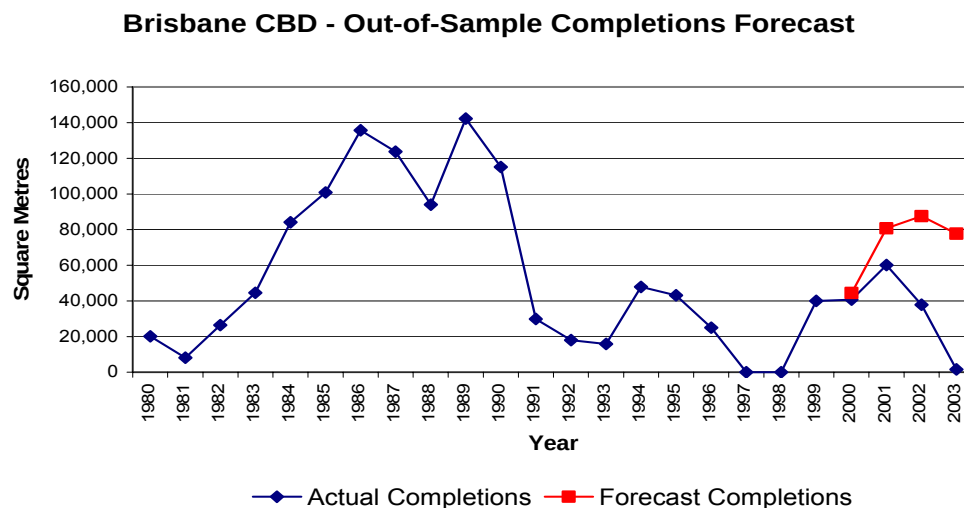


Chart 9 – Brisbane CBD Out-of-Sample Office Space Supply Forecast Using Adaptation of Wheaton, Torto & Evans (1997) London Model

This over-prediction of new building completions may have been partially driven by the prevailing historical low vacancy rate not propelling the levels of new space supply that has been evident in the past. Additionally, two office buildings (46,000 square metres) under construction and scheduled for completion in 2003

will not be completed until 2004. However, despite these factors, the equation in its current form has limited application for the Brisbane market.

4.2 RENT FORECASTING

Having regard to the results from previous research and undertaking an analysis to identify potential office rent determinants for the Brisbane CBD, measures for vacancy rate, new space supply, net space absorption and interest rates were isolated as probable explanatory variables. A new equation was estimated, taking the following form:

$$R_t = \beta_0 + \beta_1 R_{t-1} + \beta_2 V_{t-2} + \beta_3 SU_{t-2} + \beta_4 AB_t + \beta_5 I_t + \varepsilon$$

Where:

R	Prime gross effective office rent rate
V	Vacancy rate as a percentage of total stock
SU	New office supply as percentage of total stock
AB	Net office space absorption in square metres
I	Commonwealth ten year bond rate as an annual average

Using annual data covering the period from 1976 to 2003, the equation generated the following results:

Descriptor	Coefficient	t-statistic
β_0	127.778	4.592
β_1	0.533	6.088
β_2	-710.200	-4.792
β_3	30.792	0.298
β_4	0.0002	2.413
β_5	354.087	3.044
Adjusted $R^2 = 0.93$		Durbin-Watson = 1.97

The results indicate the lagged measures for the rent rate, vacancy and the expected bond rate are significant at a 99 percent confidence level while the anticipated net absorption, as a indicator of demand, is significant at a 95 percent confidence level. The vacancy coefficient is signed as expected, recognising the counter-cyclicality between rent and vacancy rates. Surprisingly, the lagged new supply of office space is not significant. A test of an alternative equation incorporating space absorption as a percentage of new supply, being a measure of the balance between supply and demand, also failed to enhance its explanatory power.

The overall explanatory power of the equation, as signified by the coefficient of determination (0.93), registers as quite strong. The Durbin-Watson statistic (1.97) signals little autocorrelation remaining in the residuals.

However, running an out-of-sample test, as done for the supply equation, found the equation over-predicts rent for the four test years (2000 +6.7%; 2001 +5.3%; 2002 +11.3% and 2003 +24.4%). While correctly forecasting a turning point in 2001, the equation incorrectly forecast an upswing in rents in 2003. This is illustrated in *Chart 10*.

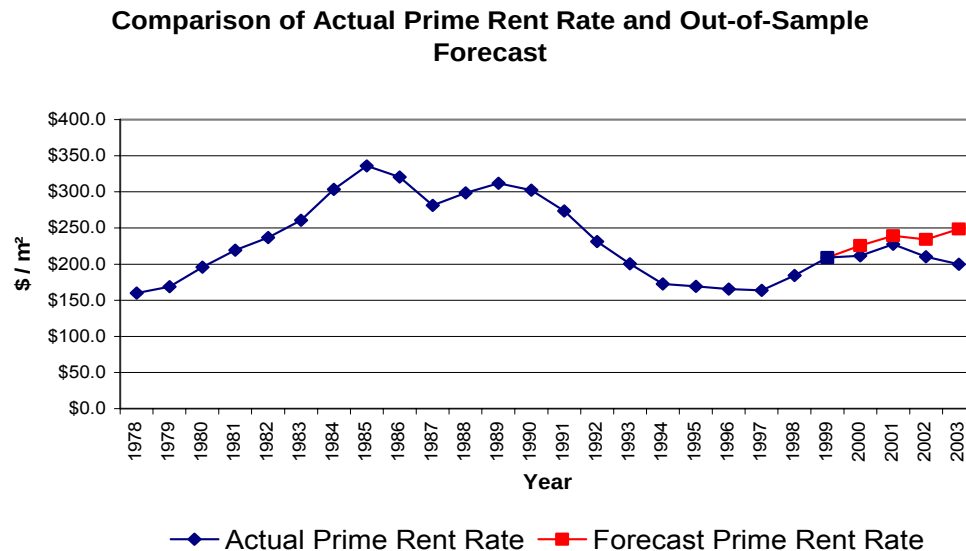


Chart 10 - Brisbane CBD Out-of-Sample Office Rent Forecast Using Estimated Model

These results confirm a necessity to exercise caution in the application of pure mathematical models to property markets. Further research is required to refine modelling techniques and to include qualitative inputs.

5. IMPLICATIONS

5.1 SAMPLE OFFICE BUILDING PORTFOLIO

The commercial building cash flow model developed through the Cooperative Research Centre for Construction Innovation (briefly introduced in *Section 1.*) is used to test the sensitivity of valuation assessments to variations in the adopted rent forecasts. Four existing Brisbane CBD buildings, built in four different decades, are used for the case studies. While the four buildings are government owned, detailed rent, operating expense and professionally projected capital expense data was collected to underpin the assessments. In addition, the owner of the buildings (Department of Public Works - Queensland) made available the recent independent market valuations for the buildings for comparative purposes.

The rent forecasts adopted for the case studies include the median of the valuers' forecasts established through the professional survey (Cowley, 2004) and rent predictions cast forward using the model discussed in *Section 4.2*. The rent model forecasts a boom / bust cycle in rents in second half of the decade.

The physical and financial details of the four buildings selected for the analyses are summarised in the following tables.

Building: 111 GEORGE STREET Address: 111 George Street, Brisbane City			
Property Description			
A modern, A-Grade, 30 level office building completed in 1994, comprising two levels of basement car parking, a lower plaza level (conference facilities), ground level and 26 upper levels of office accommodation.			
Physical Details		Financial Details	
Site Area	2,541m ²	Value (31/12/02)	\$103,000,000
Total Net Let. Area	27,402m ²	Value Rate \$/m ² NLA	\$3,759
Retail Component	0.0017%	Office Rent \$/m ²	\$350
Car Spaces	117	Park. Rent / bay pcm	\$325
Parking Ratio	1 space per 234m ²	Est. Net Ann. Income	\$8,020,485
Typical Floor Plate	998-1068m ²	Capitalisation Rate	7.75%
Build Date	1994	Est. Outgoings \$/m ²	\$78

Table 4 – Sample Building – Physical and Financial Details – 111 George Street, Brisbane

Building: EDUCATION HOUSE			
Address: 30 Mary Street, Brisbane City			
Property Description			
A semi-modern, B-Grade, 27 level commercial office building completed in 1986 and including three basement levels of parking, a lower ground plaza level incorporating parking and retail tenancies, ground level foyer and auditorium and 22 upper levels of office accommodation.			
Physical Details		Financial Details	
Site Area	3,664m ²	Value (31/12/02)	\$66,000,000
Total Net Let. Area	22,347m ²	Value Rate \$/m ² NLA	\$2,953
Retail Component	0.0075%	Office Rent \$/m ²	\$290
Car Spaces	218	Park. Rent / bay pcm	\$325
Parking Ratio	1 space per 103m ²	Est. Net Ann. Income	\$5,710,842
Typical Floor Plate	966-1053m ²	Capitalisation Rate	8.50%
Build Date	1986	Est. Outgoings \$/m ²	\$77

Table 5 – Sample Building – Physical and Financial Details – 30 Mary Street, Brisbane

Building: MINERAL HOUSE			
Address: 41George Street, Brisbane City			
Property Description			
A semi-modern, B-Grade, 30 level commercial office building completed in 1979 and including three basement levels of parking, ground level retail tenancies, office accommodation and foyer, three upper podium levels and a further 23 tower levels of office accommodation.			
Physical Details		Financial Details	
Site Area	2,811m²	Value (31/12/02)	\$77,000,000
Total Net Let. Area	29,468m²	Value Rate \$/m² NLA	\$2,613
Retail Component	0.0031%	Office Rent \$/m²	\$285
Car Spaces	124	Park. Rent / bay pcm	\$325
Parking Ratio	1 space per 238m²	Est. Net Ann. Income	\$6,867,588
Typical Floor Plate	1,065-1,107m²	Capitalisation Rate	8.75%
Build Date	1979	Est. Outgoings \$/m²	\$70

Table 6 – Sample Building – Physical and Financial Details – 41 George Street, Brisbane

Building: PRIMARY INDUSTRIES BUILDING			
Address: 62 Ann Street, Brisbane City			
Property Description			
A semi-modern, B-Grade, 10 level commercial office building completed in 1968 and including a basement level, ground level, three upper podium levels and five upper levels of commercial office accommodation. A major refurbishment occurred in 1989 and the air conditioning plant and lifts have been upgraded in recent years.			
Physical Details		Financial Details	
Site Area	2,746m ²	Value (31/12/02)	\$29,000,000
Total Net Let. Area	14,602m ²	Value Rate \$/m ² NLA	\$1,986
Retail Component	0.0%	Office Rent \$/m ²	\$265
Car Spaces	11	Park. Rent / bay pcm	\$325
Parking Ratio	1 space / 1,327m ²	Est. Net Ann. Income	\$2,751,809
Typical Floor Plate	1,351-1,819m ²	Capitalisation Rate	9.25%
Build Date	1968	Est. Outgoings \$/m ²	\$74

Table 8 – Sample Building – Physical and Financial Details – 62 Ann Street, Brisbane

5.2 RENT FORECAST SENSITIVITY

Running the cash flow model for each of the four buildings with all market and economic assumptions remaining constant except for the rent forecasts derived the results listed in *Table 9* below:

Building	CB Richard Ellis Valuation	Valuation Using Model Generated Forecast	% Variation	Valuation Using Mean Valuers' Forecast	% Variation
111 George Street	\$103,000,000	\$98,500,000	-4.4%	\$106,500,000	+3.4%
Education House	\$66,000,000	\$60,000,000	-9.1%	\$65,500,000	-0.8%
Mineral House	\$77,000,000	\$74,500,000	-3.2%	\$81,250,000	+5.5%
Primary Industries	\$29,000,000	\$25,000,000	-13.8%	\$27,500,000	-5.2%

Table 9 – Building Valuations using Model Generated and Valuers Survey Mean Rent Forecasts

The results indicate the forecasts from the rent model derive valuations 3.2% to 13.8% below the independently assessed values, while the mean of the valuers survey rent forecasts over and under value the buildings with a range from -5.2% to 5.5%. Materially significant variations exist between the valuations derived using the rent forecasts from the two sources with differences ranging from 8.1% to 10.0%. In dollar terms, these differences range up to \$8M and this confirms that the formulation, sourcing and application of rent forecasts are of consequence when adopting the discounted cash flow method of valuation.

6.0 CONCLUSIONS

Surveys of Australian property professionals have found an increasing reliance on discounted cash flow modelling as a means of assessing the value and viability of office buildings and projects. This method of assessment requires the explicit inclusion of office rent forecasts over study periods often ranging up to ten years into the future.

Historically, formal techniques used for the formulation of rent forecasts have relied upon office market modelling involving the identification and application economic and property market leading indicators or explanatory variables through the use of regression equations. Analysis of the literature on the subject found the dominant drivers of new office construction to be: rent levels; vacancy rates; previous building completions; construction costs; white collar employment growth; and interest rates. In association with this, researchers and property professionals have nominated the key determinants in office rent level changes to be: subsisting rent levels; vacancy rates; space supply; economic activity; and white collar employment growth.

After examining the historical relationships among these and other property market drivers in the sample city of Brisbane, space supply and rent equations were estimated. Out-of-sample forecasts generated by these equations were compared to actual changes in supply and rent levels. Both models tended to initially over-predict growth in the market despite their reasonable historical fit.

These results add weight to the need for further research on property market forecasting to identify supplementary techniques to improve upon purely mathematical formulation methods.

Further support for this proposal is derived from test results showing alternate office rent forecasts materially impact upon property valuations. These results were generated by a professionally developed discounted cash flow model used to assess valuations for four existing office buildings. The model was operated using real income and expense data, including detailed capital expenditure projections for each of the buildings.

Improvements in the consistency and reliability of forecasts hold potential to enhance decision making processes for investors and possibly ameliorate some of the pain producing volatility in commercial property markets.

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STAKEHOLDERS

Full Paper

THE DEMANDING AND REWARDING CLIENT

Rosemarie Risgalla and Ted Smithies

ABSTRACT

We have seen it again and again: unacceptable behaviour, conflicting business objectives, uncooperative relationships and, poor management practices by clients and service providers alike. We have all tried to change this situation. In Australia we have had two Royal Commissions, some 10 years apart, which have recommended surprisingly similar strategies. A major thrust of these strategies being that the client must demand improved performance, with the threat of loss business if the standard of performance is not achieved – is this enough?

To answer this question we need to understand the motivators of change and how these motivators must be adapted over time. We need to understand that success is only sustainable when all parties succeed. This means that if the client demands something, that same client must give something back. In other words if you demand superior performance, then you must reward that performance – what then are the implications for clients in terms of their own performance?

In this paper we use the NSW Government as a major client as the case study.

Keywords:

SETTING THE SCENE

In Australia construction industry activity which is expected to reach \$A86.4 billion in 2003-04 is regarded as an important indicator of the health of the economy. In 2002-03 the industry accounted for 6.3% of Gross Domestic Product (A\$46 billion) and over 7% of the national labour force (730,000 in 2002-03).

The industry is comprised of residential building (houses, flats, units and alterations to existing dwellings), non-residential building (shops, offices, hotels, factories, educational facilities and hospitals) and engineering construction (roads, sewerage, energy, etc). It includes architectural and engineering services and construction trades (bricklaying, plumbing, electrical, etc). The industry is extremely diverse, and activity is highly cyclic. The engineering construction sector is highly concentrated and features increasing foreign investment in the larger end of the market.

New South Wales (NSW) is the largest state, has the largest population, the largest economy and approximately one third of Australia's construction industry. Construction activity in NSW in 2003-2004 is expected to reach \$A26.1 billion. The NSW industry represents about 10% of Gross State Product and about 8% of the total workforce of the State.

In most years half the construction expenditure in NSW is in the residential building sector, a quarter in the non-residential building sector and the remaining quarter are in engineering construction. The NSW industry employs 260,000 people, which is about 33% of the national industry total. Businesses in NSW employ on average 2.5 people, with a turnover \$A278,100 and a profit margin of 10%. Subcontractors provide 90-95% of the labour for construction work. Head contractors provide between 5-10% of the labour, but manage the construction process.

The NSW Government is the major client of the industry. It is also the regulator of the industry. Its annual capital works and maintenance program (includes hospitals, schools, public housing, roads, bridges, railways) is approximately \$A6 to 7 billion, which is 25–35% of total expenditure in NSW. This investment will sustain around 96,000 direct and indirect jobs and represents between 50-70% of non-residential building and engineering work done.

During the 1980s, the Australian construction industry was at a low point in its performance. In NSW it was characterised by unethical and sometimes illegal activities and conduct, lack of customer focus, organisational fragmentation, lack of co-ordination and communication between key parties, adversarial contractual relationships, reduction in skills in critical areas for example inexperienced site management, inferior working conditions, industrial relations, adversarial relationships, fragmented practices and processes that were found to significantly affect productivity and efficiency.

Since the early 1990s considerable attention has been focussed on improving the efficiency and operation of the construction industry in Australia. This focus commenced in NSW with the Royal Commission into Productivity in the Building Industry in NSW (Gyles Royal Commission) which was established by the Liberal Coalition Government in 1990.

Using Client Buying Power

It would be fair to say that the Gyles Royal Commission Report 1992 was a turning point for the industry in NSW. The Gyles Report emphasised that the NSW Government should use its power as the major client and its regulatory responsibilities to bring about reform in both the public and private construction sectors. The NSW Government's response was to embark on an aggressive program of reform which had two strands:

- Re-establishment of the rule of law;
- Use the Government's buying power to force change, in other words act as a demanding client.

Central to the buying power strategy was the NSW Government Code of Practice and Code of Tendering for the Construction Industry (the Codes). The Codes originally released in October 1992 established the minimum standards of behaviour required of service providers (i.e. contractors, subcontractors, consultants and suppliers) seeking to do business with government. The Codes were supported by a compliance regime in which the NSW Government pursued its right as a client to choose with whom to do business.

The Government's buying power led program for industry improvement can be understood as a series of development phases. The successive industry improvements in NSW have recognised the need to modify the approach to suit changing environments, the emergence of new issues and practices, the changing needs of industry and progress made towards improvement.

The development phases reflect a movement from government direction and imposed standards to shared values and a shared vision and then to industry ownership and self-sustainability.

The Journey – From reform to incentive

Did the standards demanded or rather imposed by the government client get traction as quickly as they did because they were put in place at a time when the construction industry was desperate for work?

In the early nineties with a recession looming, the government client was the only show in town. This meant that the industry was captive to its demands. As the market started to move the reform agenda had to be adjusted to get Industry buy-in.

What does this mean for the current nationally driven reform agenda in Australia?

Imposed Standards — Reform Phase 1992 to 1996

While the right of the client to choose with whom to do business had always existed, the post Gyles environment saw the NSW construction agencies who were responsible for

more than 85% of government construction like public works, roads, rail, public housing, water and power authorities and utilities marshal that right with a single reform focus. Features of this client driven reform phase can be summarised as:

- standards imposed by Government on industry service providers;
- aggressive compliance focussed implementation by government construction agencies.

Initially this reform phase was somewhat one dimensional and dominated by an industrial relations focus. The primary aim during the early to mid 1990's was to change the industry's confrontational relationships and adversarial culture with the objective of improving productivity, time, cost and quality performance. However it was quickly recognised by the government construction agencies implementing the program that this was not meeting the whole of project needs and that there should be a wider agenda. This wider agenda was to address business relationships and practices; organisational systems and standards; project planning and management, workplace reform as well as time, cost and quality outcomes.

Shared Values — Cooperative Phase 1996 to 1998

A change to a Labor Government in 1995 in NSW saw a change of emphasis from an imposed Code of Practice to development of a new Code based on extensive consultation with industry.

The result was endorsement by the major stakeholders of the core principles and values in the Code of Practice and Code of Tendering, released in July 1996 and undertakings by them to establish mechanisms within their organisations to deal with non-observance of the Codes. NSW government construction agencies integrated Code requirements in all aspects of project delivery, in particular tendering, contractor selection and performance management.

Features of the cooperative phase can be summarised as:

- shared ownership of core values
- cooperative approach to implementation by major stakeholders

Shared Vision — Development Phase 1998 to 2000

In many ways the development phase was an extension of the cooperative phase. However it also represented a clear change of focus from imposed reform to shared core values and vision. The development phase needed a high level of cooperation and willingness to participate by all sectors of the industry. This was facilitated by a green paper released in October 1996 entitled, *The Construction Industry in New South Wales, Opportunities and Challenges*, and a discussion paper released in April 1997 entitled, *A Perspective of the Construction Industry in NSW in 2005*.

The green paper dealt with a range of issues including industry structure and relationships, training and skill formation, occupational health and safety issues, industrial relations, sustainable development and industry process improvement. The discussion paper provided a view of the industry as it could be in the year 2005.

The focus of the vision is based on four characteristics, which industry participants are encouraged to achieve:

- Seamless – Client and service focussed enterprises that deliver value added solutions;
- Efficient and profitable – Financially robust enterprises that employ a skilled and flexible workforce;
- Innovative – Clever and adaptive enterprises that are high users of technology;
- Environmentally responsible – Committed to sustainable development and sustainable construction.

This vision underpins *Construct New South Wales*, the NSW Government white paper released in July 1998 which challenged industry to:

- Shed its inward focus and become outwardly oriented, and create an integrated structure and a cooperative production process;
- Build and maintain long-term quality relationships that rest on outstanding performance and better alignment of all participants' objectives;
- Offer clients complete solutions;
- Improve business management skills through better strategic planning and market positioning, new product development, training and continuous education and improvement;
- Invest in people training to improve OHS, workforce flexibility and diversity;
- Improve its environmental management performance; and
- Acquire a competitive advantage through the use of technology;

in order to service their clients better and enhance their efficiency and profitability. The features of the development phase can be summarised as:

- shared vision;
- Government leadership and support;
- mutual respect of stakeholders;
- recognition by construction enterprises of the contribution they need to make to realise their full potential;
- Government construction agencies becoming *rewarding clients* by providing superior performers with more opportunities to do business.

Learning and Growth — Sustainable Phase 2000 to 2003

By the end of 2000 the Government was well advanced in the implementation of *Construct New South Wales*. By November 2003 a final key action was completed with the adoption of a new common form of cooperative contract known as GC21 by the government construction agencies.

The goal in this phase was to make the development program self-sustaining by working with industry to produce collaborative solutions which facilitate industry improvement.

The NSW Government maintained its leadership role during this period but progressively relied more on demanding higher commitment and performance improvement from its service providers and rewarded superior performance.

Client and Construction Industry Outcomes

The cumulative effect of this client led program over a 10 year period in NSW created significant improvements. These include:

Reducing the cost of doing business

- Public sector annual saving of \$A50m – equivalent to one major hospital or 3 colleges;
- Private sector annual saving of \$A430m;
- Consistent construction agency practices for business in dealing with Government - annual savings to Government of \$A1.4m;
- Adoption of improved procurement methods and contract management on government projects resulting in lower failure rates compared to private sector construction; and
- Improved security of payment for subcontractors which has been estimated to save the construction industry \$A10 m per year.

Improved Industry Productivity

- Improved productivity enabled the NSW industry to manage the peak levels of Olympic activity in 1999 and 2000 better than before. An assessment by the National Institute of Economic and Industry Research indicates an average productivity increase of 0.6% per year in the period 1990 to 1999, from \$A102,000 to \$A108,000 of construction output per person;
- At the workplace level, improved industrial relations management and relationships in NSW facilitated lower rates of industrial disputation which were below the national average in each year from 1994 to 2001. These lower rates were achieved despite record levels of construction activity in NSW;
- Government client requirement that service providers implement a managed systems approach to occupational health and safety (OHS) significantly improved the industry's OHS performance. The incidence rate for NSW decreased from a 10 year high of 58% in 1995/96 to 40% in 1999/2000, a reduction of 31%. This rate of decline in the incidence rate was greater than any other Australian jurisdiction in the earlier 5 years.

Can Client Buying Practices Change Performance?

So a major client calls on its service providers to improve performance and innovate. So easy to say. So difficult to do?

Demanding this sort of performance requires a client with a capacity that matches their service providers. This is in terms of expertise, systems and tools. A focus then needs to

be maintained on seeing that the demanded performance is delivered – what is the point of asking for and paying for something if you don't know if you get it?

The other side of the story is that the service provider is going to expect reciprocal standards. They will ask what are they going to get in return, will they enjoy the sort of cooperative treatment that is being demanded of them, and will they be acknowledged for superior performance?

Principles for Superior Performance

The framework for doing business in a way, which motivates service providers towards superior performance, is underpinned by the following principles:

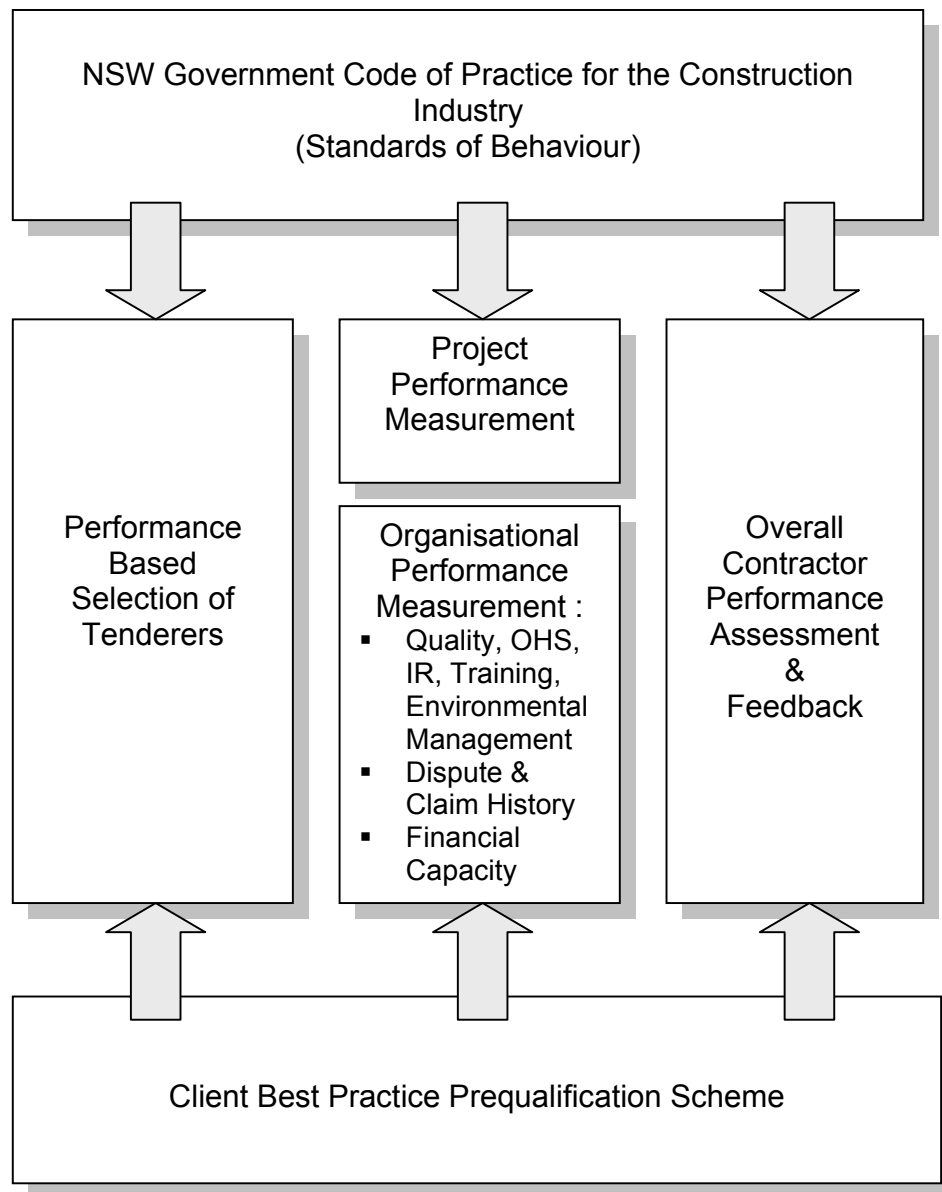
- **Principle 1:** Service Providers need to clearly understand what constitutes best practice and superior performance.
- **Principle 2:** Performance of service providers must be rigorously assessed using criteria developed from a common set of principles.
- **Principle 3:** Performance will be a primary driver in tender selection with service providers competing on quality of performance. Clients may reward superior performance on the part of service providers by improving their chances of winning work.
- **Principle 4:** Clients will reward superior performance by service providers by offering them improved terms of trade.
- **Principle 5:** Superior performance does not remain static and the expected standards must be continuously reviewed and adjusted.

Case Study

This case study outlines key components of an approach adopted by a client of the industry, the NSW Department of Public Works and Services (DPWS) to achieve superior performance by its construction contractors. In April 2003 this organisation was incorporated into the new Department of Commerce together with other departments in the portfolio of the Minister for Commerce.

The design objectives for this approach was to:

- eliminate any incompetent, insufficiently financed and inexperienced contractors from tendering and contracting opportunities;
- deliver superior outcomes for clients by directly linking the tender opportunities offered to contractors with the level of performance they had achieved; and
- include ongoing performance measurement and control processes to minimise the risk of deteriorating performance on projects.



The above schematic represents a total system approach to achieving contractor superior performance. The following are key implementation components:

- Best Practice Prequalification Scheme for construction contractors which assesses capability in: business relationships and practices; organisational systems and standards; people management policies and practices; and time, cost and quality outcomes.

- Tendering/selection of tenderers with increased opportunities based on contractor performance.
- Contractor Performance Measurement and Monitoring System which includes project specific and organisational performance measurement and feedback against the average scores of their peers in the Scheme.
- Continual improvement by regular review and raising of Scheme performance benchmarks.

Contractors accredited under this Best Practice Prequalification Scheme were given twice the opportunities to tender and won 75% of the contract value of contracts let in comparison with contractors pre qualified with DPWS but who were not in the Best Practice Prequalification Scheme.

The client benefited as the measured performance of accredited Best Practice Contractors consistently averaged 11% above contractors not in the Scheme.

The ratio of the amount paid for claims and disputes with contractors against the original amount claimed fell by approximately 30% since the Scheme was first introduced in 1996.

In 2001 an independent survey of contractors in the Best Practice Prequalification Scheme concluded that “accredited companies see value in the Best Practice scheme and have experienced improvements in their business, which exceeded the expectations of those seeking accreditation”. These improvements are likely to have an ongoing benefit with those contractors attracting new clients.

The Challenge for National Reform

The Australian national reform agenda seems to be moving towards a regulatory or compliance biased approach. Is this “demanding agenda”, too one dimensional, will it work in isolation?

Sustainable outcomes need an integrated and cooperative approach i.e. there must be positive incentives that will encourage all parties to strive for success. It is simply the win-win scenario!

The Cole Royal Commission into the Building and Construction Industry presented its final report on 24 February 2003. The Report comprises 23 volumes and makes 211 recommendations for reform and while there is a primary focus again on industrial relations, there are a number of reforms based on using client buying power to force change.

The recommendations involve wider application of the National Code of Practice for the Construction Industry in terms of standards of behavior required of service providers coupled with the more effective use of prequalification and improved tendering practice.

In the context of the foregoing, it all sounds fairly familiar; however the challenge is to decide what approach will be taken. Will they be?

- Imposed – or the one-dimensional approach. The problem here is that the big stick or compliance approach will only work for so long. Ultimately the performance improvement available through this process is limited by the negative overtures that adversely affect the business relationship.
- Co-operative – whereby client and service provider work to common goals. This effectively represents the half way house but at least the parties have consistent business goals. Depending on the size and sophistication of the client, this may be as far as they can go.
- Development and/or Sustainable – which involves the multi dimensional approach of the *demanding* and *rewarding* client. The focus here is clearly on the sustainability of both the client's business and that of the service provider i.e. you only have true success when both parties succeed.

The overriding difficulty is that the latter approach requires clients to have in place processes that manage performance. At one level this may seem obvious as why demand higher levels of performance if you have no way of assessing if you are getting what you pay for. To be able to judge performance you need to have in place a fair and robust performance management process that facilitates continuous improvement. This should be aimed at exceeding the minimum standards set by a regulatory approach.

What does it all mean?

The goals of construction industry reform and development in NSW as in other Australian jurisdictions in the last decade have been broadly similar to those of the UK and Singapore and have been driven by concerns over relatively low productivity, cost efficiency and performance. The aim of the reforms in each country has been to produce a construction industry that has a high level of productivity growth, is competitive relative to other industries and is capable of competing in a global market.

Generally Australia, the UK and Singapore have focussed on improving productivity and cost effectiveness through greater attention to prequalification contractual reform; quality management ; process improvement; innovation and take up of information technology; training; more flexible working practices and improved industry relationships.

In 2004, the construction industry continues to be an enigma. Much work and study indicates that we should all still have concerns over low productivity, cost efficiency and performance. Most informed industry observers and participants continually echo these concerns.

The industry in its structure is highly disaggregated and this creates communication and coordination difficulties. In many instances this is the weakness that is most directly linked to productivity difficulties.

At the same time this structure can be its strength because it allows the industry to rapidly scale up (and down) to meet changes in market demand. In support of this

strength the industry is capable of spectacular success - dare we forget the Sydney Olympics Construction program in the lead up to 2000. The message here is that there is a strong commitment by many in the industry to not only do a good but to do a superior job.

This paper presents strong evidence that well designed, well managed and championed industry reform and development programs, which are supported by reward based buying practices, are capable of significant improvement in industry output. The underlying requirement is to harness that desire to do a better job.

The issue then is for public sector policy setters, regulators and clients of the construction industry to understand and harness this ethos. To paraphrase something Gary Sturgess, Executive Director of The Serco Institute once said, that this requires a considerable degree of skill is obvious but then delivering high quality outcomes always does.

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VISUALISATION AND INFORMATION

Full Paper

LOGIC PROGRAMMING IN A CONSTRUCTION PLANNING WORKBENCH

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ABSTRACT

This paper describes a logic programming approach to construction planning and scheduling. It describes the use of Prolog in generating feasible job logic from an IFC database. The resulting job logic is the basis for generating a first-draft construction schedule. This is one of the core processes in the Construction Planning Workbench project within the CRC for Construction Innovation, which aims to transform a 3D model (e.g. CAD model of a building) into a 4D model (e.g. construction schedule).

This paper also shows that IFC data is a potential source of information in the generation of draft construction schedules. The paper illustrates the feasibility of using logic programming to codify knowledge and trade practices in the construction industry. The use of logic programming, instead of other software development paradigms, allows the development of a flexible and expandable domain rule base.

The results described in this paper are potentially useful in the development of practical and effective tools for generating draft construction schedules from 3D CAD models. This could be beneficial in early planning stages and as a training tool for novice planners.

Keywords: 3D CAD, 4D CAD, Construction Schedule, Logic Programming

1. INTRODUCTION

Construction planning is a fundamental and challenging activity in the management and execution of construction projects. It involves the definition of work tasks, the estimation of required resources and durations of individual tasks, and the identification of any interactions among the different work tasks. A good construction plan is the basis for developing the budget and the schedule for work. The need for planning and schedule control becomes dramatically important with the increasing complexity of a construction project.

Unfortunately, planning and scheduling of construction activities is a time consuming and error prone process where many factors need to be considered simultaneously. In the early stages of a project several plans may be developed to assess alternatives in sequencing, timing and the use of resources. During construction, the higher level plans need to be defined at greater levels of detail within the constraints imposed by the initial planning process and the evolution of the process itself. Consequently, improvements in the support for and speed of the planning of construction processes would improve the efficiency of the industry.

Previous works have tried to integrate the building product model with the construction process model. They presented three important concepts: building product component, construction process component, and the association between the product component and process component (Fischer and Froese, 1996). A possible application of this association between building product and construction process is to automatically generate a construction schedule using some sort of knowledge-based reasoning engine (Chevallier and Russell, 2001).

The goal of this paper is to demonstrate how a logic programming language, such as Prolog, with a rule base, in order to generate draft schedules automatically. The rules serve to capture domain knowledge such as basic construction principles and standard practices with the industry.

1.1 USE OF PROLOG

Forming a construction plan is a backward reasoning exercise where the required steps (i.e. construction activities) are identified to yield the desired result (i.e. completed building structure). The planning process begins with a result (i.e. a building design). Essential aspects of construction planning include the generation of required activities, and the analysis of the implications of these activities. The programming language Prolog, which stands for Programmation et Logique or Programming in Logic (Sterling and Shapiro, 1988)), has its own reasoning engine. Prolog reasoning engine is a backward-chaining procedure using depth-first search algorithm on ordered facts and rules until a solution is found. The similarity in the reasoning style of Prolog and the required mode of reasoning in construction planning is a strong motivation in investigating the use of Prolog in implementing a software-based workbench for construction planning.

1.2 USE OF IFC

The International Alliance for Interoperability (IAI, visit http://www.iai-international.org/iai_international/) IFC data format provides a catalogue of the building elements within the project and can be useful as the basis for developing a first draft construction schedule. The construction of these elements can be automatically converted into job activities, which can then be

automatically sequenced. This will provide a draft construction schedule that can then be used in existing Construction Project Management software, such as Primavera or Microsoft Project for further analysis (see Figure 1). The sequencing information can also be able to be used in 4D CAD (3D visualisation + time) software enabling users to visualise the sequence of construction on the virtual building.

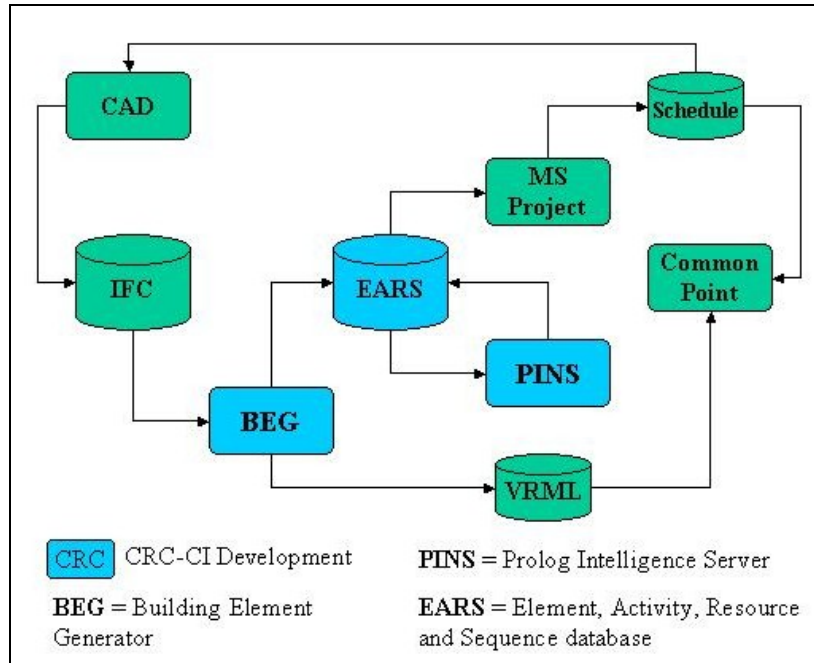


Figure 1: From 3D CAD to a construction schedule

1.3 SOME DEFINITIONS

- An element is an IFC building elements such as columns, beams and slabs.
- A component is a collection of one or more elements.
- For planning purposes, a construction project is sub-divided into segments or work units called an activity.
- An element or component is associated with one or more activities, resulting to <EA> or <CA> pairs.
- <EA> or <CA> pairs are associated with one or more resources, resulting to <EAR> or <CAR> triples.

2. JOB ACTIVITIES

The segments into which a construction project is subdivided for planning purposes are called activities. The extent a project is subdivided depends on a number of practical considerations. One suggested guideline (Clough and Sear, 1991) is to identify activities by

- Distinct structural elements such as beams, columns, footings or slabs
- Required craft, crew or equipment
- Material such as concrete, timber or steel
- Different sub-contractors

An activity can be a relatively large segment or may be limited to several steps. For example, the construction of a reinforced concrete beam may be considered as a single activity or may consist of construct formwork, place

reinforcing steel, pour concrete, cure concrete, strip formwork. The appropriate level of detail depends on several factors such as the nature of project and users (e.g. general contractor or sub-contractor).

A simple way of identifying activities is to assume a one-to-one correspondence between activities and building elements. For example, if there is a beam labelled “beam 101” then there is an activity “construct beam 101” (see Figure 2).

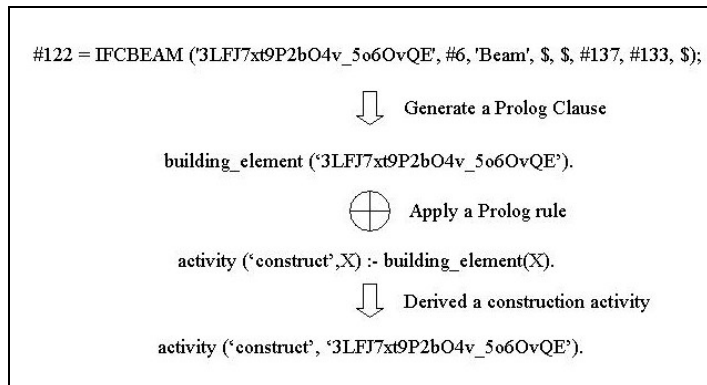


Figure 2: From an IFC building element to a job activity

More detailed job activities can be generated if there is more information about the building elements. For instance, if it is known that a beam is cast in-situ reinforced concrete then the generated activities can be construct formwork, place reinforcing steel, pour concrete, cure concrete, strip formwork.

The method of construction of a particular building element can either be explicitly defined or inferred from the IFC data as illustrated in Figure 3. Once the constructed method is known

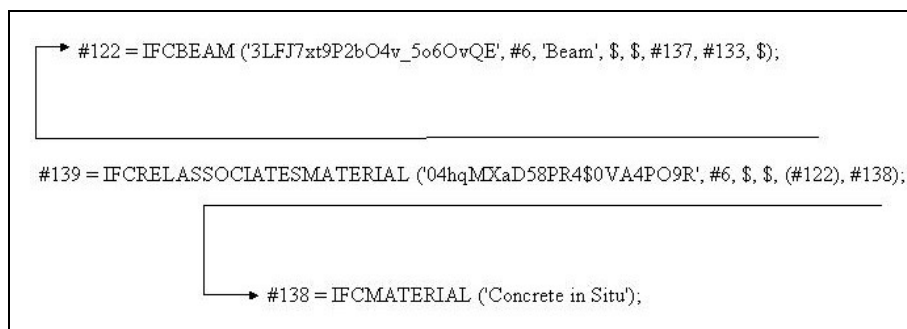


Figure 3: Inferring the construction method from IFC data

3. JOB LOGIC

A construction schedule typically represents a sequence of multiple teams (i.e. trades) that perform individual and distinct work while sharing common workspaces and resources. The logic or rationale behind the sequence of activities in a schedule is referred to as job logic. Job logic includes physical relationship between building elements or components (e.g. a column supports a beam), work team interactions (e.g. concrete work team and carpenters), or safety and code regulations (e.g. workers in a lower level should be protected from activities above them).

The start of some activities obviously depends on the completion of other activities. However, some activities may be independent from other set of activities and may

proceed concurrently. Much of job logic follows from well-established work sequences that are standard in the trade. Nevertheless, there is generally more than one approach and no unique order of activities in any significant construction project.

The job logic between construction activities can be divided into fixed logic and soft logic. Fixed logic, such as the relation between installation of the reinforcing bars and pouring of concrete, will not change in any sensible construction process. Soft logic, such as at which end of a bridge should construction start may depend on various factors.

The basic goal of using logic programming is to capture both basic construction principles and local industry practices in order to provide a guideline in generating initial construction schedule. The software architecture of this approach is shown in Figure 4.

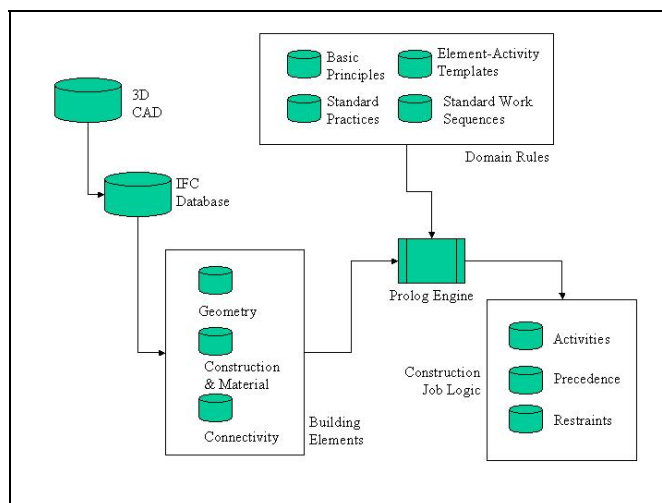


Figure 4: Data-flow diagram for generating construction job logic from IFC data

Consider a trivial example of a structure consisting of 4 pad footings, 8 columns, a stiffened raft (ground slab with 4 edge beams), a suspended beam and slab floor (with 4 beams), 4 beams (with no slabs), a roof and a wall as shown in Figure 5. All elements are of in-situ reinforced concrete construction except for the wall, which is of block work construction.

Observe that the resulting schedule, as shown in Figure 5, allows all in-situ concrete construction to be done continuously. This may be beneficial if a single sub-contractor does all concrete works.

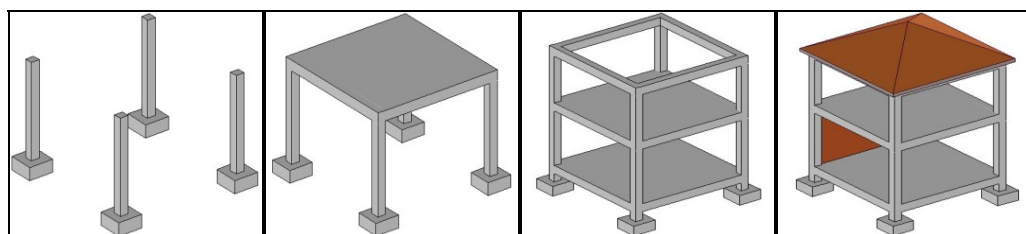


Figure 5: Construction stages of trivial building as an illustrative example

4. PROLOG STRUCTURES

Prolog is a logic language that is particularly suited to programs that involve symbolic or non-numeric computation. It is a frequently used language in Artificial Intelligence where manipulation of symbols and inference about them is a common

task (Bratko, 1986). Prolog consists of a series of rules and facts. Additional facts, called derived facts are computed from rules and known (i.e. given) facts.

A Prolog program execution is basically presenting a query and solving it using known rules and facts. For example, consider the following facts about building elements and their connectivity:

```
% Building Element
% element(id,element-type,storey,...)
element(c201,'column',2,...).      % Element c201 is a column in level 2
element(s301,'slab',3,...).        % Element s301 is a slab in level 3
% Element Connection
% connected(id,id)
connected(c201,s301)               % Element c201 is connected to s301
```

Consider also the following rule about support relation between elements:

```
% Support Relationship
support(X,Y):-                     % X support Y if ...
    element(X,'column',Lc,...),    % X is a column in level Lc
    Ls is Lc+1,                    % Ls is the level just above Lc
    \+ ground_level(Ls),           % Ls is not the ground level
    element(Y,'slab',Ls,...).      % Y is a slab in level Ls
```

The rule above can be interpreted as “If a column is connected to a slab, the column is just below the slab, and the slab is not a ground slab, then the column supports the slab”.

Given a query:

```
% Find pairs of (X,Y) such that X supports Y
support(X,Y)?
```

Such a query will result to: X = c201 and Y = s301

Other types of relationships between elements can also be defined using rules in Prolog. For instance, a “constructed together” relation can be written as:

```
% Together Relationship
together(X,Y):-                    % X is constructed together with Y if
    connected(X,Y),                % X is connected to Y
    element(X,'beam',...),         % X is a beam
    construction(X,'in-situ RC'),  % X is an in-situ RC beam
    element(Y,'slab',...),         % Y is a slab
    construction(Y,'in-situ RC').  % Y is an in-situ RC slab
```

The rule above can be interpreted as “Beams and slabs in a reinforced concrete floor are constructed together”.

Derived relationships such as “support” and “together” can in turn be used to derive other relationships such as “constructed before”.

```
% Precedes Relationship
precedes(X,Y):-                    % X is constructed before Y if
    support(X,Y),                  % X support Y
    \+ together(X,Y).              % X is not constructed together with Y.
```

5. ELEMENTS AND ASSOCIATED ACTIVITIES

Associating a set of construction activities to a building element or a group of building elements is a critical step in automatically generating workable job logic. The set of activities associated with a particular building element (i.e. column, slab, beam, or wall) depends on the construction method (i.e. reinforced concrete, steel frame, pre-cast concrete, or composite construction).

For example, the following are activities typically associated with reinforced concrete construction written as Prolog facts:

```
% Construction Activities
activity(1,'formwork').
activity(2,'place reinforcement').
activity(3,'pour concrete').
activity(4,'wait and cure concrete').
activity(5,'strip formwork').
```

Activity templates are used to associate the sequence of activities to a particular combination of building element and construction type. For instance, consider the following Prolog rule and facts:

```
% Element-Activity Pair
element_activity(X,A) :-
    element_activity_list(X,L),
    member(A,L).
% Element-Activity List
element_activity_list(X,L) :-           % L is the list of activities associated with X
    element(X,T,...),                  % T is the element type of X
    construction(X,C),                 % C is the construction method of X
    activity_template(T,C,L).

% Activity Templates
activity_template('slab','rc',[1,2,3,4,5]).
activity_template('column','rc',[2,1,3,4,5]).
....
```

Note that for reinforced concrete columns, the activity template specifies that the reinforcement be put in place before the formwork while for slabs the formwork comes before the placement of reinforcement.

5.1 ACTIVITIES AND RESOURCES

Construction resources in traditional construction management views are divided into three categories, namely, labour, material and equipment. These are inadequate for constructability review of the schedule. In recent years, construction space was identified as another important resource type in construction planning. The important role of construction space in construction planning has been illustrated in several studies. Such as:

- Space occupation as a resource constraint (Thabet and Beliveau, 1994)
- Space scheduling model (Riley and Sanvido, 1997)
- Time and space conflicts (Akinci et. al, 2002)

5.2 EQUIPMENT RESOURCES

The definition of construction activities can be extended to include required equipment resources. For example, *activity(3,'pour concrete')* can be extended to *activity(3,'pour concrete','concrete mixer')*. Unfortunately, the required equipment may vary depending on the element type and its location. For instance, pouring concrete on a ground slab may also required a trowelling tool/machine while pouring concrete above ground level may require concrete pump and/or crane. Hence, an activity may have two hierarchies of required resources: the minimum resource requirement (i.e. concrete mixer) and the conditional resource requirement (i.e. trowelling tool).

Identifying the required resources for a given element-activity pair is part of the domain knowledge and can be written as Prolog rules as follows:

```
% Element-Activity-Resource Triples
element_activity_resource(X,A,R) :-
    activity(A,_,ResList),
    member(R,ResList).
element_activity_resource(X,A,'trowelling tool') :-
    activity(A,'pour concrete',_),
    element(X,'slab',L),
    ground_level(L).
```

5.3 OTHER RESOURCES

Other traditional resources such as material and labour can be handled in the same way equipment resources are processed as described in the previous section. In fact, even a more abstract concept such as time-space constraints can be dealt with in a similar manner. Consider a fragment of a scheduling exercise shown in Table 1, Table 2 and Table 3.

The schedule fragment in Table 1 shows a construction plan without consideration to resource constraint. It only considers precedence relations (i.e. job logic) between activities. Table 2 presents the revised schedule after incorporating constraint on equipment resource, such as "There is only one crane available." Finally Table 3 illustrates that space constraints can be treated like tangible resources such as equipment and labour.

There are several issues regarding resource constraints that were not considered in this paper, these include: Shared equipment resource, level of resources (i.e. amount of material, number of available equipments, over-time work), and information type resources (i.e. fabrication drawing, detailed engineering design, union contracts)

Table 1: A construction schedule without resource constraint

ID	Task Name	Duration	Start	Finish	Predecessor
9	Erect steel columns	6 days	Tue 8/06/04	Tue 15/06/04	7
10	Erect steel beams	4 days	Wed 16/06/04	Mon 21/06/04	9
11	Erect steel joists	3 days	Tue 22/06/04	Thu 24/06/04	10,8
12	Fireproof structural steel	5 days	Fri 25/06/04	Thu 1/07/04	11
13	Install metal deck	3 days	Fri 2/07/04	Tue 6/07/04	12

ID	Task Name	Duration	Start	Finish	Predecessor
14	Erect precast concrete wall panels	15 days	Fri 25/06/04	Thu 15/07/04	11
15	Pour concrete topping on metal deck	2 days	Wed 7/07/04	Thu 8/07/04	13
16	Build forms for slab-on-grade	3 days	Wed 7/07/04	Fri 9/07/04	13
17	Install reinforcement for slab-on-grade	3 days	Mon 12/07/04	Wed 14/07/04	16
18	Pour concrete in slab-on-grade	2 days	Thu 15/07/04	Fri 16/07/04	17

Table 2: A schedule with constraint on equipment resource

ID	Task Name	Duration	Start	Finish	Predecessors	Resources
9	Erect steel columns	6 days	Tue 8/06/04	Tue 15/06/04	7	crane
10	Erect steel beams	4 days	Wed 16/06/04	Mon 21/06/04	9	crane
11	Erect steel joists	3 days	Tue 22/06/04	Thu 24/06/04	10,8	crane
12	Fireproof structural steel	5 days	Fri 25/06/04	Thu 1/07/04	11	crane
13	Install metal deck	3 days	Fri 2/07/04	Tue 6/07/04	12	crane
14	Erect precast concrete wall panels	15 days	Fri 9/07/04	Thu 29/07/04	11	crane

Table 3: A schedule where space constraint is treated as ordinary resource

ID	Task Name	Duration	Start	Finish	Predecessors	Resources
14	Erect precast concrete wall panels	15 days	Fri 9/07/04	Thu 29/07/04	11	crane, space
15	Pour concrete topping on metal deck	2 days	Wed 7/07/04	Thu 8/07/04	13	crane, space
16	Build forms for slab-on-grade	3 days	Wed 7/07/04	Fri 9/07/04	13	
17	Install reinforcement for slab-on-grade	3 days	Mon 12/07/04	Wed 14/07/04	16	
18	Pour concrete in slab-on-grade	2 days	Fri 30/07/04	Mon 2/08/04	17	space

6. CONSTRAINT LOGIC PROGRAMMING

A constraint can intuitively be thought of as a restriction on a space of possibilities. Constraints arise naturally in most areas of human endeavour. For instance, the three angles of a triangle sum to 180 degrees or the trusses supporting a bridge can only carry a certain static and dynamic load.

Constraint Logic Programming (CLP) is a powerful programming framework with significant applications. The design of the CLP framework is based on the insight that Logic Programming is a constraint-solving algorithm and as such can be combined with various other constraint-solving algorithms (Vlahavas et al, 1998).

Today CLP is contributing exciting new research directions in artificial intelligence (i.e. natural language understanding, scheduling, planning, configuration), operations research and combinatorial optimization. The field is being driven by the demands of increasingly sophisticated real-world applications, one of which could be construction scheduling.

6.1 WORKFLOW SCHEDULING

Construction scheduling can be expressed as a workflow-scheduling problem, which states, "Find an execution sequence of activities in a workflow such that all constraints are satisfied." A workflow is defined as "a coordinated set of activities that act together to achieve a well-defined goal".

Several research works have addressed the classification of sequencing rationale or constraints. In particular, a CIFE working paper (Koo and Fischer, 2003) investigated existing approaches for classifying and representing project-independent sequencing rationale. The paper focused on physical relationships between building elements or components, workspace interaction, path interference and code regulations. A modified version of their classification is presented in Table 4.

Table 4: Typical constraints in a construction scheduling problem

Type	Constraints	Flexible?	Effect
Physical	Supported by	No (Normally) ^a	Enabling
	Connected to	Yes	Impending
	Covered by	No	Enabling
	Damaged by	No (Normally) ^b	Impending
Resource	Equipment	Yes	Impending
	Labour	Yes	Impending
	Trades	Yes	Impending
Space	Shared Workspace	Yes	Impending
	Obstruction	No	Impending
	Provide access	Yes	Enabling
Code Regulation	Safety	No	Impending
	Inspection	No	Impending
	Testing	No	Impending

^a - A supported by constraint can be relaxed if temporary support can be provided

^b - A damaged by constraint can be relaxed if the element or component can be protected

6.2 USING ECLISPE

ECLiPSe provides an excellent tool to create hybrid algorithms to solve large-scale combinatorial optimization problems (LSCO) such as resource constrained scheduling. Combinatorial optimization problems that have the scale and complexity of real-world requirements are interesting because of their commercial importance. LSCO problems are approached from a constraint-programming (CP) angle. Especially, the ECLiPSe CP platform strongly supports such algorithm specialization. One such real world based LSCO is the kernel resource feasibility problem (KRFP), which generalizes most scheduling benchmarks including resource constrained project scheduling. In the KRFP, there are several types of resources and a given quantity of each. There are also a fixed number of activities, which may require a quantity of a specific resource type during its execution. The aim is to schedule activities so that all

the constraints are satisfied, and the demand on any resource does not exceed its resource quantity at any time on the scheduling horizon.

Consider a trivial set of construction activities shown in Table 5. Note that all activities except the 4th task require a crane. The best construction schedule will take 23 working days, with the 4th and 6th activities being done in parallel. This scheduling problem can be expressed in ECLiPSe as:

```
solveSchedule(End_date, T1, T2, T3, T4, T5, T6) :-  
    Tasks = [T1, T2, T3, T4, T5, T6, Source, Target],  
    R1 = resource with [equipment : crane],  
    Source = task with [start : 0, duration : 0, need : []],  
    T1 = task with [duration : 6, need : [Source], use : [R1]],  
    T2 = task with [duration : 4, need : [T1], use : [R1]],  
    T3 = task with [duration : 3, need : [T2], use : [R1]],  
    T4 = task with [duration : 5, need : [T3]],  
    T5 = task with [duration : 3, need : [T4], use : [R1]],  
    T6 = task with [duration : 6, need : [T3], use : [R1]],  
    Target = task with [duration : 0, need : [T5, T6], start:End_date],  
    ....
```

Table 5: A trivial set of construction activities

ID	Task Name	Duration	Predecessors	Resources
1	Erect steel columns	6 days		crane
2	Erect steel beams	4 days	1	crane
3	Erect steel joists	3 days	2	crane
4	Fireproof structural steel	5 days	3	
5	Install metal deck	3 days	4	crane
6	Erect precast concrete wall panels	15 days	3	crane

7. CONCLUSION

This paper has presented an overview on how logic programming can be use in construction planning, specifically in the generation of a draft construction schedule from 3d CAD model. It described the transformation of a 3d IFC data model into a draft construction schedule and finally into a 4d visualisation.

The authors of this paper would also like to highlight that the work on automatic generation of draft construction schedule from IFC data is far from complete. Much work is yet to be done is developing a more robust domain rule base in order to account for actual construction projects.

The paper also includes the potential use of constraint logic programming in construction schedule generation. This research stream is not part of the CRC supported project.

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VISUALISATION AND INFORMATION

Full paper

THE USE OF 3D AND 4D CAD SYSTEMS TO REDUCE ERROR RATE AND REWORKING IN CONSTRUCTION

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ABSTRACT

Currently much work on 4D CAD concerns its use as a design tool, this paper will explore its uses as a construction management and construction education tool. 3D and 4D CAD systems offer the potential to reduce several areas of miscommunication between designers, engineers, fabricators and builders. The particular kind of error resulting from discrepancies between plans and elevations may be expected to be eliminated with integrated 3D CAD. Omissions should be reduced due to the cross checking inherent in 3D and 4D CAD systems. Errors that result from the failure of any of the players to fully visualise the 3D object should also be greatly reduced. The facility with which 4D CAD enables dry runs of the construction process to be tried out should reduce those errors resulting from a failure to appreciate the order of construction operations.

Design or construction errors that result in rework cost the industry both in the value of the rework itself, as well as in the time delays caused. Improved visualisation techniques will address the documentation quality issue which is a perennial problem in the construction industry. 4D CAD has a particular application in the education of the workers involved in the construction process. Complex geometrical and structural objects can be displayed in a way that is readily accessible to all participants and not just to those who are able to visualise the solid object from its representation in plan and elevation. The result of widespread industry adoption of these tools is anticipated to be greater efficiency and predictability in the process from documentation to completion.

Keywords : Construction industry, housing, training, 4D CAD, simulation

1. INTRODUCTION

Although the residential construction industry in Australia is a significant slice of the national economy in dollar terms, it has been slow to adopt new technologies. This research aims to show that productivity gains and improvements in end-user satisfaction can be made by the adoption of integrated computer based training and documentation systems. Although the home building process has tended to remain resolutely “low-tech”, this has not led to a lack of defects or a low rate of necessary reworking. In fact, consumer dissatisfaction with the products of the home building industry is at a high level, and complaints about shoddy workmanship and the cost of repairs are rapidly increasing. Of course, shoddy workmanship can have other causes apart from failure to properly communicate the task at hand to the construction worker. Inadequate time allocation, pressure of ongoing work schedules, lack of adequate supervision and even deliberate sabotage may all contribute to poor quality results (Tilley 1997). The use of training and documentation based on animated CAD modelling may be expected to reduce or eliminate at least those defects that are due to discrepancies, omissions and simple mistakes in the drawings and specifications (Atkinson, 1998). In addition, the effect of animating the construction process is hypothesized to lead to a better level of understanding in the building worker, and therefore result in less reworking.

Research conducted at Virginia Tech on the topic “industrialising the residential construction site” (HUD, 2000) suggests that physical integration and information integration can enhance the productivity and performance of the residential construction sector. This can be achieved with the aid of object oriented CAD and information technology tools. With basic computing skills already on hand in most builder's offices, information integration (beginning with object oriented CAD systems) is likely to be the key to addressing higher levels of physical integration (Sarshar et al, 2002). Performance gains may be realised by simply addressing information communication, an area previously identified as the source of problems.

Modern tools already in use in the manufacturing sector (e.g. Object Oriented 3D CAD, Robotics, and Information Technology encapsulating information originating from designers and constructors) are not yet widely integrated in a structured way within the construction industry (HUD, 2000). This research attempts to address this deficiency.

By way of explanation of some of these tools, it is necessary to look at definitions for the terms involved. 4D CAD is a term that has lately come into use in the construction industry. It is generally held to mean the integration of a 3D CAD model with a construction schedule, thereby adding the element of time to the 3D CAD document (Cory, 2001). Cory further states that 4D CAD focuses on “integrating the technical design information respectively within the design and construction phases”. Dawood et al (2003) agree that 4D CAD planning consists of systems “where the process is visualised by building the 3D product model through time according to the critical path method”. 3D CAD is thus converted to “virtual reality” simulation. 4D construction simulation or visualisation is described by Chau et al, (2003) as being “generated automatically via integrating the 3D geometrical model with the associated activity schedule”. Clayton et al (2002) describe a process where architecture students are able to produce virtual construction by building “3D CAD models showing all components and animating them to illustrate the assembly process”. Koo and Fischer, (2000) explain that a “4D CAD model

results from the linking of 3D graphic images to the fourth dimension of time. In the 4D model the temporal and spatial aspects of the project are inextricably linked, as they are during the actual construction process". As a result of their case study, Koo and Fischer concluded that "... 4D CAD models are effective in evaluating the executability of a construction schedule" (Koo and Fischer, 2000). The proposed experiment in this paper will investigate whether 4D CAD models of construction tasks to be developed based on Koo and Fisher's study would help to improve the accuracy of construction as it is carried out.

Kamat and Martinez, (2002) make an important distinction between 4D CAD and "dynamic 3D visualisation of operation simulations". This, they say, attempts to do more than integrate 3D CAD models with scheduling. It also depicts "the interaction between involved machines, resources and materials". 4D CAD, they state, can depict the evolution of a construction project but not the interaction of resources that build it. This may well be an avenue worthy of future investigation. Furthermore, recent developments of software to perform various tasks have brought into currency the term "nD CAD". This is held to involve a 3D CAD model with various extensions that include scheduling, costing, structural sufficiency and automatic code checking (Rowlinson and Yates, 2003).

2. ADVANTAGES OF OBJECT ORIENTED CAD

It has been estimated that somewhere in the vicinity of 135 people, including order processors and shippers, are involved with the process of making a house from design to final inspection (HUD, 2000). Given that a house is the largest investment that most people make, changes are often requested during the construction phase. Among the many and varied causes of these changes may be the inadequate initial design or the failure by the participants to clearly understand the project from the documentation. Most changes require that the work stop, the changes be evaluated, existing work be removed, material be removed, new materials be ordered and installed, and schedules be pushed back. Recent developments in three-dimensional visualisation of buildings, linked to object-oriented CAD databases, are already enabling owners to view "their" house in its final colour, material, and upgrade configuration, with rapid pricing of changes (Evans, 1999 in HUD, 2000). This three-dimensional visual presentation can significantly reduce misunderstandings, avert owner-initiated changes and improve construction programming generally (Heesom and Mahjoubi, 2004).

2.1 AUSTRALIAN INDUSTRY RESPONSE

A survey was conducted among various construction industry personnel to gauge attitudes to, and interest in the various forms of CAD documentation. The survey sought responses from architects, building designers, quantity surveyors, building estimators, construction managers, project managers, builders and building surveyors.

Both email and personal interviews were used to seek responses. 87 surveys were sent out and 29 responses were received with a completed questionnaire (a response rate of 33%). The survey sought to ascertain whether the general response to the use of new technology in construction was positive or negative, and whether any pattern emerged in the responses

Generally, the response to many questions was significantly more negative than anticipated. There maybe several reasons for this. Most of the questionnaires were responses to unsolicited emails. It could be that those wishing to lodge a protest about CAD systems would make the time to respond. The percentage standard error for the individual questions ranged from 9% to 18% (Siegel 1988). It is noteworthy that on a number of the questions asked, the largest response was neutral. Comments indicate that this may, in fact, mean simply that judgement is reserved on the matter. No conclusions can yet be drawn. In other words, there is a considerable constituency waiting to be convinced of the value of new systems and ways of working.

Table 1 General Survey Response (29 responses)

Proposition	Total Positive	Total Neutral	Total Negative
1. 3D CAD is the way of the future	61%	32%	7%
2. 3D CAD is my preferred form	42%	29%	29%
3. 3D CAD leads to fewer drafting errors	39%	32%	29%
4. 3D CAD is easier for builders	42%	33%	25%
5. 3D CAD leads to fewer construction mistakes	36%	28%	36%
6. 3D CAD makes costing more accurate	29%	42%	29%
7. 3D CAD is useful for construction scheduling	50%	36%	14%
8. 3D CAD is useful for training design office staff	61%	32%	7%
9. 3D CAD is useful for training management staff	57%	32%	11%
10. Animated (4D) documentation would be useful for training workers	61%	22%	17%
11. 4D CAD would be useful in construction planning	54%	36%	10%
12. Accurate 4D CAD would make estimating more precise	29%	39%	32%
13. Residential building is resistant to increased computer use	29%	39%	32%
14. My current work method will not change in the next ten years	25%	18%	57%
15. The next ten years will see increased use of computers in residential building	86%	14%	0%

The response to proposition 1 indicated that a clear majority of those surveyed see 3D CAD as “the way of the future”. However, proposition 2, which sought to determine the level of current usage of 3D CAD systems in the respondent group had roughly 40% preferred users to 60% who prefer other options. It is clear, however, that a positive attitude to CAD usage was significantly more common among architects and building designers than among other professionals surveyed. Overall there was some scepticism that 3D CAD would lead to fewer discrepancy-type errors (proposition 3). Further research is necessary to determine whether this response correlated with negative answer to the second question.

Slightly less than half of the respondents agreed that 3D CAD was easier for builders to understand. Comments indicated that this was due to a widely held belief that it is the quality of the construction knowledge of the documenter that is crucial rather than the system used. This theme was also reflected in the responses about whether fewer construction mistakes or more accurate costing

would result from 3D CAD usage (proposition 5). Architects as a group were negative on this proposition in contrast to their general attitude.

The response was more positive from all groups on the use of 3D CAD for construction scheduling (proposition 7) and comments indicated that some of the extensions related to CAD systems could lead to the automation of some of the repetitive areas of construction planning. There was a definite positive response to the proposed use of 3D and 4D CAD for training purposes (propositions 8, 9 & 10). This is an area that seems to have a ready market for well-developed reality-based construction modelling. Scepticism reasserted itself, however, on the question of whether 4D CAD could make estimating more accurate (proposition 12). Once again the industry remains to be convinced that such systems will work in practice. The survey shows widespread acknowledgment of the likelihood that the use of computer technology in residential building will increase in the coming decade (proposition 14). Furthermore there is considerable willingness to respond to this change. A large majority of respondents perceive that their own working methods will change in the next ten years (proposition 15). The standard error percentages for the overall group ranged from 9 % to 19%.

It is clear that despite some cynicism there are demonstrable advantages to be gained from the use of integrated IT systems in the residential construction industry. In particular, Object Oriented CAD documentation systems can have a number of positive effects for the industry (Anadol & Akin 1994). For example, the ready exchange of information on computer file between the various design and construction consultants can be expected to lead to fewer discrepancies in design documentation. Land surveyors, architects, structural and mechanical engineers are able to produce documents in the same format, so that conflicts of interest may be resolved at the documentation stage rather than on site at greater expense. Quantity surveyors can also have input at this stage with resultant better control over cost outcomes. This appears to be well recognised in the industry (Drogemuller, 1997).

Nevertheless there remains considerable resistance to the wholesale transfer of the industry to IT based work systems. There are a number of sources for this disquiet. Firstly, several industry sources in our survey stressed that it is the skill of the operator rather than the operating system that determines the quality of the documentation. "Garbage in –garbage out" was the refrain of several architects and quantity surveyors interviewed for this study. Jim Peet, senior principal of Widnall, Quantity Surveyors, stated that

"In my experience (now over 45 years) and having developed computer systems for our own practice over the last twenty years, any form of drawing is only as good as the level of knowledge of construction of the person doing the drawing work by whatever method".

In addition, some respondents believed that newer CAD systems could (temporarily) mask the skill level of the operator, and lead to documentation that appeared to be adequate when this was not in fact the case.

The second area of objection to the computerisation of the documentation process related to the constant updating of platforms and systems. This leads to an ongoing capital outlay in order to keep up with the latest technology and small business particularly finds this prohibitive. In addition, incompatibility of old and new systems and between platforms is a further difficulty that plagues small business. Some architects have chosen to remain outside the CAD revolution and

continue to produce traditional documentation for this reason. This is an issue that needs to be addressed before further integration of computer technology into the construction industry can proceed (Heesom, 2004).

Thirdly, there is some concern among designers that many CAD systems fall short of their promise in terms of producing usable construction documents in 2D form. The kind of diagrammatic sections so easily produced by 3D CAD systems may not contain sufficient information to make them useful for structural and engineering services purposes (Dakan, 2001). One of our survey respondents, Vanovac Associates confirmed this opinion stating that although “We use 3D Studiomax for 3D modelling and animation. 3D documentation is not, in our opinion, very effective.”

Finally, our contractual and legal system still makes it necessary to produce a 2D paper document than can be signed off as the “Contract Document”. This tends to mean that some of the benefits of integrated transfer of information are lost when the legal system ties all parties to the initial document produced to establish the project. On the other hand some of the survey respondents did feel that resistance to implementing integrated IT throughout the whole construction industry was largely due to the inertia of established businesses. Many of these wished to go on operating in the manner they had first learnt when they started out in the industry.

There was broad agreement among our surveyed group that 4D animated documentation of construction processes could be a useful training tool. Furthermore it was believed that it might be useful in construction scheduling. Independent research has confirmed this (Kang 2001 and McKinney et al, 1998). However, the view was strongly expressed that the use of animated documentation for actual construction projects was likely to meet with firm resistance. Respondents suggested that experienced construction workers were certain to feel condescended to by such documentation and to believe that it impinges on their exclusive territory. There is a great deal of existing expertise in turning paper documents into finished buildings and this would be somewhat threatened by animated documentation that purported to tell a builder how to do his job. To borrow from the terminology used in the Building Code of Australia, it could be said that builders prefer “performance based” documentation that specifies the outcome required, rather than “deemed to satisfy” documentation that tells them precisely how to do it.

3. RESEARCH PROPOSAL AT UWS

Specifically, this proposed research aims to investigate whether object-oriented computer-aided 3D drawing (CAD) with the addition of the time element through animation (which is called 4D CAD in this study), can improve the level of understanding that construction workers have of a building project. Initially, this simulated object-oriented CAD will be used to indicate the individual steps of the construction process to students. The proposal is designed to validate the effectiveness of 4D documentation in on-site conditions. Work is proceeding in many places on the assumption that 4D CAD will provide better communication tool than traditional paper documents. This proposal seeks to test that assumption.

In the proposed pilot study a small two room Autoclaved Aerated Concrete panel (Hebel™) structure, will be modelled using 3D AutoCAD software integrated with a

critical path construction schedule. The background and advantages to this object-orientated CAD followed by aims, plan and methodology of the research is presented below.

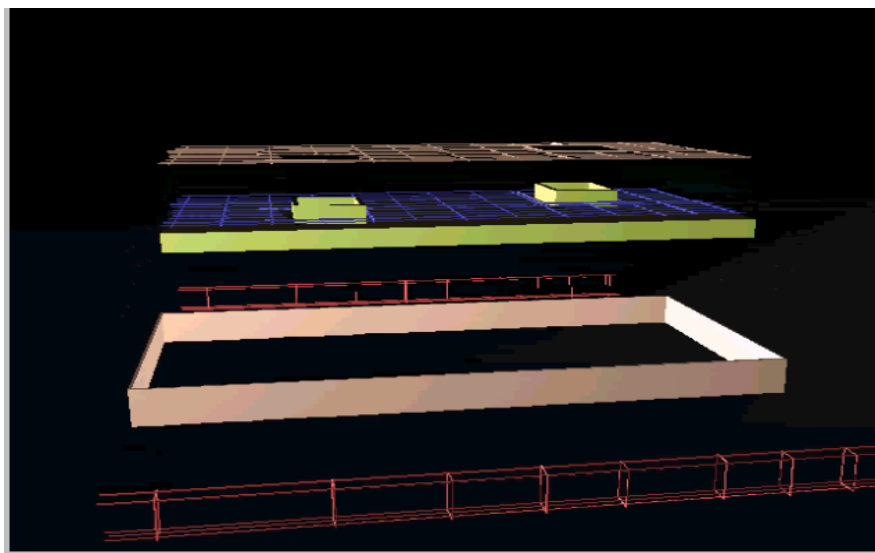
- This study aims to verify the supposition that the performance of workers and inspectors on a construction site can be improved through the adoption of modern computer aided technology. The functions of the workers and inspectors will be replicated using a group of second and fourth year building/construction management students. The two groups will clearly have varying levels of knowledge and experience, which will be quantified with initial questionnaires. Such varying levels of expertise are hypothesised to mimic a segment of the range that exists within the construction industry workforce generally.
- The study will be used to investigate the effects of the use of the CAD-oriented simulation on productivity and waste.
- This research will attempt to determine if some categories of information available to the worker or the inspector on site are particularly suited to the well-understood transfer of ideas.

In particular, this research aims to investigate whether object-oriented computer aided drawing (CAD), with the additional element of animation can improve the understanding of construction for all workers involved.

3.1 RESEARCH PLAN, METHODS AND TECHNIQUES

By using the '3D Viz' and 3D AutoCAD programs a small two room cabin will be developed into a 4D model. This model will consist of footings, floors walls with openings and flat roof. All the components will be developed separately and then assembled together with the assistance of animation software. Three-dimensional drawing files and an animated model will then be made available to the students for the construction and inspection of the cabin. A partially completed three-dimensional slab model as shown in Figure 1 used for a previous project is presented below. This model shows all the components of the slab including edge forms, top and bottom mesh, block-out forms, and edge beams reinforcements and develops work done on error rate in construction inspections (Saha et al, 1999). The aims, objectives and methodology of the proposed experiment are discussed below:

Figure 1: Components of a reinforced concrete slab in three-dimensional format



3.2 THE EXPERIMENT: INSPECTION & CONSTRUCTION OF AUTOCLAVED AERATED CONCRETE CABIN STRUCTURE.

3.21 Objective

The aim of the experiment is to investigate:

- Productivity and performance improvements due to 3D visualisation.
- The effect of experience/training on rate of detection of errors in a construction inspection.
- The effect of experience/training on cycle time (inspection time/construction time).

3.22 Method

Typical AAC panel components will be drawn using 3D viz and 3D AutoCAD softwares. This 3-dimensional drawing with cross sections and dimensions will be made available to the participants. Animated panel components showing step-by-step construction will be also made available to the students prior to physical construction. It should be pointed out that student body in the Bachelor of Building/Construction Management course at the University of Western Sydney contains people with a wide variety of experience levels in the construction industry. Students include both part-time and full-time students. Many of them have significant industry experience, some have previous TAFE training and a relatively small number come directly from high school. As such they present a reasonable facsimile of the range of skill and experience likely to be encountered on a construction site.

This experiment will be imitating a typical construction site where an inspection approval is needed for an occupation certificate to be awarded. A number of students will be designated as workers and/or inspectors. These workers and inspectors will be divided into two separate categories before the start of physical construction namely, Category A and Category B

The Category A workers and inspectors will be exposed to a short presentation containing object-oriented 3D CAD drawings including step-by-step construction animation before the start of the cabin construction. The Category A workers and inspectors will be supplied with three-dimensional drawings containing plans, cross-sections, specifications and etc. The Category B workers and inspectors will be asked to build and inspect the cabin using traditional two-dimensional drawings. A group consisting of three construction workers from each category will be assigned to physically build the cabin. Inspectors will arrive on site after the completion of construction. Inspectors will be also provided with a standard checklist for monitoring the defects, the contents of which will available to all participants.

It is expected that 5 groups from each category will be involved to physically build the cabin up to the pre-occupation inspection. The cabin will be built by using standard Hebel panel materials in a replicated site condition. A number of second and fourth year Bachelor of Building/Construction Management students (enrolled in BG209A: Building in Practice 1 and BG413A: Quality Systems offered in spring semester) will be expected to participate in this research activity. Students will be only asked to assemble all structural components not render or finish off the job. Components of the cabin will be designed in such a way that building time for the cabin will not exceed six hours. Building in Practice 1 students are allocated to conduct six (6) hours of site work per week as part of their curriculum. Students (estimated forty inspectors) from the final year subject BG413A: Quality Systems

(also offered in spring semester) are then expected to detect the most common errors arising from this type of construction (listed below). Activities performed for this research work are normally part of their major assignments. Therefore, it is expected that students will be motivated to participate in this project. This cabin construction and inspection task will last for 10 weeks, which will be scheduled during the spring semester (week 3 through to week 12).

After the completion of construction of cabin by second year students, each inspector (from fourth year students) will be provided with approved plans, drafted to industry standard (depending on their category), for the cabin and will be given a generous amount of time to inspect and report using a checklist based on current Australian Standards, with room for comments, on the following items as listed below.

- Correct number and accurate positioning of panels.
- Level surface of floor panels.
- Plumb alignment of wall panels.
- Level alignment of ceiling panels.
- Correct maximum gaps between panels.
- Proprietary fixings correctly installed.
- Workmanship

It is anticipated that the following data will be gathered from the above experiment from two categories of crews:

- Experience level of the workers.
- Experience level of the inspectors.
- Education/ qualification level of the inspectors & workers.
- Errors detected (according to survey made by an independent experienced inspector).
- Errors undetected (as above).
- Total time taken for inspection.
- Total time taken to construct the cabin.

The data collected will be examined with reference to probability concepts described for engineering planning (Ang and Tang, 1984).

The construction industry is likely to experience an explosive growth in the use of 3D and 4D CAD documentation in the next ten years. This research proposal aims to verify the effectiveness of such documentation as a means of reducing errors and therefore improving efficiency. It will also examine the attitudes of a section of the construction workforce to such forms of documentation and their readiness to accept change.

4. CONCLUSION

When compared to the manufacturing sector the construction industry worldwide has been slow to adopt the potential benefits that are afforded by new technologies based around 3D and 4D CAD. This has been due to a combination of attitudinal reluctance for change and technical difficulties in making the computer models reflect the complexity of the construction process. Nevertheless, computerisation of the construction industry is inevitable as a new generation of workers emerge with greater familiarity with Information Technology from their schooling. The ongoing research described in this paper is part of an effort to understand and quantify the consequences of the coming changes. The potential benefits from the adoption of innovative technology in documentation are enormous. They offer the possibility of a reversal of the trend towards diminishing construction

documentation quality. Properly implemented 3D and 4D CAD systems can improve communication of the construction process and therefore close the proverbial gap between the idea and the implementation.

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PROCUREMENT AND RISK SHARING

Full Paper

NON-PRICE CRITERIA FOR SELECTING INNOVATIVE CONTRACTORS

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ABSTRACT

Public clients increasingly use other criteria than lowest price when awarding construction contracts. The primary purpose of this paper is to explore whether these non-price criteria provide incentives for contractors who develop innovative processes or technologies. Theories of innovation and entrepreneurship are applied, focusing on the role of public sector clients, their response to innovative ideas, and innovation management among contractors. Empirically, use is made of data from an ongoing Swedish study of public procurement practices, related to current EC directives. A comparison is also made with Australian prequalification practice. Results indicate that non-price criteria not necessarily stimulate innovative efforts among contractors. It appears that the type of criteria and their weights play an important role. Moreover, the effect of specifying award criteria in advance is found to be ambiguous. However, the effects on process and product innovation differ. It appears that contractors when deciding upon areas of improvement need to be alert to multiple criteria procedures used by public clients. In addition, policy-makers should be careful when choosing the degree of transparency and precision in public procurement.

Keywords: construction, entrepreneurship, innovation, public procurement, technology

1. INTRODUCTION

It has been well recognized that government agencies in several countries increasingly use multiple criteria instead of lowest price when awarding construction contracts. Recent examples include China, where the introduction of competitive tendering practices (Shen and Song, 1998) has resulted in construction contracts being awarded on a multi-criteria basis (Lai et al., 2004; Shen et al., 2004), and Turkey, where multiple criteria are used in contractor prequalification (Topcu, 2004). This movement can be explained partly by increased knowledge about negative consequences of lowest price selection (Hatush and Skitmore, 1998). Another contributing factor is reforms in legislation and regulation on public procurement which have opened up for multiple criteria practices. Whereas the traditional lowest price regime results in a certain type of price competition between contractors, it could be asked whether this multiple criteria movement has led to another type of competition—more focused on innovation and technological change. This is not necessarily the case.

This paper deals with non-price criteria in municipal construction procurement. The purpose is to investigate the relation between multi-criteria contractor selection and innovation. It is generally acknowledged that innovation and technological change are important sources of productivity growth and material welfare in countries (Edquist, 1997). There are also studies that have investigated whether governments can adopt a pro-active approach and stimulate innovative activities through its procurement practices. Lichtenberg (1988), for example, studied procurement by design and technical competition in the U.S. and found that this kind of competitive procurement stimulated considerable private R&D investment. Dalpé *et al.* (1992) studied the public sector as first user of innovations and concluded that public procurement practices may indeed affect the pace and direction of innovative activity in industry. In construction, procurement has been recognized as an instrument (Manseau and Seaden, 2001: 17), but not a major one. The literature on multi-criteria contractor selection and its relation to innovation seems scant and underdeveloped.

The remainder of this paper is organized as follows. First, an analytical framework based on theories of innovation and entrepreneurship is presented. Second, the use of non-price criteria in construction procurement is discussed and empirical data from a recent survey of Swedish municipal construction procurement is described and analysed. Some alternative routes of action for government agencies are also covered. Third, a brief comparison between Swedish and Australian practices is made. Finally, the conclusions of this paper and their implications for practitioners and future research are presented.

2. INNOVATION AND ENTREPRENEURSHIP

In this section the analytical framework is presented.

2.1 PRICE COMPETITION VS TECHNOLOGICAL COMPETITION

Schumpeter held technological competition (competition through innovation) to be the driving force of economic development and growth (Schumpeter, 1942). He criticized the strong focus on price competition and argued that what counts is technological competition, “[...] competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives” (Schumpeter, 1942:84). Thus, following his view, a nation striving for sustainable economic growth is heavily dependent on technological competition and innovation.

In construction procurement it could be argued that the traditional lowest price regime results in price competition between contractors. Thus, if we adopt the distinction between product and process innovation (Abernathy and Utterback, 1988), price competition leads to process innovation rather than product innovation. However, do multiple criteria open up for technological competition that in turn open up for product innovation? This could be the case if the non-price criteria refer to features of technological competition.

2.2 THE NOTION OF ENTREPRENEURIAL OPPORTUNITIES

In research on entrepreneurship the notion of entrepreneurial opportunities is at the centre. Shane and Venkataraman (2000) have defined the field of entrepreneurship as involving “[...] the study of sources of opportunities, the process of discovery, evaluation, and exploitation of opportunities; and the set of individuals who discover, evaluate, and exploit them.” One source of entrepreneurial opportunities is technological inventions where entrepreneurs with particular prior knowledge (Shane, 2000) can discover how an invention can be used and introduced in the market. Technological development and change thus created entrepreneurial opportunities. Another source of entrepreneurial opportunities is the division of knowledge (Hayek, 1945) in the market. Krueger (2003) has noted that entrepreneurs are likely to recognize patterns in the myriad of cues and signals that we receive; patterns that may indicate entrepreneurial opportunities. If contractors discover entrepreneurial opportunities this may be an incentive to invest in R&D. Here, the important question that we should ask is whether non-price criteria create entrepreneurial opportunities or not.

In a seminal article Kline and Rosenberg (1986) argued that in successful innovation both technical and market needs must be fulfilled. Kline and Rosenberg questioned the conventional “linear model” of innovation (where R&D leads to production and marketing of a new product) and pointed out that innovation is both complex and uncertain. If we are to link innovation and entrepreneurship we can note that invention and innovation might result in new entrepreneurial opportunities (Shane, 2000). Conversely, if individuals or companies discover entrepreneurial opportunities this may result in R&D investments that later on result in new products or processes. Both demand and supply matter.

3. THE USE OF NON-PRICE CRITERIA

Procurement of construction projects can be performed either as a single-stage procedure or as a two-stage procedure. In the single-stage procedure

all contractors are allowed to submit tenders on a construction contract. In the two-stage procedure the buyer usually distinguishes between prequalification and final selection of contractors. All contractors are allowed to enter the prequalification stage, but only those that qualify are allowed to enter the final selection stage. Multi-criteria contractor selection can thus refer to both single-stage and two-stage procedures.

3.1 NON-PRICE CRITERIA IN SWEDISH MUNICIPAL PROCUREMENT

In order to gain an understanding of various non-price criteria an empirical survey was conducted in the spring of 2004. The sample consists of 386 tendering documents, representing construction projects procured by 171 (out of 290) Swedish municipalities in 2003. Lowest price selection was used in 42 tendering documents (11%), but these are not referred to further in this paper. In Sweden it is common that government agencies use a standardised system (AF AMA) for tendering documents. The AF AMA system facilitates the review and codification process as information is presented under particular headings in the documents (e.g. AFB.52 for information on award criteria). The tendering documents were derived from a commercial database which contains records of tender invitations from government agencies in Sweden. Construction procurement was defined according to the Common Procurement Vocabulary codes (CPV) employed in the European Union. There is probably a slight bias in the sample towards municipalities that use more sophisticated approaches, since this might be correlated with a propensity to provide electronic tender documents. In line with the scope of this paper we focus on three factors that have been extracted from the empirical data. These factors are (a) the type of award criteria, (b) the weightings of non-price criteria, and (c) the degree of transparency and precision.

3.1.1 The type of award criteria

A great diversity of multiple criteria practices is represented in the sample. However, based on an analysis of the tendering documents ten main categories of award criteria could be identified. These were (1) tender price/unit price, (2) operation and maintenance cost, (3) contractor capability, (4) project duration, (5) environmental issues, (6) quality issues, (7) function, (8) references, (9) service quality and attitude, and (10) financial capacity. Thus, one category refers to price criteria and nine categories refer to non-price criteria. Given these criteria categories we can ask whether using them stimulates innovation. Criteria that are most strongly related to technological competition are 'operation and maintenance cost', 'quality issues' and 'function'. These criteria refer to general features, while most of the other criteria refer to prescriptive specifications. 'Contractor capability', for example, is more related to how efficiently the construction project can be carried out, than the introduction of new products.

3.1.2 The weights of non-price criteria

In using multiple criteria government agencies also have to rank and assign weights to these criteria. Thus, they have to make a trade-off between price and various non-price criteria. The empirical data shows that some municipal agencies assign very low weights to non-price criteria compared to the tender

price criterion. The lowest weight that was identified for a non-price criterion was 0.5% (mean 11.3%). Obviously, by assigning low weights to non-price criteria, municipal agencies lower the incentives for contractors to improve their non-price performance. In fact, very low weights for alternative criteria result in a selection of contractors that resembles lowest price selection.

3.1.3 The degree of transparency and precision

When private companies procure construction projects they may decide to keep their initial preferences secret. They can review tenders and make the trade-off between price and non-price criteria *ex post*, instead of *ex ante*. In public procurement, on the other hand, there is need of transparency and precision in contractor selection. Otherwise there is always a risk of government personnel being accused of favoritism or sweetheart deals (Wilson, 1989). Based on the empirical data a Transparency and Precision Index was created (see Table 1). The index indicates how transparent and precise the municipal agencies were in their award criteria. The tendering documents in the sample achieved a score of 3.17 on average (standard deviation 1.30).

Table 1 The Transparency and Precision Index

Transparency and precision index	Description
5	Award criteria with rankings, weights, and scales
4	Award criteria with rankings and weights
3	Award criteria with rankings
2	Award criteria without rankings
1	No information

A high score signifies that the municipal agency revealed much information on how tenders were to be evaluated. This gives contractors a chance to analyse their competitiveness on the basis of the weights and scales assigned to each criteria. A low score signifies that the municipal agency revealed little or no information on how tenders were to be evaluated. Thus, contractors were faced by greater uncertainty regarding their competitive advantages.

At first glance one might argue that a high score in this index is more beneficial for innovation among contractors, especially in light of the new European Union Directives on public procurement which requires that weights shall be assigned to all award criteria. A high score indicates that there is close to perfect information rather than a confusing “myriad of cues and signals” where skilled entrepreneurs could discover commercial opportunities. Those opportunities that exist are decided *ex ante* by the municipal agency, and they are likely to be discovered by all contractors. In contrast, when little information is given to contractors *ex ante*, municipal agencies have greater possibilities to make the trade-off between price and non-price criteria *ex post*. There is also a chance that contractors discover opportunities that were unknown by the municipal agency *ex ante*. A lower degree of transparency and precision thus gives a municipal agency a wider range of possibilities to reward such discoveries. This analysis suggests that it would be optimal to combine a low degree of transparency and precision in tender invitations (*ex*

ante) with a high degree of transparency and precision in contract award notices (*ex post*).

3.2 A NOTE ON ALTERNATIVE ROUTES OF ACTION

Indeed, there are other routes of action available for government agencies than using non-price criteria (either as prequalification or final selection). One example is performance-based specifications that could result in a type of technological competition that fosters innovation and technological development. Another example is when government agencies allow contractors to propose alternative designs or technologies, even though traditional prescriptive specifications are used. A contractor can, thus, question decisions made by the government agency or its designers in earlier stages of the process. Is this design the most appropriate? Could space be used more efficiently? These routes of action could be combined with lowest price selection of contractors and yet stimulate innovation in industry.

4. A COMPARISON WITH AUSTRALIAN PRACTICE

A detailed discussion of Australian practice is beyond the scope of this paper. The Australian Procurement and Construction Ministerial Council has published a *National Prequalification Criteria Framework*, aiming to achieve national consistency in government agency prequalification of contractors (APCC, 1998). The document presents eleven prequalification criteria: (1) technical capability, (2) financial capacity, (3) quality management, (4) occupational health and safety & rehabilitation, (5) compliance with code of practice, (6) human resource management, (7) commitment to client satisfaction, (8) co-operative contracting and partnering, (9) management of environmental issues, (10) management for continuous improvement, and (11) compliance with legislative requirements.

It is interesting to note that this Australian framework bears similarities to the ten categories of criteria that were identified in the Swedish sample. However, while Australian practice appears to be characterised by an increased degree of national consistency, Swedish municipal practice is characterised by diversity. It is also interesting to note that the prequalification criteria under 'management for continuous improvement' include the following: "[t]he extent of a contractor's commitment to continuous improvement can be gauged from [...] a corporate policy on research and development, including the encouragement of improved design and/or construction processes or products [...]". This prequalification criterion is closely related to innovation. None of the non-price criteria in the Swedish sample had an explicit reference to contractors' R&D track record. One reason can be that Swedish legislation stipulates that award criteria should be narrowly related to what is being procured, which makes it uncertain from a legal viewpoint whether Swedish municipalities could use a R&D track record criterion.

5. CONCLUSION

In the introductory section I posed the question whether multiple, non-price, criteria foster innovation in industry. As we have seen this is not necessarily

the case. Multi-criteria contractor selection can promote innovative initiatives, but that depends on the type of criteria used, and the weights that are assigned to such criteria. Furthermore, the degree of transparency and precision seems to play an important role. A high degree of transparency and precision implies a trade-off between price and non-price criteria that is frozen in the early stages of the procurement process.

What are the practical implications of these findings? Contractors need to be alert to the type of non-price criteria that government agencies use, and their weightings, when deciding upon areas of improvement. There might be limited opportunities for contractors to introduce new products in the tendering stage. However, process innovations for more efficient construction seem to be more easily implemented. For policy-makers, there seems to be need of an understanding of the potential negative effects of higher demands on transparency and precision in public procurement. This is also an area where more research is needed. The field of entrepreneurship can provide a useful framework for describing and analysing this phenomenon further.

6. ACKNOWLEDGEMENT

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PROPERTY IN BUSINESS – INEFFICIENCIES IN CORPORATE PROPERTY INVESTMENT IN AUSTRALIA

Full Paper

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ABSTRACT

Australian companies still do not adequately recognise or manage their corporate real estate. The estimated total cost of office accommodation in Australia is identified and the value of wasted space quantified. Some \$550 million could be added to business's bottom line if new office techniques and basic strategic asset management planning were to be adopted. The consequences on the future need for office development may also be affected by developing facilities management techniques.

Keywords; Corporate real estate, property performance, resource sustainability, Australia

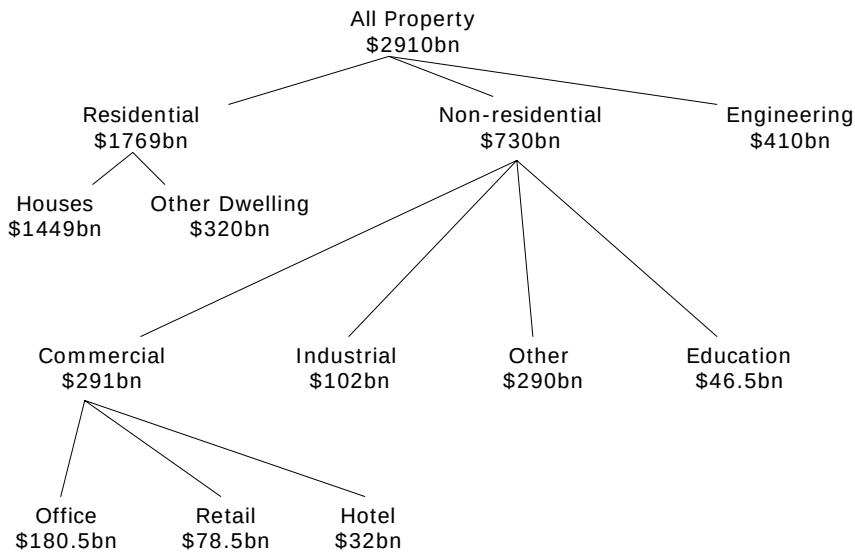
INTRODUCTION

The management of corporate real estate by facilities managers can represent a major contribution to the profitability of an organisation. The facilities management profession grew out of the recognition that the property assets of business represent a significant proportion of the company's available assets, both as a proportion of total investment and in terms of annual operating costs. This investment in property has been recognised for many years. Back in 1983, (Cock, R. and French, N. 1997, Zeckhauser, S. and Silverman, R. 1983) urged business to '*Rediscover your company's real estate*'. In a survey of 300 US companies, the authors found that at least 25% of total companies' assets were held in real property. The total invested in US corporate property is estimated at nearly 45% of the total market capitalisation of US companies. (Roulac, S. E. 2003) In Europe, research reflected the results of those in the US. (Varcoe, B. J. 1993) reported that leading UK businesses had 30% to 40% of their capital held in real property and that 10% to 20% of annual operating cost was property related. (Gibson, V. A. 1994), highlighted the need for organisations in the public and private sectors to develop strategic management tools and to gather property information in order to understand how this enables the effective delivery of business functionality. Thus corporate real estate is an important contributor to the economy and efficiency of business.

INVESTMENT IN THE BUILT ENVIRONMENT

Investment in Australian corporate real estate constitutes a very significant proportion of the nation's total wealth. Before proceeding to analyse the effectiveness of that investment, it is necessary to quantify the level of investment and to define corporate real estate. The total value of the developed environment in Australia is estimated at almost \$3 trillion, (Ruthven, P. 2002), which is more than four times GDP. The investment can be subdivided using Australian Bureau of Statistics' classifications of residential, engineering and non-residential. The non-residential and engineering categories represent an estimated \$1,140bn or 39% of all built assets, while residential totals \$1769bn. The area of most interest to business, non-residential, can be further split into a number of sub-categories to differentiate the various classes of property use; commercial, industrial etc. as shown in .

Figure 1 The Built Environment



Source: Ruthven, P. 2002

The sector comprises a number of uses ranging from business use to public sector property use, which includes schools, hospitals and other organisations with a 'not for profit' objective. If one deducts from the total non-residential those assets which are generally not of a corporate or business nature, the health, education and public sector investments, then there remains the commercial and industrial properties. These can be calculated to represent a value of \$393bn or 13.5% of the total built environment.

Investment in property continues with the total value of the built environment growing at about \$48.5billion annually. The construction industry is an integral part of the economy, contributing 4.6% of the gross product of all industries and employing 7% of the workforce, which translates to 668,000 individuals. Last year some \$12.6bn was invested in new, non-residential construction. Of this total, 19%, or \$2.3bn, was invested in office and retail, while \$790m, or 6%, of the total was spent on industrial building. Table 1. It can be seen that a very significant investment has been made in our built environment, and this investment increases annually with a 1.6% addition to the estimated total value.

Table 1 Value of Non-Residential Building Work Done

	2001 \$m	% of total
Total	\$12,615	
Retail	\$2,366	19%
Office	\$2,337	19%
Other business	\$1,558	12%
Factories	\$790	6%
Entertainment	\$886	7%

Source: ABS Building Activity (8752.0)

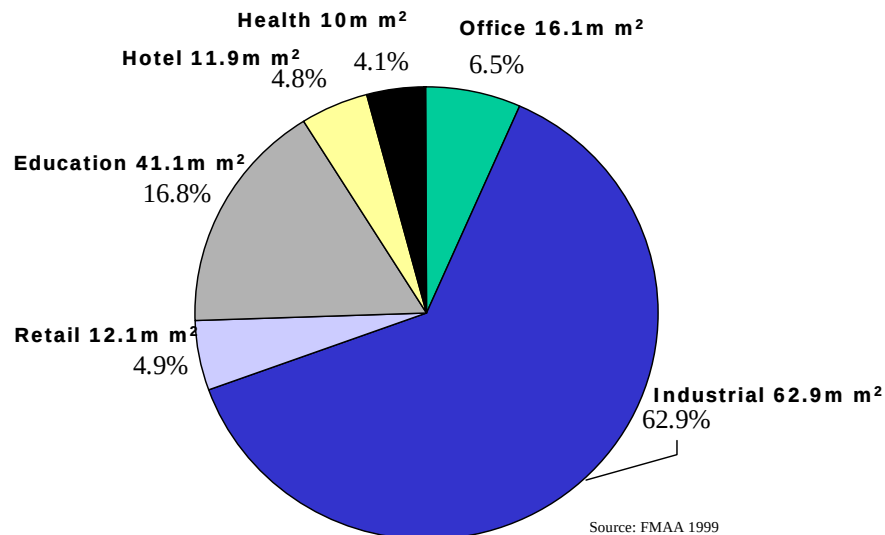
Buildings are constructed for a variety of purposes; to provide shelter, security, amenity and a place to carry on business, improving the utility of our environment. The focus of this paper, as previously stated, is in the non-residential category and, more specifically, the premises occupied for business purposes. Property assets are held principally for two purposes, as owner occupiers in which the property provides a place from which to conduct business, or as investments. The property in the latter category is held by organisations that acquire their assets to derive an income flow from tenants.

Property occupied as a place to conduct business is commonly termed Corporate Real Estate and is defined as property assets held by a company for the purpose of providing that company with enabling resources of shelter and a place to operate the business from. It has a fundamentally different ownership purpose from property assets held by companies for investment purposes. The investor wants to maximise the return on investment, while the corporate occupier seeks to maximise the benefit to the business from ownership. In considering this division between owner-occupied property and that held for investment, it becomes evident that, from a corporate real estate perspective, the investment properties of one organisation become the leasehold properties of another. It is further evident that the eventual leasehold occupier of the property will be in occupation to use the property as a business base and, therefore, has the objective of deriving maximum business advantage out of the property for the duration of the lease. Thus, in considering the total stock of property, the important differentiation comes between owner occupied and leased property and not whether it is held for investment or owner occupation.

Ultimately all commercial property is occupied as corporate real estate, with the exception of space vacant which is to let or withdrawn from the market for refurbishment. Some allowances, therefore, must be made in calculations for vacant property within the total stock, as this does not form a part of what may be described as corporate property. The amount of office stock which is vacant and available to let varies from location to location, over time depending on economic cycles, with the level of new stock entering the market and the demand for additional space from corporate occupiers. Current vacancy figures range from a high of 27% for C grade in Adelaide CBD, to lows of 8% for Prime and A grade stock in Brisbane's and just 4.5% in Canberra.

The total stock of Corporate Real Estate comprises some 245million metres square of gross area. Figure 2 shows property classes with estimated percentage of total stock. (FMAA 1999) Industrial property comprises the largest proportion by area at 62.9%, while, by comparison with only 14% by value of non-residential capital expenditure.

Figure 2 Non-residential Property Australia – percentage by area



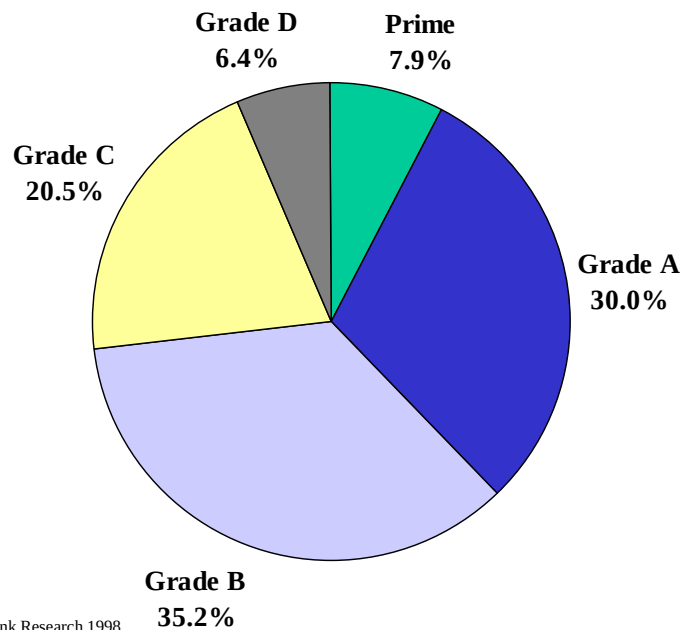
By contrast, the office sector represents just 6.5% of the total non-residential area yet comprises 25% of the invested capital. This is the highest cost to area ratio within the corporate property categories and, as such, affords the best opportunity for business to make cost and efficiency savings. The office sector is largely concentrated in the State Capital CBDs and close fringe regions. Of the 17.6 million metres square of office space monitored by the Property Council of Australia, 12.89m² is located within six CBDs. The majority of the remaining 4.8m² is located in twelve fringe or satellite centres around the capitals.

Table 2 Australian Office Stock - m²

Region	CBD	Non-CBD
Sydney CBD	4,248,557	
North Sydney		782,448
Parramatta		547,992
Chatswood		300,892
Crows Nest/St Leonards		303,121
Newcastle		188,716
NSW Total	6,371,726	
Melbourne CBD	3,150,793	
St Kilda Road		765,505
Southbank		296,577
Victoria Total	4,212,875	
Brisbane CBD	1,552,558	
Brisbane 'Near City'		639,513
Gold Coast		254,166
Queensland Total	2,446,237	
Perth CBD	1,265,599	
West Perth		332,738
Western Australia Total	1,598,337	
Adelaide Core	898,152	
Adelaide Frame		211,512
Adelaide Fringe		181,710
South Australia Total	1,291,374	
Canberra Region	1,448,914	
Hobart CBD	326,458	
Australia Total	17,695,921	
Source; PCA 2000		

Office stock within Australia is categorised according to the quality of the accommodation provided, utilising PCA grading categories which differentiate buildings based on a series of locational, functionality and technological criteria. The prime category represents the few, very high quality, technologically advanced and well located properties within the CBDs.

Figure 3 Office Stock - Grade by Percentage



Source: Knight Frank Research 1998

While the majority of office accommodation falls within the A and B grades and comprises those buildings, which although still of a good quality and providing good facilities, are not quite 'state of the art'. The C and D grades tend to comprise those buildings at the fringe of the business district or which are ageing and lack some of the modern conveniences.

ASSESSING THE COST OF CORPORATE REAL ESTATE

The total costs to business of occupying corporate real estate is not simple to estimate. The costs for leased accommodation can be ascertained through records of lease deals. The costs of owner occupation can be derived from company accounts in the case of public companies that are owner occupiers. These figures, however, include items which obscure the cost of real property, as company accounts include other operational plant and machinery in this category. In order to quantify the costs of occupation, and to compare on a like for like basis, it is necessary to work from a common cost base for both owned and leased property.

It is not an unreasonable assumption to make that a competent, prudently managed company would seek to maximise the value of its assets. Thus, if a corporation in owner occupied property vacated that property, then it would seek to maximise return on the property which would be sold or made available to lease at the current full market rack rental. Alternatively, the corporate occupier could, as many have done in recent years, sell the property and lease back the accommodation at a market rent. Similarly, any lessee of accommodation could, subject to lease covenants, sub-lease or assign that lease again at the current full market rental. It is, therefore, justifiable to examine the costs of corporate real estate in terms of the rent which would reasonably be expected to be paid in the market for that class of property.

It might be argued that a long lease at below market does not fit the assumption, as the lessee is receiving a benefit, in valuation terms a profit rent. Like an owner occupier, however, it is not unreasonable to expect that the lessee could realise this value in the market by assigning or surrendering the lease. The only exception to this assumption would be in the currently rare case of an over-rented property. This basis is to some degree supported by the increasingly common practice within major corporations of charging internal rents based on market equivalent figures to their individual departments. (Cock, R. and French, N. 1997). This supports the notion that the cost to the occupying department is the market cost of providing that accommodation in the open market and that any costs or benefits associated with ownership or otherwise of the asset is a matter of sound corporate asset planning and not a factor of business production.

METHODOLOGY

The estimation of the costs of occupation of office accommodation is derived from a series of market based cost parameters, including rent, outgoings and vacancy rate. The current effective rental paid, not asking rents, or face rents, is used as the levels and type of lease incentive vary from location to location and can be as high as 30% of rack rent. Using effective rents reflects the actual cost of occupation.

Figure 4 Effective Rents shows the rental rate and applies this to the estimated total office area in each location from Figure 2. These rents were sourced from published data from leading valuer and agency firms. (Colliers International Aug 2003, FPD Savills Research 2002, Laing Simmons 2003). Allowance is also made from the total office stock for vacant space using published average vacancy rates. (Property Council of Australia 2000),

Figure 4 Effective Rents

Region	Net Effective Market Rent / m/pa					Net Effective Rent				
	Prime	A	B	C	D	Prime	A	B	C	D
Sydney CBD	\$666	\$495	\$350	\$280	\$224	\$235,778,074	\$572,715,139	\$486,867,542	\$208,035,400	\$52,685,465
North										
Sydney	\$350	\$350	\$320	\$256	\$205	\$12,887,700	\$73,858,426	\$122,652,708	\$25,147,112	\$2,104,320
Parramatta		\$270	\$216	\$173	\$138	\$0	\$64,465,008	\$24,144,130	\$16,750,028	\$8,286,404
Chatswood		\$330	\$264	\$211	\$169	\$0	\$50,219,358	\$24,408,578	\$7,827,546	\$263,467
Crows										
Nest/St										
Leonards		\$350	\$280	\$224	\$179	\$0	\$16,308,597	\$26,724,963	\$29,396,496	\$2,512,026
Newcastle		\$270	\$216	\$173	\$138	\$0	\$10,724,113	\$15,262,461	\$10,281,828	\$683,518
Melbourne										
CBD	\$470	\$300	\$190	\$152	\$122	\$272,876,543	\$250,173,479	\$152,457,577	\$75,265,335	\$22,637,056
St Kilda										
Road		\$210	\$165	\$132	\$106	\$0	\$44,628,578	\$47,448,423	\$21,126,077	\$989,476
Southbank		\$210	\$165	\$132	\$106	\$0	\$24,385,586	\$15,264,087	\$8,096,806	\$333,471
Brisbane										
CBD	\$235	\$131	\$105	\$84	\$67	\$23,843,282	\$67,550,103	\$63,342,134	\$14,156,075	\$3,579,147
Brisbane		\$166	\$133	\$106	\$85	\$0	\$26,989,734	\$36,308,142	\$10,926,238	\$1,649,865
'Near City'		\$166	\$133	\$106	\$85	\$0	\$13,740,133	\$11,721,478	\$5,100,896	\$713,336
Gold Coast										
Perth CBD	\$300	\$235	\$140	\$120	\$95	\$54,962,950	\$109,468,795	\$33,934,252	\$25,706,203	\$1,094,908
West Perth		\$200	\$160	\$100	\$80	\$0	\$11,402,079	\$19,752,578	\$10,116,274	\$1,286,828
Adelaide										
Core	\$230	\$165	\$125	\$100	\$80	\$11,132,797	\$47,188,703	\$26,091,187	\$15,013,099	\$6,369,053
Adelaide		\$160	\$110	\$88	\$70	\$0	\$4,827,341	\$8,239,523	\$3,851,285	\$2,833,464

Frame Adelaide Fringe	\$150	\$105	\$84	\$67	\$0	\$2,968,950	\$10,689,589	\$3,277,070	\$497,694
Canberra Region	\$215	\$172	\$138	\$110	\$0	\$79,235,095	\$77,120,599	\$52,020,869	\$20,138,880
Hobart CBD	\$140	\$112	\$90	\$72	\$0	\$12,965,510	\$8,759,382	\$6,061,015	\$2,974,589
Australia Total					\$611,481,346	\$1,483,814,728	\$1,211,189,334	\$548,155,651	\$131,632,966
Total Rent Australia					\$3,986,274,025				

The effective rent is also typically quoted on a net rent basis that excludes the outgoings for the property. The outgoings costs vary by location and property grade and represent the costs to the lessor of statutory outgoings, energy costs, and repairs and maintenance for the operation of the building. These costs should be accounted for in deriving the total costs of occupation. (Property Council of Australia 2002)

In order to derive an estimate of the total costs to Australian business of their corporate office accommodation, the cumulative cost of net effective rent and outgoing for each property grade and location are calculated. This figure is then multiplied by the net Lettable area for each market after allowance is made for vacant offices. Using the PCA source, the estimated total office space is 17.7 million metres square. This total space is reduced to 16.1 million metres square of space when the vacancy rate for each locality and grade of property is equated. (Property Council of Australia 2000).

The total costs to business of occupying this 16.1 million metres square of space is calculated to be total net effective rent, equating to A\$3.986 billion per annum. The total operating costs paid for this space adds a further B\$1.36 billion to the rent. Thus, we are now able to estimate, with a reasonable level of confidence, the market equivalent cost of providing all corporate office space within Australia. This figure is expressed as the gross rack effective rental of all occupied space and is estimated to be C\$5.34 billion per annum. Having quantified the cost of providing corporate office space, it is now possible to apply this figure to measures of space efficiency to give an indication of what potential savings may be available if sound management is applied, or innovative occupancy techniques employed.

THE COST OF WASTED SPACE

The design and use of the workplace has significantly changed over the past few decades as business strives to maximise its efficient use of assets. The office layout has developed from rigid cellular designs, through open plan, to multi-function, team based workspace. This change has resulted in a deconcentration in which property and information systems have been fused and work is no longer bounded in place and time but enabled to work flexibly anywhere. The enabling infrastructure becomes a strategic resource of the organisation, no longer a sleeping asset, but a source of competitive advantage. (Apgar IV, M. 2002)

The changing pattern of work has spawned new innovative techniques to intensify the use of space and free workers to be more flexible in their work hours, location and type of workplace. Hot-desking and hotelling seek to directly increase the ratio of employees to workstations by requiring employees to share workstations at different times, while virtual officing and teleworking free employees to work from home or a satellite or drop-in centres. The reengineered workplace, which promotes flexibility, knowledge exchange and is responsive to the unstable business environment, provides for greater efficiency in capital expenditure on space. (Lizieri, C. M. 2003)

The extent to which Australian business has recognised the potential savings from reengineering or deconcentrating their office has a direct, proportional financial return to the organisation. The intensity of space use *ceteris paribus*, when professionally managed, can add to the strategic advantage of the company and provide a positive

return from property assets. Studies in the UK show that business could save £18 billion per annum, or add 13% to their bottom line profit, by properly monitoring property use and adopting benchmark occupancy standards. A staggering £7 billion could be saved by owner occupiers just by being as efficient as tenants in their use of space (Bootle, R. and Kalyan, S. 2002). A comparative study in Australia (Warren, C. M. J. 2003b) reveals an even greater spread in the intensity of office use, with average office densities of 20.6m² per full time equivalent employee (FTE), compared to the UK figure of 16.3m² (RICS and Gerald Eve 2001). Comparison of UK and Australian office use data consistently shows that Australian office use is much less dense than that in the UK, however, the increased office densities resulting from the take up of new office techniques reveals similar space savings between the two countries. (Warren, C. M. J. 2003a)

The study of corporate office space reveals that, even after several decades of research and attention being paid by the property and facilities management professions in Australia to the strategic use of real property assets, only two thirds of organisations are benchmarking their property use. This means that of the \$5.34 billion calculated above, which corporations spend annually on rent, some D\$1.76 billion is paid but yet remains unmeasured as a corporate resource. More importantly, by comparing those business organisations which do benchmark their property performance with those that don't, there is a 10.3% saving in space, equating to E\$550 million which could potentially be added directly to the bottom line of those companies which benchmark. A similar saving of 5.2% of office space, or F\$278 million, could be saved if the 35% of organisations which do not have a strategic property plan for their organisation were to implement this basic management technique.

The waste of corporate funds is highlighted in a number of other areas. The difference between owner occupied and leasehold space, discussed above in the UK research, is repeated in the Australian market. The space efficiency of tenants reveals a 13% space saving compared to their owner occupier counterparts. The ratio of owner occupiers to tenants within the market is 31/69, thus the organisations which own their accommodation are potentially wasting the equivalent of G\$215 million.

There has been a tendency for corporations to move from owner occupation toward leasehold premises to release capital back into their organisations. This move could also increase the efficiency of space use, resulting in the savings above, if these organisations implement the same management strategies of those organisations currently leasing accommodation. There is some evidence that corporations which have little directly owned property are more profitable than corporations with large property portfolios, (Liow, K. H. 2003). It could also be argued, however, that these savings are there to be achieved through efficient management of those facilities and the loss of flexibility resulting from sale and leaseback arrangements could be avoided.

INNOVATIVE OFFICE DESIGN

The adoption of innovative new office techniques has revealed a considerable space saving, particularly for larger companies. Those organisations utilising, to some degree or another, techniques such as hot-desking, hotelling, home-working and virtual office solutions are, on average, saving 4% of their office space. The take up of these techniques within Australia is encouraging, with 43% of organisations using home-working for some employees. The adoption of hot-desking and hotelling is

much less, with 14% and 5% of organisations respectively using these techniques. (Warren, C. M. J. 2003b). The financial savings afforded by hotelling and hot desking are, however, significant. Those organisations using hotelling occupy, on average 16.7m² /FTE which is 20.8% less than the Australian average for all offices. Hot-desking is saving 11.4% of the average, at 18.7m² /FTE. In financial terms this 19% of companies are saving \$155 million by hotelling and a further \$30 million by hot-desking. Thus the savings from changing patterns of office use in Australia are not insignificant. Widespread adoption of these innovations could save up to \$1.1billion, though it is recognised that these techniques are not applicable to all situations.

The underlying occupancy densities in all categories of office property are considerably less than those found in the UK. (Warren, C. M. J. 2003a) If office densities were increased to match those of the UK and, assuming this paradigm shift in space use could be achieved without any significant loss in productivity of the organisation, then the potential saving, as previously indicated, could be as high as 4.3m² for every employee. This is far from an insignificant space saving. When equated across the whole market it would inject some \$1.1 billion or, in terms of space which potentially could be vacated, 3.68 million metres square, an area equivalent to half of the Sydney CBD. Figure 5 provides a summary of the potential savings. It is obvious that not all methods of space reduction can be applied in all situations, nor is it suggested that by applying all techniques that the savings become cumulative. They are based only on comparison of organisations applying the various techniques with those yet to undertake change. Also, the calculations are based on market figures and thus do not make any allowance for changes that might occur in the market should widespread adoption of these savings techniques be adopted.

Figure 5 Summary of Potential Savings

Space Innovation	Percentage space saved	Potential \$ saving pa
Strategic Space Planning	5.2%	\$278million
Space Benchmarking	10.3%	\$550million
Owner become Tenants	13%	\$215million
Use Innovation Hotdesking / Hotelling	20.8% (assumes 100% use)	\$1.1billion
Density equal to UK	21%	\$1.1billion

CONCLUSION

Corporate Real Estate in Australia is still a grossly undervalued asset. Our companies are failing to recognise the huge potential locked up in their real property assets, be they owner occupiers or tenants. The potential to save a staggering \$3.68 billion dollars every year and add this directly to the bottom line of the organisation is being overlooked. Even if our cultural and workplace practices are so different than those in Europe and we cannot, or do not want to, achieve their levels of office occupancy density, ignoring the potential savings from proper space use planning and monitoring cannot be justified. The expenditure of \$550 million dollars per annum by companies, simply because they fail to monitor and plan for their real

property use, is an unacceptable waste of potential shareholder revenue. In an age of triple bottom line reporting, it is evident that wasting office space assets in this way significantly contributes to overbuilding of cities and the overall sustainability of our office environments.

The message for the investment and construction industries is clear. Corporate occupiers are beginning to look at space use and recognise that huge savings are available. The continuing adoption of innovative office use solutions, combined with ever increasing technological advances in computing and communication, and a focus on human resource effectiveness will see the office environment change and result in greater intensity of use. (Materna, R. and Parker, J. R. 1998). This will require buildings that are able to meet these demands of a flexible, high-use, highly serviced space. The challenge for the design and development industries will be to provide buildings that attract tenants. The challenge for the investment industry is to find solutions that provide this space in a market which potentially has a diminishing demand. The challenge for facilities managers is to strategically manage space requirements while implementing new space use innovations and at the same time, maintain an efficient and effective workplace which adds value to the organisation.

If corporate real estate management continues to grow at its current pace and implements the potential savings identified in this paper, then our cities will undergo a dramatic change. As space use intensifies, older, less flexible buildings will fall by the wayside. The potential release of surplus space into the market would create a significant vacancy factor, with flow on effects on rentals and property capital values. Developers and institutional investors should be cognisant of this potential contraction in office space demand and carefully monitor developments in corporate real estate practices. They will need to find new, innovative features to attract and retain tenants in an increasingly tenant led and volatile office market of the future.

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INNOVATIVE ASSET MANAGEMENT

Full Paper

CREATING A PROACTIVE DECISION SUPPORT ENVIRONMENT IN MANAGING ROAD TRAFFIC NOISE

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ABSTRACT

Properly designed decision support environments encourage proactive and objective decision making. The work presented in this paper inquires into developing a decision support environment and a tool to facilitate objective decision making in dealing with road traffic noise. The decision support methodology incorporates traffic amelioration strategies both within and outside the road reserve. The project is funded by the CRC for Construction Innovation and conducted jointly by the RMIT University and the Queensland Department of Main Roads (MR) in collaboration with the Queensland Department of Public Works, Arup Pty Ltd., and the Queensland University of Technology.

In this paper, the proposed decision support framework is presented in the way of a flowchart which enabled the development of the decision support tool (DST). The underpinning concept is to establish and retain an information warehouse for each critical road segment (noise corridor) for a given planning horizon. It is understood that, in current practice, some components of the approach described are already in place but not fully integrated and supported. It provides an integrated user-friendly interface between traffic noise modeling software, noise management criteria and cost databases.

Keywords: Road traffic noise, decision support tool, amelioration analysis, traffic noise modeling

1. INTRODUCTION

The purpose of road traffic noise management is to minimize environmental harm through cost effective measures undertaken in a proactive and informed manner. This can be achieved by creating a knowledge base for a given road segment and conducting comparative cost/benefit assessments of the alternative ameliorative treatments. One of the aims of the research project, funded by the CRC for Construction Innovation, is to develop a framework and a tool that could be used to facilitate this process of conducting comparative cost benefit assessments within and outside the road reserve. Presented in this paper is a description of the proposed proactive decision support environment and the framework.

The proposed decision support tool (DST) incorporates a number of distinct features. It facilitates the integration of a widely accepted traffic noise model, provides the cost database for alternative amelioration treatments within and outside the road reserve, incorporates the relevant noise amelioration criteria and generates reports. The software has an interactive user interface that enables the user to conduct cost/benefit analyses of feasible alternative amelioration options.

The decision support environment comprises of seven information and processing platforms, labeled as 'zones'. Each of these zones may be regarded as a platform on which information is written to and read from. The seven zones are:

- Noise impact and code assessment zone
- Option identification zone
- Amelioration analysis zone
- Feasibility options zone
- Concept costing zone
- Benefit analysis zone
- Report generation zone

The proposed software is an interactive tool which is designed to provide various input and output reports, which will be stored for future use. The decision support comes in the way of filtering all possible options to provide feasible and reasonable options meeting noise amelioration criteria given in the guidelines to help the user and decision maker. A number of planning horizons may be tried out by changing predicted traffic, terrain and feature data to identify a number of alternative scenarios for a given road segment. Retaining such information would enable informed decisions on planning amelioration strategies through a number of stages.

2. THE DECISION SUPPORT FRAMEWORK

2.1 ZONE 1 – NOISE IMPACT AND CODE ASSESSMENT

Figure 1 illustrates the noise impact and code assessment zone, which represents the initiation of the decision support environment. In this zone, the road segment under investigation is identified and described in terms of both the traffic noise source details and the surrounding terrain and feature data. The parameters which define the traffic noise source are the speed, average annual daily traffic (AADT), vehicle composition and road surface type. The user would interactively input, store and upgrade this information for the road segment under investigation over a period of time. The intention is to map, upgrade and maintain an up-to-date knowledge base for any road segment which is identified as having traffic noise related issues.

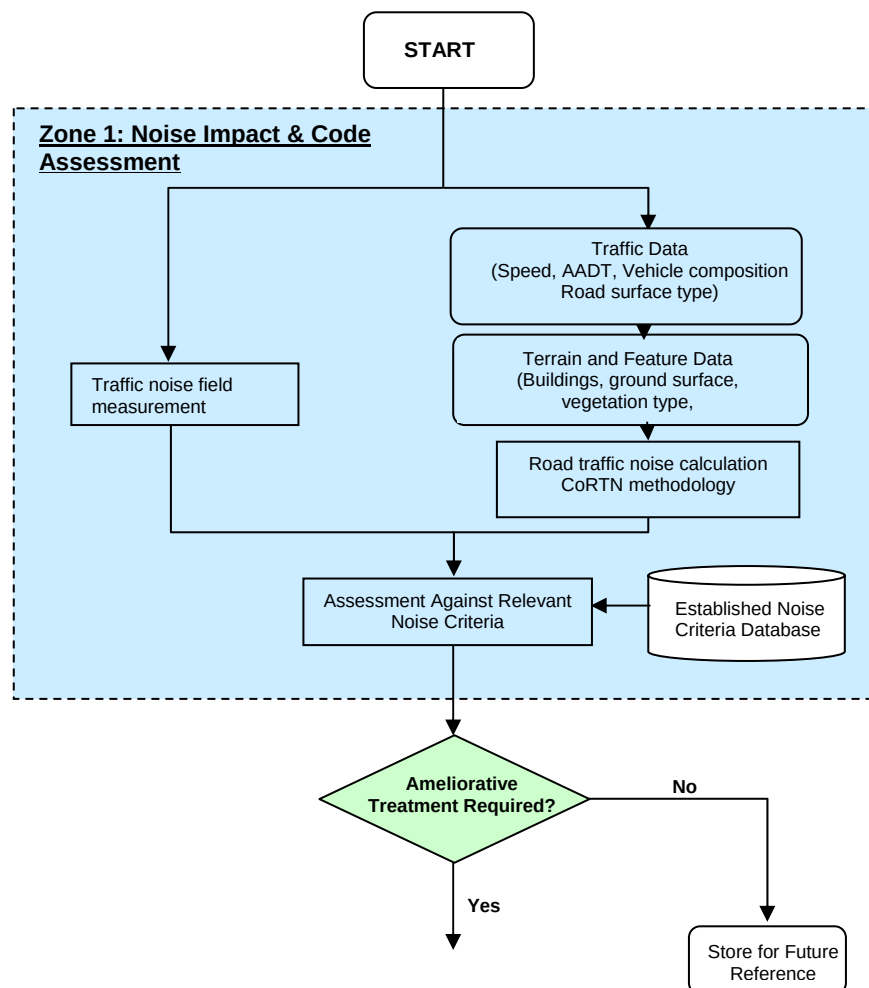


Figure 1 – Flow chart of the noise impact and code assessment zone

The terrain and feature data are represented by three dimensional models in a form typical of an AutoCAD file that contain spatial information for the road and the environment surrounding the road segment. The terrain and feature data includes topography, vegetation type, building property, road and road reserve boundaries. Although not stored in the database, the terrain and feature data is stored in a directory of which the path is recorded so that it is possible to easily access such files at the appropriate stages of the assessment/evaluation process.

The noise impact and code assessment zone of the DST is also designed to provide a user interface to call or launch the commercially available road traffic noise modeling software. The road traffic modeling software can access the terrain, feature and traffic data of the road segment and surrounding environment in DXF format. When executed, the modeling software is used to calculate (based on the CoRTN methodology (GBDoT, 1988)) the noise level in the environment surrounding the road segment from which the traffic noise emanates. The output noise level data which is associated with various receivers (residences, schools, hospitals, etc) in the surrounding environment is stored via the user interface in the database.

As shown in Figure 1, zone1 also facilitates storing traffic noise field measurement data for the road segment. This would enable the user to retrieve and compare the corresponding noise levels simulated by the modeling software with the field measurements. Provided the difference between the measured and simulated noise levels are within acceptable limits, the simulated noise levels are considered as reliably representing the noise impact.

Having established the noise impact on the surrounding environment, the decision support framework facilitates the code assessment. This is to determine whether the receivers are exposed to a noise level that exceeds the external noise criteria permissible by the guidelines. The external noise criteria are a set of limiting noise levels that receivers (private residences, schools, etc) can be exposed to without the need for ameliorative treatment. External noise criteria vary from country to country and within Australia from state to state (Berglund, 1999; QDMR, 2000; NSWRTA, 2001). As shown in Figure 1, the established noise criteria database provides a user interface for the decision maker to establish the need for intervention by the road authority. If the receivers are exposed to a noise level that exceeds the external noise criteria then ameliorative treatment is required.

If ameliorative treatment is not required at present, the decision support tool facilitates retaining all such information generated in order to reach this decision for future reference. However if ameliorative treatment is deemed necessary then further analysis is required and the decision maker needs to identify a number of alternative ameliorative options which are feasible and preferable. The Zone 2 - 'option identification' platform is designed to achieve this objective.

2.2 ZONE 2 – OPTION IDENTIFICATION

Figure 2 illustrates the functionality of the 'option identification' zone. The purpose of the zone 2 is to identify all the amelioration options that could potentially be used to reduce the noise level at the receivers that exceed the noise criteria.

The proposed decision support framework facilitates possible treatments not only within the road reserve but also outside the road reserve as given in Figure 2. The user is presented with the 'inventory of all possible treatment options'. Possible options are derived from two databases as shown, which satisfy a set of guidelines outlining internal and external criteria. This is an interactive process where the experience and know how of the decision maker plays a major role in ruling out options which are not practicable, already in place or fully exhausted. At this stage the treatment options are separated according to whether they are applied within or outside the road reserve. This is mainly due to the fact that the current guidelines of many road authorities recommend amelioration strategies, such as treatment to

building envelopes, as the last resort. However the proposed decision support framework facilitates a combination of external and internal criteria to achieve the desired outcome. This approach is desirable when all amelioration options within the road reserve have been fully or partially exhausted.

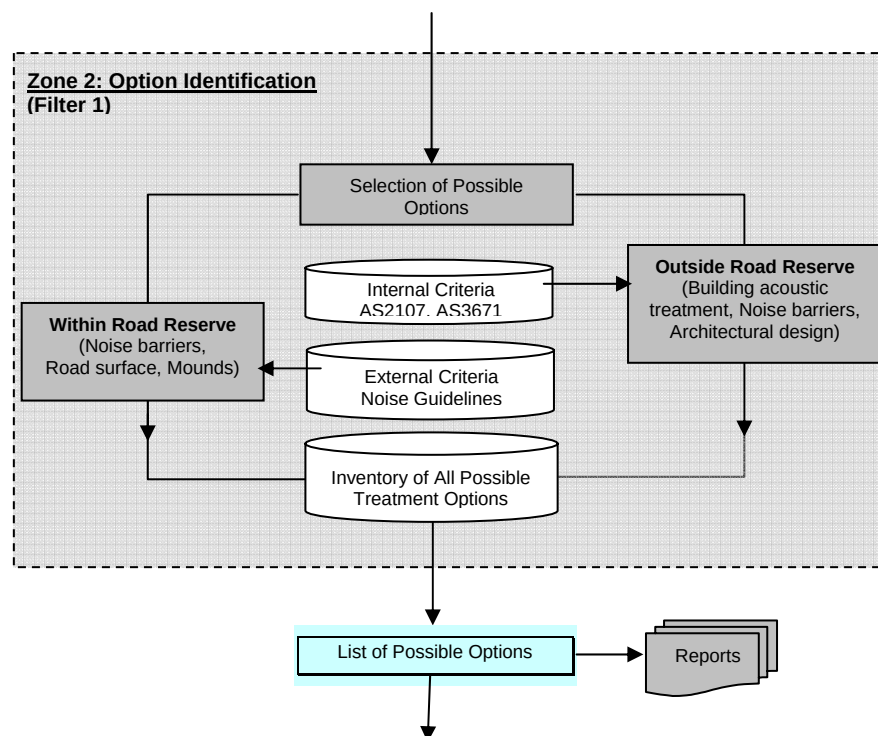


Figure 2 – Flowchart of the option identification zone

Treatment options that are applied outside the road reserve include treatments to the building envelope and/or screens/fences. The purpose of treating the building envelope is to reduce the internal noise only. The Australian standard (AS3671, 1989) provides a procedure for determining appropriate treatments that correspond to the noise reduction required. Accordingly by following this procedure it would be possible to identify from the initially selected treatment options those that could reduce the internal noise level to the allowable level set by the relevant criteria. At this point the treatment options that were considered unsatisfactory would be discarded.

The internal noise criteria, like the external noise criteria also vary from country to country (Berglund *et. al.*, 2001; AS2107, 2000). At the time of writing, in Australia the state road authorities had not explicitly defined their own internal noise criteria or adopted internal noise criteria given in the Australian standard (AS2107, 2000). The values given in the AS2107, like those established by the World Health Organization [Berglund, 1999, De Silva & Douglas, 2004], recommend very low internal noise levels that would be difficult and costly to achieve.

The decision support tool provides access to the relevant sections of the Australian Standard (AS2107, 2000), which are stored in the internal criteria database. Provisions are made to determine the necessary construction category of the building envelope to achieve desired reduction of noise through transmission losses at the building façade. The type of construction used in the noise sensitive building could then be assessed to determine if it was equivalent to or could be realistically

upgraded to be equivalent to the construction category required. If the construction category of the building envelope was found to be unsuitable for treatment then this option would have to be discarded.

Treatment options that are applied inside the road reserve include road resurfacing, noise barriers and mounds. The user interface also provides selective access to the relevant road authority noise guidelines. The user is able to determine, based on the guidelines, if the selected treatment option is potentially suitable for the application. All the treatments, both within and outside the road reserve options that have been found to be potentially capable of satisfying the noise reduction required, are then stored in an inventory so they can be further evaluated at a later stage.

Before beginning the amelioration analysis the user is able to display a list of the possible treatment options. At this stage the user is able to discard any options considered unsuitable. It is also possible to generate a report describing the treatment options and the reasons why they have either been accepted or discarded.

2.3 ZONE 3 – AMELIORATION ANALYSIS

The functionality of 'Zone 3 - amelioration analysis', as illustrated in Figure 3, is to determine if the preferred treatment options identified in Zone 2 are technically viable to achieve the relevant noise criteria. The decision support tool makes provisions for technical validation of preferred amelioration options within the road reserve, outside the road reserve and the combination of both. The commercially available traffic noise models can be called upon to model and analyse preferred treatment options within the road reserve which include the provision of noise barriers, road surface treatments, earth mounds, etc. The provision is made available through specifically developed software based on the Australian Standards (AS3671, 1989; AS2107, 2000) to deal with preferred treatment options outside the road reserve, such as provision of screens and treatment to building envelopes etc.

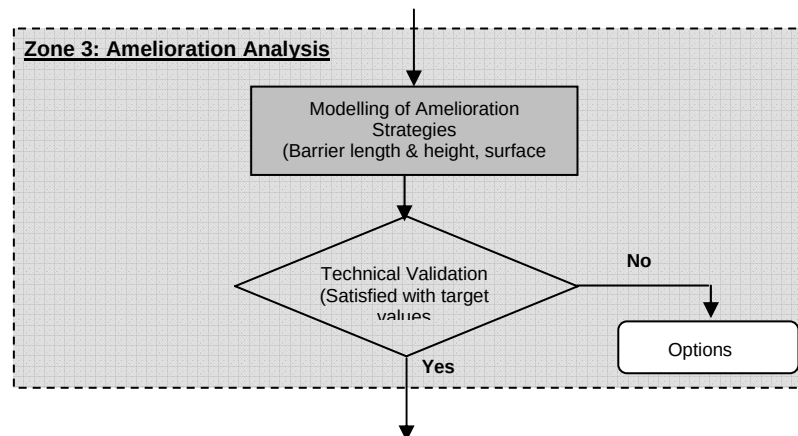


Figure 3 – Flowchart of the amelioration analysis zone

In this stage the traffic noise impact assessment model developed in zone 1 can be called upon to incorporate preferred treatment options. The model is executed for each preferred option and the predicted environmental noise levels at the sensitive receivers are compared to the target reduced noise levels. Interactively, by a process of iteration, the amelioration treatment parameters are varied and the models re-run until the predicted noise levels are lower than or equal to the target values.

Outside the road reserve amelioration strategies include; erecting screens, maintaining closed windows, sealing facades, acoustic/thermal insulation and improving façade elements such as solid core doors and double glazing (De Salis *et al.*, 2002).

The software for outside road reserve treatments has capabilities in evaluating composite noise transmission losses through the building envelope. The user is able to select the target values based on; the internal noise criteria set by state road authorities or in the absence of such criteria, the Australian Standards (AS2107, 2000) or international bodies such as the World Health Organization (Berglund *et al.*, 1999), the room type (living or sleeping).

Having selected the appropriate internal noise criteria and knowing the external noise levels the target reduction is established. The user is then able to try out different acoustic treatments to building façade elements until either the internal noise level is equal to, or lower than, the target value or it is found that it is not possible to sufficiently reduce the noise level. The user is also able to select the number of buildings of this type that would require similar treatment. This process can be repeated for each different building type that is exposed to a noise level that exceeds the external noise criteria.

The noise level data and the design parameters for each amelioration strategy that was found to be capable of satisfying the target noise levels are then stored using the user interface.

2.4 ZONE 4 – FEASIBILITY OF OPTIONS

All the treatment options that were technically viable of reducing the noise level to the target value are presented in the form of a list to the user in the feasibility of options zone.

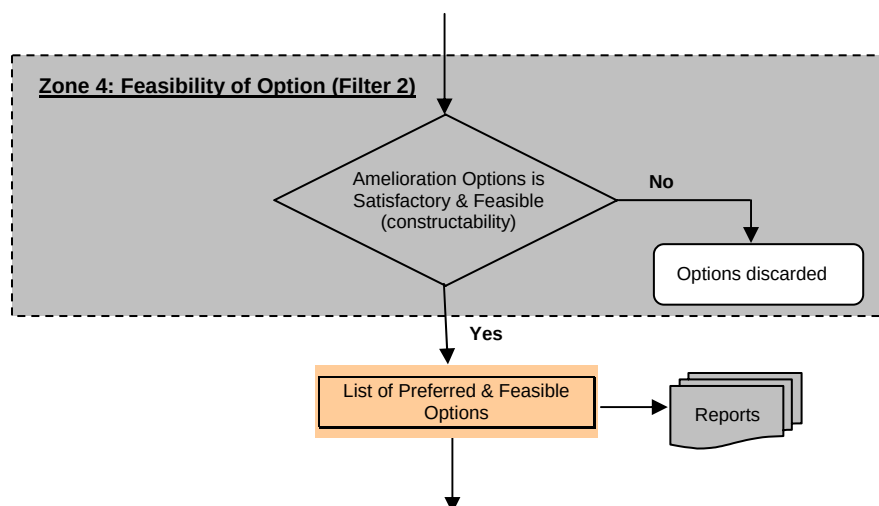


Figure 4 – Flowchart of the feasibility of options zone

The user is then able to narrow down satisfactory and feasible options with due consideration to technical viability and constructability. In order to make a final decision as to whether or not an option is selected, the decision maker is required to draw on information that may not necessarily have been available within the decision support environment. This type of information might be based on reasons that are

social or political in nature and are only known to each respective decision making body.

The treatment options that do not pass through these selection criteria may be discarded. The selected treatment options are then stored and are available for concept costing to determine cost/benefit ratios. It is also possible to generate a report describing the treatment options and the reasons why they have either been discarded or considered as preferred and feasible as shown in Figure 4.

2.5 ZONE 5 – CONCEPT COSTING

The cost of implementing the selected preferred and feasible treatment options is evaluated in the 'Zone 5 - concept costing' illustrated in Figure 5. This zone provides a cost database for standard noise treatments both within and outside the road reserve.

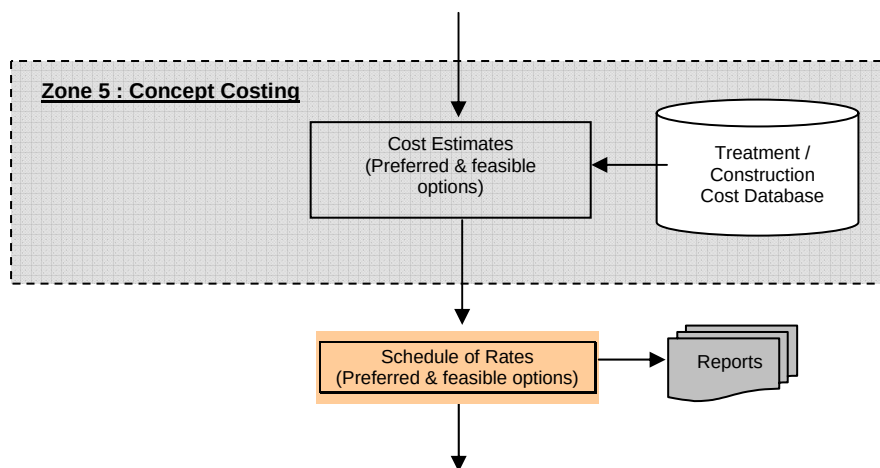


Figure 5 – Flowchart of the concept costing zone

At this stage each selected treatment option is conceptually developed and the technical details are available for proper cost estimates. The concept design of the treatment option has been developed to the extent that parameters such as the length, height and material type have been determined. Reasonable cost estimates and therefore the schedule of rates can be established for each option based on the cost database.

The concept costing module of the DST has a user interface through a pull down form where relevant items can be selected and the quantity entered in by the user. A schedule of rates similar to a bill-of-quantities is produced by the software giving the total cost of the treatment option including general costs such as project management, survey/design and service relocation etc.

The user also has the option to evaluate the costs in terms of present value or discounted future values. Such an option provides the user with the possibility of comparing a series of treatments developed over a number of planning horizons that aim to satisfy immediate needs only with a one off treatment or that aims to satisfy both present and future needs through a number of stages.

It is also possible for the user to generate a report that details the cost estimates for each of the preferred and feasible treatment options in terms of either present or future values.

2.6 ZONE 6 – BENEFIT ANALYSIS

The benefit of a treatment option depends on the perspective of who is to receive the benefit as well as on how it is measured. Accordingly there are many different ways to measure benefit. For this reason, a number of different measures of benefit are presented to the user in the benefit analysis zone. The possibility of using a measure that includes a weighted combination of measures is also being investigated.

Although at this stage the exact measures of benefit have not been determined it is envisaged that they will include; the average cost per household, the cost per decibel reduced and the increase in the value of exposed households resulting from the reduction in noise level evaluated using hedonic pricing methods (Morrison, 2002; Nijland *et.al.*, 2003).

In a similar interactive fashion to that of zone 4, the decision maker will be able to select from the range of measures those that are most appropriate for the given application. In addition the user is also able to generate a report detailing the cost and the selected measures of benefit for each of the preferred and feasible treatment options.

At this stage it may be found that an option although preferred and feasible is not financially reasonable. Although such an option would not be included in the final report, the results associated with the option could be stored for future reference as given in Figure 6.

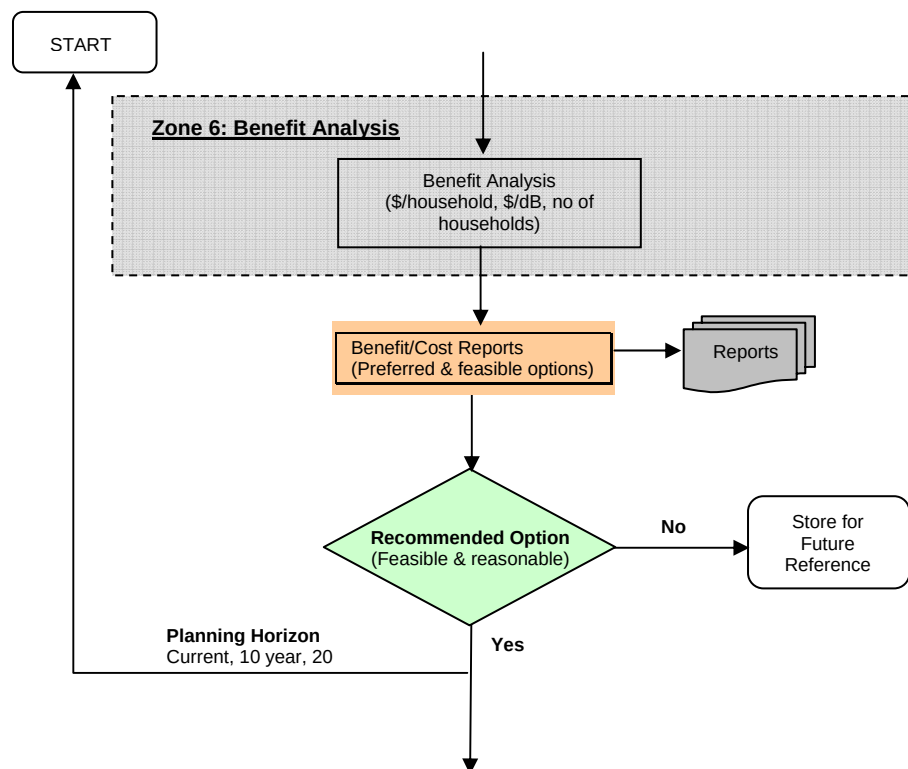


Figure 6 – Flowchart of the benefit analysis zone for different planning horizons

At this stage it is also possible to assess the feasible and reasonable treatment options at planning horizons such as 10 or 20 years into the future. The process is the same as for assessing treatment options in the current planning horizon where the user again follows the procedures from Zone 1 to Zone 6 as discussed in this paper.

There are two main differences between the cost/benefit assessment of the treatment options for current and future planning horizons. The first is that the traffic data and terrain data used in Zone 1 would be measured for current assessment where as predicted in case of the future planning. The second difference is that in Zone 5 the future values would be given as present values so they could be directly compared with treatment options developed for the current planning horizon.

2.7 ZONE 7 – REPORT GENERATION

In Zone 7 a final report is generated for all the feasible and reasonable treatment options. The report includes cost estimates and benefit analyses for current and future planning horizons as given in Figure 7.

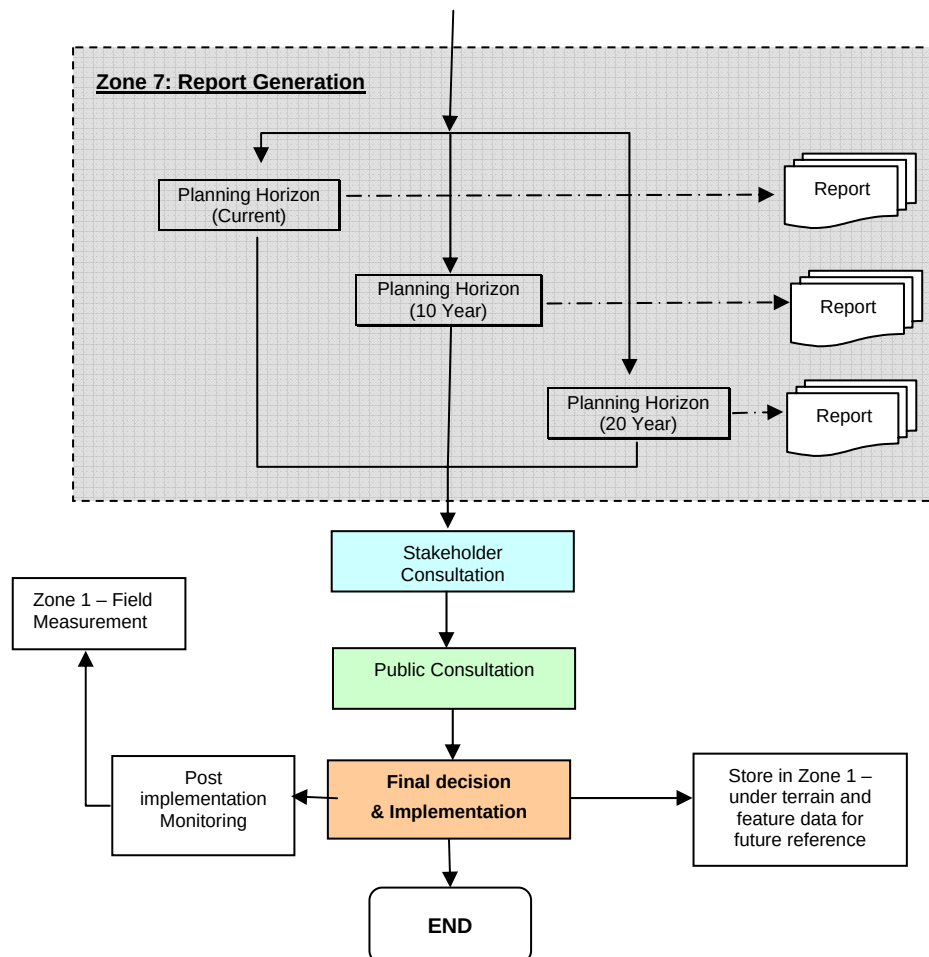


Figure 7 – Report generation zone

The report can then be made available for stakeholder and public consultation before the final decision can be taken and implemented. All the information in the report is

then stored in Zone 1 under terrain and feature data for future reference. Once the treatment option has been implemented post implementation monitoring is carried out and the results are stored in Zone 1 under field measurement data again for future reference.

3. CONCLUSIONS

A decision support framework is proposed to encourage a proactive traffic noise management strategy.

Decision support software is currently being developed to incorporate the proposed framework.

The proposed decision support framework and the tool incorporate noise amelioration, both, within the road reserve and outside the road reserve such as architectural treatments to building envelopes.

When developed the proposed framework and the tool will be tested and calibrated using four trial sites located in Queensland.

Software is designed to integrate commercially available traffic noise models, capabilities in evaluating composite noise transmission losses through different building envelopes and cost/benefit analysis of alternative amelioration options to support decision making.

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OCCUPATIONAL HEALTH & SAFETY ... THE CARING CLIENT?

Full Paper

THE BENEFIT TO CLIENTS OF A ZERO ACCIDENT AND ILL HEALTH CULTURE, THE UK'S APPROACH

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ABSTRACT

Clients that play a full role in helping construction achieve a zero accident and ill health record benefit in the process. Clearly the client has an interest in the health and safety aspects of the finished product that their workers and customers will use. Their business will be affected by the whole life costs of use and maintenance. The key to a successful health and safety outcome lies in effective design. The paper considers the role of design and advocates the need for a holistic approach to health and safety that embraces risks that arise not just during construction but also during operation, use and maintenance. The principles of 'Rethinking Construction' and the call for action in 'Accelerating Change' when taken together set out a vision and a route map for industry improvement. The paper expands on the benefits from strong client leadership, integrated team working, and tackling people issues. It focuses on achieving cultural change – and the range of issues that need to be addressed. These lie well beyond the traditional approaches to health and safety. The paper reviews the current UK approach to improving industry performance and reports on the results of the £7bn demonstration project programme, funded by government. Evidence of achievements already made through demonstration projects and performance measurement is presented. The data show that projects which adopt the principles of 'Rethinking Construction' are not only more than twice as safe as the industry average but clients receive better value for money and contractors make more profit. Excellence in health and safety is 'win-win'.

Keywords : Construction; Client; Safety; culture; Design;

INTRODUCTION.

How do clients – those who procure construction solutions for their business needs - benefit from a zero accident culture? Projects that achieve higher levels of safety performance compared to the industry average also deliver higher client satisfaction with both the product and the service. They also deliver better projects, with fewer defects. The performance data reflect a simple truth: companies and projects where health and safety is well managed are more likely to be managing the rest of the business well – and that means delivering value for money services and products to customers. Health and safety is a good proxy for general good management – which is why it is well worth clients – especially inexperienced clients – taking a close interest in the health and safety performance of their supply side during their selection.

Clients – the customers of construction want key deliverables from the supply side. They want projects, buildings and infrastructure developments that are on time, within budget and to the desired quality. In order to achieve this enlightened clients realise they need a supply side that is both productive and profitable. And highly enlightened clients also want their projects delivered safely. To achieve this they take an active interest in their projects and work with the supply side to achieve mutual goals.

HEALTH AND SAFETY – ALTRUISM OR BUSINESS SENSE?

Commercial clients are in business to make a profit, whilst UK Government projects are increasingly driven by the quest for value for money, not lowest cost. Clients want buildings that support their business needs and are flexible and responsive as their needs change. Governments want public buildings and a built environment that reflect their society's values and aspirations, and meet and respond to people's needs with an ever increasing emphasis on effective delivery of public services.

All want value for money – but value can be an elusive concept. UK Government defines 'Value For Money' as the optimum combination of whole life cost and quality to meet the customer's requirement. The UK Government is clear: value for money is not delivered solely when construction is complete - value continues throughout the lifetime of a building.

Sir John Bourn the Comptroller and Auditor general of the National Audit Office recently stated¹ that good design is essential for achieving value for money in construction. And he added "Value is not just about buildings being completed on time and within budget; it is also concerned with ensuring that the costs of operating buildings over their whole life are optimised and that those who use and work in public buildings gain real value from them."

Sound creative design is an essential ingredient if value for money is to be achieved. Design development costs are likely to be small in relation to whole life operating costs and it is through the design process that the largest single early impact can be made on these costs. Excellence in both design and construction together make service delivery more efficient and clearly can have a huge impact on overall health and safety. And the impact of poor design on health and safety is huge. The

¹ Improving standards of design in the procurement of public buildings, Commission for Architecture and the Built Environment/Office of Government Commerce CABE/OGC Report

European Union stated in the introduction to the 1992 construction directive² implemented in the UK by the Construction (Design and Management) Regulations 1994³ (CDM) 'Unsatisfactory architectural and/or organizational options or poor planning of the works at the project preparation stage has played a role in more than half of the occupational accidents occurring on construction sites in the Community' Other studies put the figure as high as 60%.⁴

Altruism however laudable does not pay shareholder dividends! So the reality is that unless clients really understand the business benefits from safe construction projects they are unlikely to be fully engaged in the issue.

'Too few clients view the design and construction of their project as part of their business, nor do they realise that the health and safety of people who construct and maintain as well as those who subsequently work in their buildings are their responsibility. The health and safety of all these people depends on the quality of the design and construction. Indeed, many of the difficulties faced by designers and contractors are the result of unreasonable pressure put on the price and time by the client.'⁵

Unfortunately many clients still think that construction health and safety problems are not –and should not be – their problem – and certainly not their responsibility. These are clients who don't realise that dangerous sites where health and safety is not a priority will be sites that produce a lot of waste – both of materials and time. Dangerous sites are sites where working practices are shoddy; work is likely to be sub-standard as necessary management controls are not in place. Remedial work will be necessary to remove defects – work which itself introduces new health and safety risks – concrete removal, for example, can rarely be done without dust, noise and vibration. Goods delivered to sites left lying around can be damaged or stolen as well as being tripping hazards. Such sites have increased likelihood of being late, over budget and have a high probability of defects that may later prove costly to put right.

One clear reason why clients should take an interest is the simple fact that they are paying for all this waste. There is very little money in the construction industry that has not originated with a client. Clients pay either directly or indirectly. Directly - through cost overruns and the impact on their business of delays. Indirectly – by raised tender prices that result from all the companies on their tender list being similarly inefficient, and wasteful and simply pricing this into their cost estimates.

It is perhaps surprising that clients do not realise how much more they may be paying than they need. A study carried out by the University of Bath⁶, for the UK's National Audit Office⁷ showed that 73% of Government construction projects were over budget, and 70% were delivered late. But 13 out of 14 clients thought this was an acceptable level of service!

² Council Directive 92/57/EEC of 24 June 1992 'Implementation of minimum safety and health requirements at temporary or mobile construction sites.'

³ The Construction (Design and Management) Regulations 1994, HMSO, ISBN 0110438450.

⁴ From Drawing Board to Building Site; ISBN 92 825 8685 5, European Foundation for the Improvement of Living and working Conditions.

⁵ Revitalising Health and Safety in Construction, HSC

⁶ The Government Client Improvement Study: Agile Construction Initiative, University of Bath, 1998

⁷ Modernising Construction, Report by the Comptroller and Auditor General HC 87, Session 2000-2001.

There had to be – and fortunately there is - a better way. The purpose of this paper is to help show clients that they can get a better project – and certainly one that is safer – and at the same time meet their business needs be they hard-headed or altruistic.

SAFETY IN THE PROCESS: SAFETY IN THE PRODUCT

The UK's Royal Academy of Engineering set out, in a 1998 Report⁸, a simple ratio about the long term costs of buildings. If the construction cost is 1, the maintenance and building operating cost is 5, but the **business** operating cost (over a 20 year time frame) is 200. Put another way for every \$1 spent on construction a company is likely to spend \$5 on maintenance and \$200 running its business. It is worth noting in passing that design costs are typically 1/10th the construction costs⁹ – and it follows that emphasis on design and specification can bring a huge return on investment over the life of a building. Whilst many of these costs may lie in the future what is clear is that the design decisions lock in many of these costs.

Quality in design is an essential ingredient if clients are to achieve value for money. Excellence in both design and construction together make service delivery more efficient, increase buildability and enhance the environment for all. In the UK Design Quality Indicators (DQI's)¹⁰ have been developed to enable clients to measure design quality focusing on build quality, impact and functionality.

For example, well designed and maintained:

- Buildings are a business asset and enhance productivity. They also:
 - o provide safe access and egress
 - o help reduce occupational stress and create a sense of well being
 - o can be safely cleaned e.g. safe access for window cleaning, roof repair;
 - o can be safely maintained e.g. to reduce the risk from legionella.
- Offices are more productive with less time off work for sickness, stress or other ill health;
- Hospitals are places where people get better quicker;
- Schools create an environment in which education and learning can flourish;
- Urban environments help reduce crime and enhance quality of life for all.

Design excellence clearly helps deliver the clients business needs. It should also help deliver improved health and safety. This is why the UK government places so much importance on design excellence. And it is the construction process that turns design ideas into practical reality. The scale of the problem is highlighted by comments made by the Royal Institute of British Architects (RIBA) to the National Audit Office.¹¹ RIBA questioned whether there were sufficient incentives for designers to 'design out' hazards, as this would lead to an increase in costs to the designer which could not necessarily be passed on to the client. The impression given is that bad design is cheaper than good design!!

When things go wrong it is often the client that carries the cost, and bears the responsibility. For example in a prestigious London bank refurbishment the foyer was fitted out with a highly polished granite floor. When it rained the floor was so slippery

⁸ The Long term costs of owning and using buildings, The Royal Academy of Engineering, 1998

⁹ 'The industry formerly known as Construction' Richard Saxon CBE, Reading Construction Forum

¹⁰ www.dqi.org.uk

¹¹ Improving Health and safety in the Construction Industry, HC 531 Session 2003-4: 12 May 2004

and the risk of an accident so high it had to be taken out of service – at considerable expense and embarrassment to the client. In another example a brand new local authority library, which had won an architectural award had to close when light bulbs needed replacing, as the designer had not considered how they could be safely reached! The fact is that when things go wrong the public tend to remember who the client was – long after those involved in its construction have left the site.

It is clear that a more holistic approach is needed to achieve a zero accident culture. It should consider safety of the product during its operation, maintenance and repair, as well as an integrated team approach to the construction process.

UK CONSTRUCTION : HEALTH AND SAFETY RECORD.

Over the last 40 years or so the number of fatal accidents resulting from UK construction work has fallen significantly (Fig. 1) but still remains unacceptably high. Figure 1 does not show incidence rates, and needs to be considered against the backdrop of construction activity at the time. With long term data there are subtle issues about year on year comparisons of data – definitions of what is or is not a 'construction' accident change. But in the main the definitions are broadened rather than narrowed. Hence over a long time frame the likelihood is that improvements are masked rather than overstated.

Fig. 2 shows the rise in labour productivity¹² (given at 1995 prices to adjust for inflation) over a similarly long term. Taken alongside fig. 1 it helps dispel the myth that improving safety performance can only be made at the expense of productivity.

Comparison of the downward trend in construction accidents (fig. 1) with the UK Health and Safety Executive's model for long-term reduction in accidents is helpful. (Fig. 3)¹³ Taken together it is clear that the emphasis on physical aspects of safety in the 1960's brought about a significant reduction in accidents; the regulatory emphasis on management systems during the 80's and early 90's also made a contribution. CDM also began to have a significant impact on some of the cultural aspects – especially with the emphasis for the first time on designer duties, and the benefits of collaborative working.

If a zero accident and ill health record is to be achieved emphasis must be placed on tackling the underlying cultural factors that contribute to the way the industry operates. And this must, of course, be done without any let up in the emphasis on the provision of physical safeguards and effective risk management. Some might think a zero accident record is not realistic yet some companies do report many million man-hours worked without any lost time incidents.

¹² Source: DTI Construction Statistics Annual and the Housing and Construction Statistics Annual

¹³ Author's interpretation taken from 'Successful health and safety manahemen. HS(G)65, HSE

Figure 1: Fatal accidents in construction

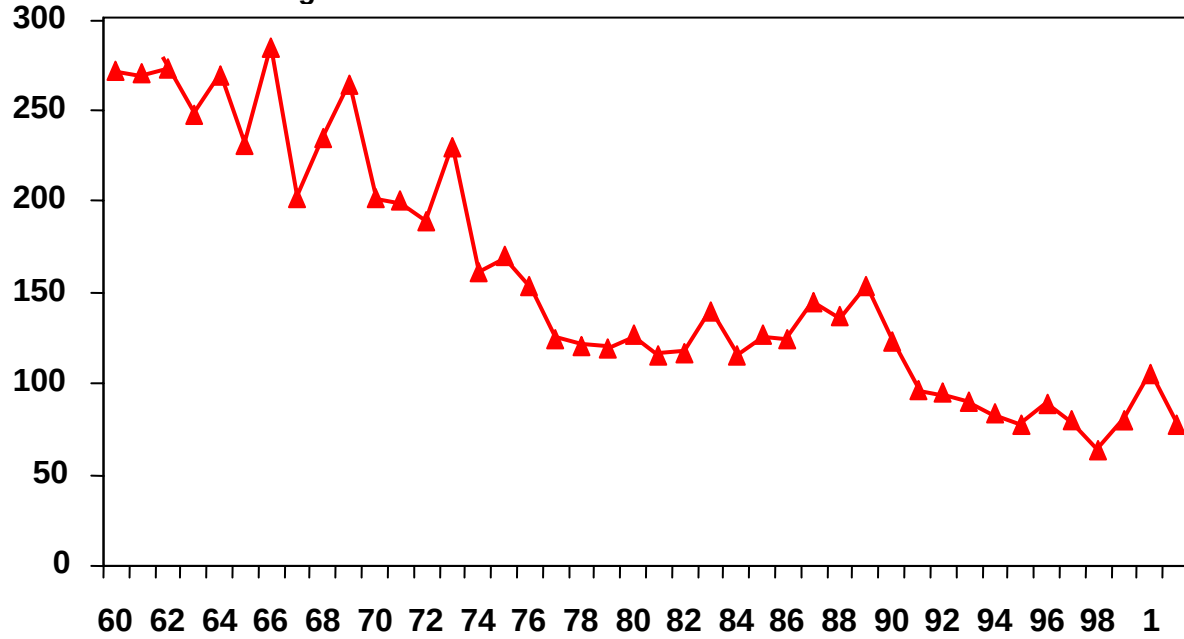


Figure 2 : Labour Productivity in Construction (1995 prices)

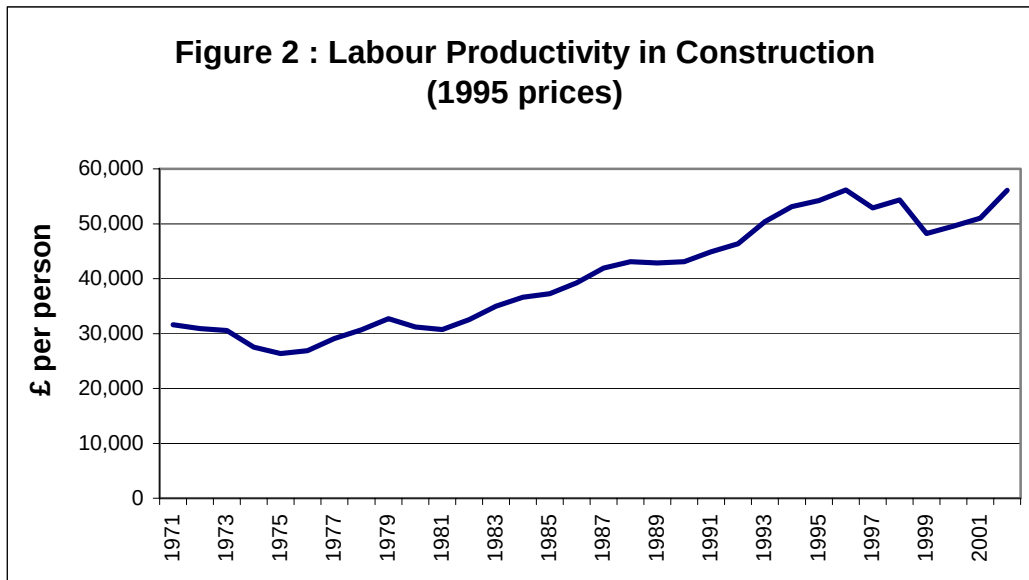
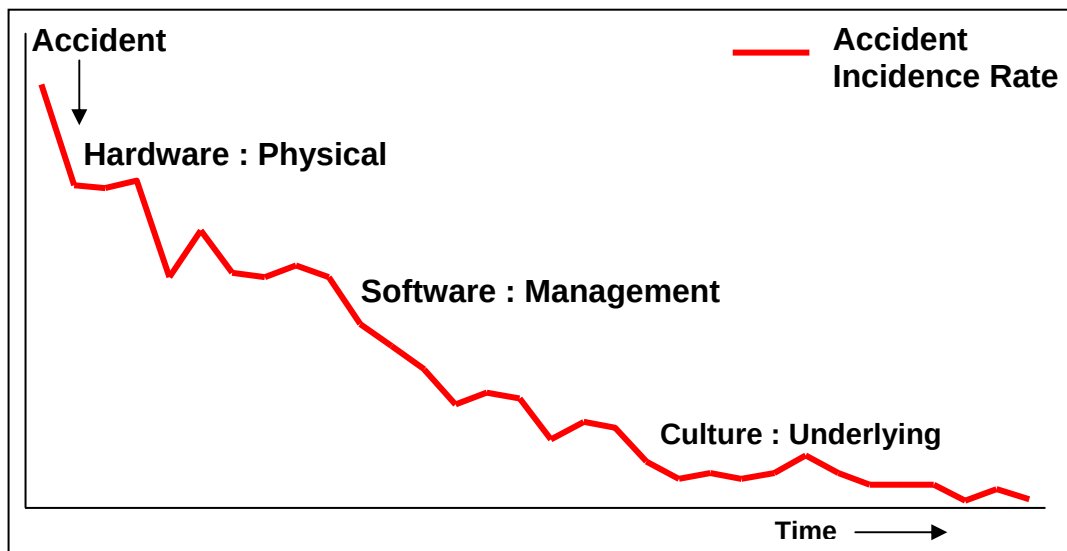


Fig. 3 : Management of Health and safety



RETHINKING CONSTRUCTION

The problem as seen by the UK (although by no means confined to the UK) in 1998 was that taken overall the industry under-performed. It:

- frequently failed to satisfy its clients;
- had low margins of profit and did not attract the interest of investors;
- failed to invest in its people through training;
- failed to invest in research and innovation;
- had an unacceptable health and safety record;
- had difficulty in recruiting and retaining its workforce;
- delivered projects often of poor quality, delivered late and over budget.

Tony Blair's newly elected Labour government asked Sir John Egan, then chairman of BAA (British Airports Authority) to chair a task force comprising leading industrialists who were major clients of the construction industry to make recommendations for improvement. They produced a report '*Rethinking Construction*'¹⁴. It set targets for annual improvement.

These were:

- a reduction in Defects and Accidents by 20%;
- a reduction in Capital Cost and Construction Time by 10%;
- an improvement in Predictability by 20%; and
- an improvement in Productivity and Turnover and profits by 10%.

These targets are for improvement year on year. Many said – and some still say – that it can't be done. By any benchmark these are tough targets for any company to meet. But the fact is that some are achieving it – and the evidence has come both from Rethinking Construction's demonstration project programme and from the work of the DTI funded 'Construction Best Practice' programme.¹⁵ It also identified five drivers for change and four ways of improving the project process.

On health and safety it said 'The industry must provide decent and safe working conditions and improve management and supervisory skills at all levels. The industry must design for ease of construction making maximum use of components and processes.'

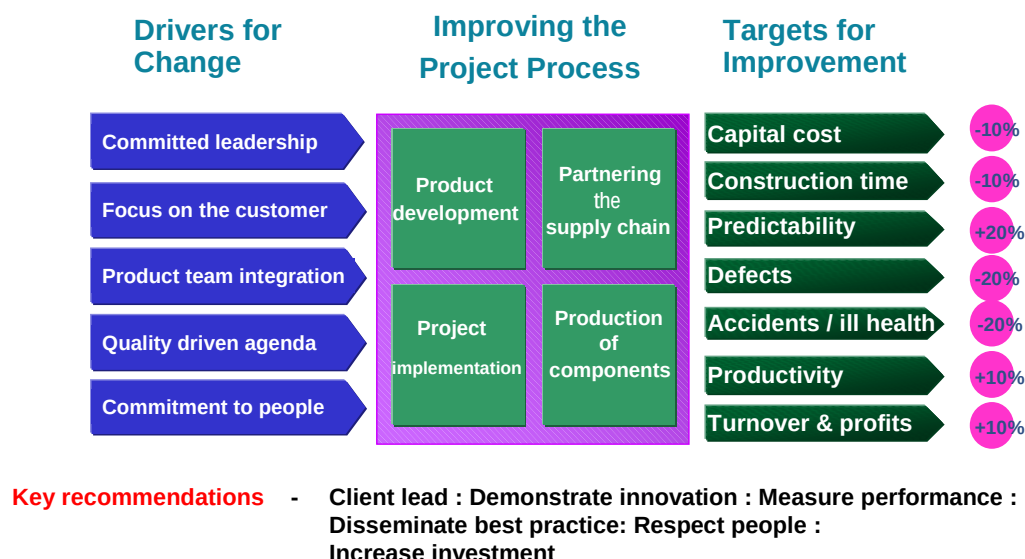
Rethinking Construction needed to pass what Sir John Egan called 'the dustbin test'. Was it simply to be the latest in a long line of government reports into the ills of the industry that produced a flurry of interest but no long lasting change. The UK government thus called for 'demonstration projects' which were to be real industry projects where those involved committed to achieving in practice the Egan performance targets; as well as undertaking to share the lessons learned in putting the Rethinking principles into action through published case studies, involvement in workshops and best practice clubs. Under the '*Rethinking Construction*' banner 'The Movement for Innovation' (M4I), the Housing Forum and the Local Government Task Force were born. 374 demonstration projects representing a combined construction value over £7bn have now participated in this movement.

¹⁴ '*Rethinking Construction*': The report of the Construction Task force. ISBN 1 85112 094 7

¹⁵ The organisations Rethinking Construction and Construction Best Practice have now merged to form 'Constructing Excellence'

Figure 4

Rethinking Construction – change mantra



But just trying new ways of working is not enough. Measurement is vital. Only through benchmarking against the 'best in class' and by measuring can the industry truly demonstrate that it really is successfully improving its performance and improving its business. All Demonstration Projects (now renamed as '*Demonstrating Excellence*') strive to out-perform the '*Rethinking Construction*' improvement targets. Performance is measured using the Key Performance Indicators (KPIs) published by Constructing Excellence. This allows projects not only to monitor progress on a regular basis it also provides the opportunity to benchmark against the rest of the industry.

ACCELERATING CHANGE

'*Accelerating Change*'¹⁶ published in September 2002 is a report by the Strategic Forum for Construction, then chaired by Sir John Egan. The Forum's membership represents the whole industry – clients, contractors, suppliers and product manufacturers, and trade unions. '*Accelerating Change*' reinforces and complements '*Rethinking Construction*'. Reinforces because it endorses the rethinking principles for change, and complements because it focuses in on the three major themes that can drive change and remove the barriers to change. And it does that for the first time within the context of a shared vision for the industry.

Taken together these two reports set out a clear vision for the future of the UK construction industry, set targets for achievement, and provide a programme for change that will result in a safer, more profitable and productive industry, and add value to business and to society in general.

¹⁶ '*Accelerating change*' A report by the Strategic Forum for Construction ISBN 1 898671 28 1

VISION

The Strategic Forum for Construction set out its vision for the industry. This was the first time the whole industry had come together to work out what it was trying to achieve. The vision statement was:

“Our vision is for the UK construction industry to realise maximum value for all clients, end users and stakeholders and exceed their expectations through the consistent delivery of world class products and services.”

The phrase ‘exceeding expectations’ raised a few eyebrows – some thought that meeting the clients’ needs was enough. We might do well to remember the words of Michelangelo when he said ‘The greatest danger for most of us is not that our aim is too high and we miss it, but that it is too low and we reach it.’

In order to realise its vision the industry must -

- Add value for its customers;
- Exploit the economic and social value of good design and construction to improve
 - o Functionality; and,
 - o Enjoyment for end users;
- Become more profitable and invest in its future; and
- Enhance the built environment in a sustainable way to improve the quality of life.

To achieve such an industry, ‘Accelerating’ identifies three key action themes – client leadership, integrated team working and people issues.

CLIENT LEADERSHIP

Client leadership is important as a driver for change. Clients need to be fully engaged from the outset. The UK's Office of Government Commerce (OGC) sets out some key messages for management leadership,¹⁷ stating that success is associated with projects (inter alia) that:

- Are clearly the best option to meet the business need;
- Reflect the business ethos; (*including the safety culture*)
- Have client and supply side commitment to clearly defined objectives (*which include health and safety*)
- Are managed through personal accountabilities; (*management of health and safety and safety policy*)
- Plan, identify and obtain sufficient resources to deliver the project (*make suitable provision for health and safety*)¹⁸

The industry, too, needs to respond by putting its clients’ needs at the heart of the design and construction processes. With a clear understanding of both their ‘business needs’ and their environmental and social responsibilities, clients will better understand how their construction procurement will impact on their ability to perform better for their own customers.

¹⁷ Achieving Excellence in Construction, Initiative into action. OGC. www.ogc.gov.uk

¹⁸ Author's italics to link client leadership with impact on health and safety.

Clients need to engage at an early stage with their integrated teams so as to ensure effective deployment of their combined skills and experience and release their ability to deliver successful, safe projects. And crucially they need to select the team based on factors including their health and safety record. The best of the industry's professionals are playing a key role in driving this process along.

Accelerating Change also recognised that most clients are not expert – nor is it likely if they only engage with the industry once that they will become expert. To be successful they need help and guidance. The report concluded that clients should have access to independent advice – that is professional advice that is not financially dependent on the outcome.

Expert or not, clients have a key role in ensuring that health and safety is not compromised in the process. Inexperienced clients will generally have the greatest difficulty deciding exactly what they want in advance of work starting. The trick is to ensure everyone on the team knows that there will be changes, and that mechanisms for managing them are established early on. Whenever meetings are held to consider design changes it is essential that the impact on health and safety, including buildability, is carefully considered.

The Clients' Charter¹⁹ was developed by leading clients, following a government challenge.²⁰ It sets out general principles whose adoption can assist both clients and the supply side to work effectively together. These are – leadership and focus on the client; product team integration; quality; and, people. It identifies that 'Setting high standards for health and safety and respect for people' brings benefits to clients.

Charter clients that achieve excellence in the people category have selection criteria and performance monitoring in place for suppliers that requires them to have:

- established policies and practices for successful delivery of health and safety on their projects;
- a policy setting out site condition standards;
- a workforce that is properly trained and certificated;
- clear policies for recruitment, retention and succession planning for their workforce;
- monitoring systems in place with regular review of data.

And such clients also need to have a commitment to train and develop their own staff.

INTEGRATED TEAMS

The benefits gained from integrated team working are emphasised in *Accelerating Change*. Integrated teams include: clients, product manufacturers, designers (architects and engineers), contractors, specialist sub-contractors, consultants and other professionals. And it emphasises the importance of these teams staying together, building up long term relationships based on trust, and delivering improved services to clients through partnering and strategic framework agreements.

Team working helps unlock potential and release value. Integrated Teams are better placed to 'get it right first time' and 'design out' safety risks. Industry professionals –

¹⁹ The Clients' Charter, formerly Confederation of Construction Clients (CCC), now Construction Clients Group (CCG)

²⁰ Nick Raynsford MP – challenge to the Industry, M4I Conference 1999

particularly designers are making a major contribution. Increased use of off-site fabrication, and product standardisation are delivering benefits in quality, predictability and safety – and reducing time on site. Integrated teams working closely together (especially in partnering arrangements) have reported a considerable reduction in the old style adversarial approach. Such teams create a positive work environment where the contributions of all members are valued. They are encouraged to innovate, tackle problems co-operatively, and share the benefits. The emphasis is on solving problems collaboratively rather than arguing who is to blame. And there has been a substantial decrease in litigation on projects embracing non-adversarial practices.

Integrated **team** working is similar to but not the same as supply **chain** integration. Each team member is likely to have relationships with a supply chain. The benefits of working with integrated supply chains can greatly enhance the ability of the organisation to play an effective team role. Integrated teams can also exploit the additional potential that comes from cooperation between distinct supply chains. A tool kit has been developed to help increase uptake of this approach.²¹

PEOPLE ISSUES

Thirdly the industry needs to value, and respect the people who work for it. Companies that have embraced *Rethinking Construction* are raising the value they place on those working for them. They are creating a culture of respect for their people, this helps them recruit and retain a workforce that is committed and fulfilled, a workforce that is free from the threat of accident or ill health. Safety is now at the top of the agenda. And the link to the business improvement agenda is clear. As Sir John Egan has said 'Pre-planned, well designed projects, where inherently safe processes have been chosen, which are carried out by companies known to be competent, with trained work forces will be safe: they will also be good, predictable projects.'²²

The UK industry needs to attract 75,000 new people a year simply to replace those who are leaving or retiring. The UK industry also needs people with new skills – skills in e-commerce – skills in information technology and communication...even customer care skills...skills which are taken for granted in other industries but which are still rare in construction. But without such skills it becomes difficult to ensure full stakeholder and end user involvement in the design process. We need to see greater diversity in the workforce – more women and people from visible ethnic minorities. The construction industry needs to attract people from across the social spectrum. The proportions of women and ethnic minorities in construction are woefully low, especially on site. The industry needs to recognise the positive benefits that diversity in all its manifestations can bring to the workplace.

The business case for doing this is clear. Companies that respect their workforce – and we have developed a comprehensive set of measurement tools to help them assess this – will end up with more productive, safer and healthier workers, who will contribute to on cost, on time and on quality delivery, which leads to more satisfied clients, which helps such companies win more work, enhance their reputation in the market place, and through increased profitability they can afford to invest in their workforce – which helps make them more productive.

²¹ www.strategicforum.org.uk

²² 'Accelerating change' *ibid*

RESULTS

Quite frankly since '*Rethinking Construction*' was published the results have been startling, and indeed have exceeded most expectations.

These demonstration projects show what the best can achieve (table 5). The safety record in 2001 was twice as good as the industry average and by 2003 it was 3 times as good. A new measure introduced in 2004 shows that the percentage of all companies achieving a zero accident incident rate is 42% for all construction and 78% for all CE demonstration projects. And the demonstration projects show an increase in productivity from £37,000 mean added value/employee in 2001 to £55,000 for 2004. So safety is not being achieved at the expense of productivity: on the contrary improved productivity is strongly linked to improved safety performance. These projects are also delivering higher client satisfaction with both product and service; they are delivering fewer defects, and are more predictable in cost and time. The results help prove the thesis that good health and safety makes good business sense; and that projects with exemplary health and safety are well managed projects that satisfy their clients. Year on year data need to be viewed against a backdrop of enormous change across the whole industry, not just the Constructing Excellence demonstration projects. In some cases the gap has narrowed between the best and the rest, but at the same time the best have gone on getting even better.

Detailed case studies are published on the web at www.constructingexcellence.org.uk which also gives details of the tools and training programmes that have been established to help people through the change, and continuous improvement process.

The cost savings are also substantial. The demonstration projects amounting to £7bn by turnover have achieved additional profit of £140m, reduced construction costs of £420m and reduced costs of accidents of £363m. (Figure 6)

Figure 5. Constructing Excellence demonstration project performance compared to All Construction.

Headline KPI	Measure	All Construction 2003	Constructing Excellence Demonstrations 2003	Constructing Excellence Enhancement
Client Satisfaction - product	% Scoring 8/10 or better	78%	90%	+15%
Client Satisfaction - service	% Scoring 8/10 or better	71%	86%	+21%
Defects	% Scoring 8/10 or better	68%	87%	+28%
Safety	Mean accident incidence rate/100K employed	1097	428	+156%
Cost Predictability - design	% On target or better	65%	71%	+9%
Cost Predictability - construction	% On target or better	52%	64%	+23%
Time Predictability - design	% On target or better	53%	66%	+25%
Time Predictability - construction	% On target or better	59%	69%	+17%
Profitability	Median profit on turnover	5.8%	6.0%	+0.2% percentage points
Productivity	Median value added/employee (£000)	£31	£36	+16%
Cost	Change compared to 1 year ago	5.0%	-2.9%	+7.9%
Time	Change compared to 1 year ago	1.0%	-2.4%	+3.4%
Environmental Impact - Process	% Scoring 8/10 or better	51%	76%	+49%
Environmental Impact - Product	% Scoring 8/10 or better	28%	62%	+121%

Figure 6.

Demonstration Projects' performance 4 year average	Rethinking Construction Demonstration Projects (£7bn)	Construction Industry, as a whole (£70bn)
Profitability Rethinking Construction projects achieve 2 percentage points more profit than the industry average	Increased profit from Demonstration Projects = £140m	Increased profit if one-third of industry take up = £466m
Construction Cost Demonstration project costs are 6.0% lower than industry average	Reduced construction costs from Demonstration Projects = £420m	Reduced costs if one-third of industry take up = £1.4bn
Safety Demonstration project accidents are 61% lower than industry average. Estimates put accidents costs across the industry at 8.5% of turnover	Reduced costs of accidents from Demonstration Projects = £363m	Reduced costs if one-third of industry take up = £1.2bn

CONCLUSION

The UK construction industry is undergoing massive change and at the heart of this change is a new focus on the underlying cultural issues that have to be addressed if accidents are to be eliminated. There are real signs that the old adversarial culture that lead to increased risk, which delivered projects that were late, over budget and of low quality, is changing. The National Audit Office – the UK's government spending watchdog – has recently reported on Construction Public Finance Initiative contracts²³. It found in 1999 that 73% of projects exceeded the price agreed at contract, and in 2002 that figure had dropped to 22%. A similar improvement was reported for projects that were delivered late. Significant improvements in quality were found.

Many clients and construction supply teams are embracing the changes set out in Rethinking Construction – and are delivering real benefits to their shareholders through better performance; their clients through increased satisfaction; and their workforce through improved pay and working conditions.

It is important to understand a crucial issue about the change agenda. It is not simply about doing what is done now better: it is about doing things differently. Those on the sidelines wondering whether to embrace change need only to consider one question. "Is the gap between you and your competitors narrowing or widening?" The evidence is now clear. Unless 'Rethinking Construction' principles are embraced and companies start to work in the new way they will be gradually ... if not quite quickly ... left behind. Such companies will find it more difficult to compete and win work on the back of a proven track record of success, and will become less profitable. The road to success is clear – the message for success is clear – unless companies embrace the change process they may not be doing anything at all!

In the UK many companies are embracing change. There is, however, one remaining challenge: those involved in design need to learn how they can contribute to reducing construction health and safety risks. And designers need to consider their contribution not just in relation to the construction process, but for the finished product, which is ultimately the client's responsibility.

Finally on health and safety it is clear that this holistic approach is paying real dividends in fewer accidents, and in the longer term fewer cases of occupational ill-health.

²³ National Audit Office, PFI: Construction Performance, HC 371 Session 2002 – 2003:5th Feb. 2003

STAKEHOLDERS

Full Paper

RAISING THE PERFORMANCE BAR: GAUGING ASSET MANAGEMENT IMPROVEMENT IN A GOVERNMENT CONTEXT

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ABSTRACT

To achieve a better alignment of assets with service delivery requirements, thereby enabling more efficient delivery of government services, the South Australian Government developed a strategic asset management (SAM) framework supported by an information system (SAMIS) and training programs.

An asset management improvement framework was also developed to gauge the uptake of these processes by government agencies. Using this framework, a 2002 self-assessment by agencies revealed a weakness in their understanding and application of performance management principles. Against this background, a more intensive survey of selected agencies was undertaken in 2004, enabling comparisons to be drawn with the findings of the previous self-assessment. In addition to providing further qualitative information about stakeholders' understanding of SAM after two years of participating in the development of SAMIS, this helped gauge the effectiveness of various piloting and training programs focussed upon performance management.

Whilst it was recognised that the performance management approach could provide a powerful decision tool, there were barriers - including the costs of implementation and failure to acknowledge the benefits - to acceptance and implementation of such principles. For agencies to become committed to improving their asset management performance, it was critical that they first embraced strategic thinking and *business* performance excellence principles. The key to motivating agencies to improve their asset management knowledge and practices may be them to view the performance of their assets as critical to improving their service delivery performance.

Keywords: strategic asset management, performance assessment, continuous improvement frameworks

1. INTRODUCTION

Over the last decade, there has been a growing recognition that buildings and other facilities should be considered against the requirements of business and end users - that they should be 'a useful means to a business end' (Prior and Szigeti, 2003). In a government context, achieving a closer match of assets with user requirements, stemming from improved asset management practices, may be expected to support better service delivery in a more cost effective manner.

The South Australian Government therefore developed a strategic asset management (SAM) framework, consistent with that promulgated by the Australian Procurement and Construction Council (APCC). Performance assessment is an important component of this framework; it helps gauge the degree of mismatch between service demands and asset capability, leading to the development of asset strategies to achieve a better alignment. The paper describes the development and introduction of SAM and a performance assessment model, supported by a strategic asset management information system (SAMIS).

This process has been overseen by an Asset Management Task Force, which has sought to measure the propensity for government agencies to take-up SAM practices. An asset management improvement framework was created in 2002, with a self-assessment by agencies clearly revealing a low level of understanding and application of performance management principles. Since that time, an effort has been made to improve SAM practices through seminars and training programs, coupled with the piloting of SAMIS.

Against this background, a selected number of government agencies were again surveyed in 2004 to ascertain – in more depth - their level of understanding of asset performance management, its degree of acceptance, the barriers to its adoption and how these might be overcome. This process, using a questionnaire and interviews, was conducted by students of a Masters Program in Facilities and Asset Management at the University of South Australia.

2. BACKGROUND

2.1 FROM ASSET DEVELOPMENT TO ASSET MANAGEMENT CULTURE

The growth periods of the 1970s and 1980s were characterised by an asset development culture. To meet the education, health and other needs of the 'baby-boomer' generation, the construction of new assets was seen as the primary strategy. New assets were equated with better service, whilst short-term solutions were pursued without proper regard to the long-term consequences.

We are now left with the legacy of assets built for the needs at that time, assets which require substantial resources for their maintenance and upkeep. The SA Public Accounts Committee (1987) forecast that by 2010 the funds required to maintain and replace the existing asset base would be so great

that no funds would be available to fund new assets. In addition, the ageing assets are often inappropriate for contemporary service delivery requirements; the needs of the ageing population are quite different from those of the previous generation requiring new schools.

2.2 STRATEGIC ASSET MANAGEMENT (SAM)

SAM is essentially about aligning assets with service delivery requirements – matching the supply of assets to the demand.

The SAM process is important not only for the management of existing assets but should also form the context for the procurement of new assets. Through the Australian Procurement and Construction Council (APCC), a number of State and Territory Governments are advocating this process as an important component of establishing business cases for investment in new projects. Within the APCC framework, the strategic planning process begins with consideration of service demand and resources to meet this demand. These resources may include not only assets such as buildings, equipment and vehicles, but also human resources, information technology and the like. This leads to asset planning, which encompasses plans for procurement of new assets and management/maintenance of existing assets, including plans for refurbishment, redevelopment, and asset disposal.

Asset performance assessment or measurement is at the core of SAM. Daniel Saul Goldin of the North American Space Agency once said, 'if you can't measure it, you can't manage it' (see Lambright, 2001). As will be discussed later in this paper, this philosophy applies equally (and perhaps more importantly) to measuring the success of an organisation in meeting its service delivery performance goals.

2.3 ASSET PERFORMANCE MEASUREMENT

The SA Government embarked on the development of a process and supporting system to measure and improve the performance of its assets in supporting service delivery requirements.

Against the background of a performance based building approach developed in Europe and Australia (PeBBu), this was assisted by advice from the Ottawa based International Centre for Facilities (ICF) and by liaison with the developers of the 'Logometrix' performance assessment system (Brackertz and Kenley, 2001).

The asset performance management process can not only assist performance assessment of existing assets but can also lead to better design briefs for new projects. According to Prior and Szigeti (2003), this is about 'using performance requirements to define a building, or a building's fitness for purpose, right from the outset'. It begins with the selection of key performance criteria or measures, coupled with the definition of service delivery requirements and corresponding asset requirements or targets. These should be at a level appropriate to the service demands that may not necessarily be the highest level (Davis and Szigeti, 2001).

The performance of facilities can then be assessed against the required performance levels, in terms of their capacity (whether they are in the right place and of the right size), their suitability (whether they support service delivery in terms of functionality and environment), and whether they are in the required condition and meet legislative standards. The gaps between actual and required performance can then be analysed and prioritised, options to bridge these gaps considered, and a staged asset management plan including refurbishment and other works can be put in place.

The SA Government has developed the SAMIS decision-support tool to support this process. In addition to a preliminary test involving a government owned office building, the system is being piloted on selected health and education facilities. It was recognised that a lack of knowledge and understanding of performance management principles could prejudice the successful implementation of SAMIS and the realisation of its potential benefits. Hence, a basic training program in SAM and performance management has accompanied the introduction of the new system.

2.4 IMPROVEMENT FRAMEWORKS

ISO 9004: 2000 'Quality Management Systems – Guidelines for Performance Improvements' gives guidance on the continual improvement of an organisation's overall performance and efficiency, as well as its effectiveness. It includes guidelines for self-assessment in Annex A, with 'performance maturity levels' ranging from no formal approach (level 1) to best-in-class performance (level 5) characterised by 'strongly integrated improvement process; best-in-class benchmarked results demonstrated'. Annex B of the standard describes two fundamental ways of making improvement: breakthrough projects and the more common small-step ongoing improvement.

Similar to their application to individual assets, gap audits may be applied across organisations. As Byrne, Edwards and Wilson (2002) have outlined, such audits 'provide a powerful tool for measuring the confidence level embedded in an organisation's asset management decision-making environment'. Their 'quality element gap analysis' maps progressive levels of practice – from 'innocence' upward through 'awareness' and 'competence' to excellence. Another example of this process being used in asset management is the version of the EFQM Business Excellence Model customised by Woodhouse (2001).

2.5 ASSET MANAGEMENT PERFORMANCE OF AGENCIES: SURVEY 2002

In 2001 the SA Government established an Asset Management Task Force to drive improvements in asset management practices across government and facilitate consistency in approaches. These practices reflect those in the APCC model and involve planning to meet service demands in terms of resources and physical assets - including asset planning with its acquisition, refurbishment, disposal and maintenance plans.

In 2002 the Task Force developed an asset management continuous improvement matrix (Appendix A) to gauge the level of understanding and application of various asset management practices. This mapped the level of

competency (from reactive to best practice) against the range of asset management practices. Although rudimentary, the framework is broadly consistent with continuous improvement under ISO 9004: 2000 and with other approaches - such as the 'Quality Element Gap Analysis' developed by Byrne, Edwards and Wilson (2002). The consolidated results of the self-assessment by portfolio agencies are shown in Appendix B.

According to ISO 9004: 2000 (Annex A), 'the self-assessment approach...is intended to provide a simple, easy-to-use approach to determine the relative degree of maturity of an organisation's quality management system and to identify the main areas for improvement'.

In this instance, the self-assessment revealed that levels of asset management awareness across government agencies had significant room for improvement particularly in the areas of asset performance measurement and audit/review - with the smaller agencies scoring considerably lower levels in relation to all aspects of asset management.

The overall results of a subsequent student survey, discussed in the following section, are overlaid on the matrix in Appendix B for comparative purposes.

3. RESEARCH METHODOLOGY (2004)

As part of its asset management improvement program, the SA Government assisted the University of South Australia in establishing a Masters Program in Facilities and Asset Management, which commenced in 2004. The coordinator of the course on Facilities and Asset Performance arranged for a group of seven post-graduate students to survey the status of SA Government agencies in asset performance management. This was intended to serve the dual purpose of, firstly, undertaking the empirical research upon which this paper is based and, secondly, of providing a unique educational opportunity for the students (constituting a group assignment). The possibility of being published in an international arena was expected to provide an added incentive for the students.

A sample of 10 asset managers drawn from 7 key organisations (including health, education, justice and arts) was selected to participate in the survey. Although mainly directed at government, one interviewee was chosen from the University sector for comparison. Interviews were selected as the most appropriate method as face-to-face contact enabled exploration of culture and motivation, as well as aiding the educational experience. These interviews were based upon a standard questionnaire and addressed the main elements of asset performance management, namely performance assessment and strategy development.

To enable some comparison with the results of the 2002 self-assessment conducted by the Asset Management Task Force, the levels of understanding and application were gauged using a similar improvement matrix, with the levels ranging from reactive (lowest) to best practice (highest).

The survey aimed to ascertain the acceptance of asset performance management, its culture and methodology within the SA Government. It was intended to explore these matters in more depth than had been possible

using the broad self-assessment conducted in 2002. Using a similar matrix, interviewees were asked about their current status and the targets to which they aspired. Importantly, their views were sought on the benefits they perceived in working towards the targets, the costs or barriers in terms of time, resources and the like, and the ways in which such barriers might be surmounted.

4. FINDINGS

4.1 PERFORMANCE ASSESSMENT

The survey indicated there are various degrees of use of performance measurement tools across Government agencies. For example, two organisations noted no current use whilst two others had quite detailed and defined measurement tools in place. Generally, the type of tools utilised were varied and based on the information the agencies sought to acquire.

Key performance categories currently implemented included capacity, suitability, condition and compliance.

The following matrix (Figure 1) highlights the current and ideal position of agencies in regard to knowledge and utilisation of performance assessment tools. The matrix shows that, relative to the target of 3-5, agencies' current use is generally low.

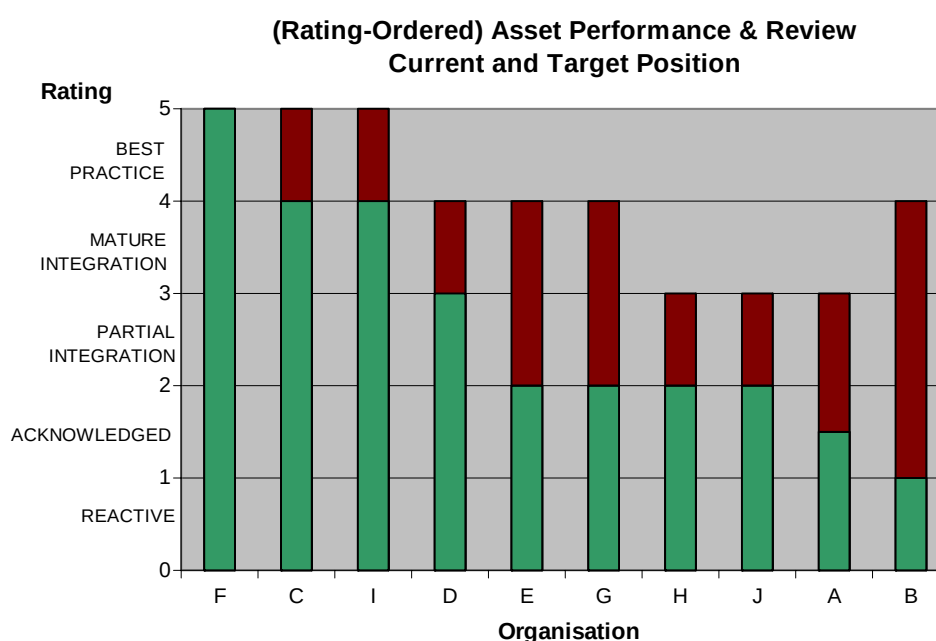


Figure 1. Asset Performance Review (Current and Target Position)

Agencies across the spectrum noted varying degrees of resistance to implementing performance-measuring tools within their organisations. However, all agencies acknowledged that such resistance must be overcome for ongoing asset management systems to be successful and continually improve. The main areas of resistance included:

- Lack of knowledge by the whole asset team;
- Lack of knowledge within higher level management;
- Obsolete information provided by old systems;
- Lack of both human and financial resources;
- Community pressures.

As one agency commented, the 'human factor' (general understanding) was a major barrier. Another admitted: 'the organisation does not acknowledge the importance of implementing the tools'.

Common strategies to overcome the resistance included:

- a) Improve employee involvement;
- b) Provide relevant training;
- c) Organisation to endorse procedures;
- d) Implement new government system (SAMIS);
- e) Engage suitable personnel.

Agencies that currently utilised performance measurement tools claimed they assessed gaps in the context of all assessments completed, rather than on an individual basis. The gaps were also managed differently according to the agencies' key strategic issues and directions, which ranged from occupational health, safety and welfare (OHS&W) compliance through to service delivery and corporate strategy.

Most agencies recognised the usefulness of developing reports from information gathered during performance assessments. Reports allowed some agencies to aggregate information, forecast essential and preferred works and projects and, in most instances, led to clear and accurate funding bids. However, other agencies had no formal reporting structure and (alarmingly) management of one agency 'had no perceived requirement for reports'.

Whilst current use of performance assessment tools varied from low to high across agencies, all acknowledged the importance of working towards implementation of performance management and continued improvement. All agencies believed that performance measures and assessments oriented to service delivery could have a substantial influence on asset management decisions (e.g. refurbishment, replacement, disposal) within organisations. They were powerful tools for asset management, management and strategic direction. Typical comments were: 'supports managers' position in recommending the allocation of scarce resources'; 'powerful / influential based data generated provides for a well-informed view'; and 'ability to provide clear cases for funding proposals'.

4.2 ASSET MANAGEMENT PLANNING

Figure 2 highlights the current and ideal position of agencies in regard to knowledge and utilisation of asset management planning.

The ratings recorded by respondents indicated that intermediate levels of asset management planning (average 2.5) were currently implemented by organisations. A distinctive finding was the importance associated with further integration of asset planning in the organisations' futures, shown in the average target of 4.2. This indicates that the majority of agencies aspired to significantly higher standards of planning of built assets, compared with current practices.

Generally, performance assessments were becoming more important to organisations in *all* areas of decision-making and planning. The resulting

data was considered critical when developing business cases, making decisions affecting an asset's life cycle and preparing long-term plans. However, consistent with the findings concerning performance assessment, such planning tended to be closely associated with *operational* matters, related to continued maintenance of existing assets. The availability of operational level data and lack of strategic information tended to impede higher level strategic planning.

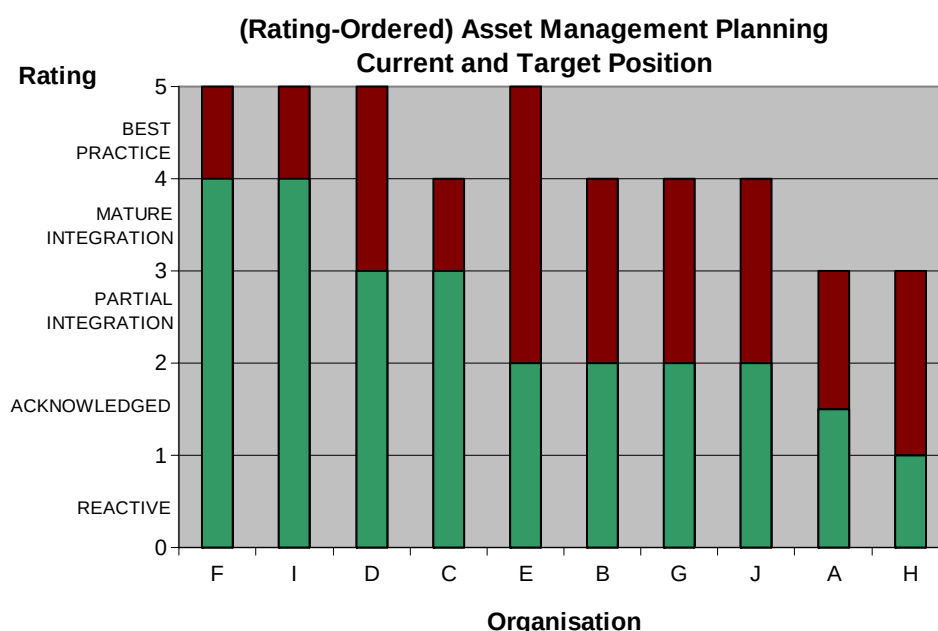


Figure 2. Asset Management Planning (Current and Target Position)

Inconsistencies existed in the degree of implementation and integration adopted throughout organisations, due to divisions in different management levels. Generally, asset management planning was integrated into annual budget cycles, reviewed annually, with a more comprehensive review being conducted tri-annually. It provided a useful tool to support the role of asset and facility managers in planning and making recommendations, especially at an asset or site level, with the ability to accurately forecast future expenditure being critical in securing finance. One organisation admitted it 'does not currently benefit from asset management, as it has not been implemented apart from in a reactive state'.

Factors such as technological developments, strategic directions of governments, changes to legislative requirements, political pressures and financial constraints could have a substantial effect on particular agencies and on their built assets used to support service delivery. Other influences included changing public demand and expectations concerning the provision and delivery of fundamental services. There were potentially serious consequences and emotive issues associated with poor performance. A major challenge was that of managing the tension between what is required (by the public and consumers) and what is provided (by the existing asset base) within limited resources. The structure and logic of performance management procedures and decision processes could be undermined by

‘irrational’ factors, such as politically motivated and unplanned human intervention.

Respondents recognised that rigorous, defined performance management processes (based on ensuring service provision) improved the ability of an organisation to allocate scarce resources to areas of highest risk and priority to the service or business. They offered flexibility to adjust or adapt to changing business environments and assist in coping with tight constraints on resources. One respondent commented: ‘formalised assessments providing empirical evidence (based on conventional / recognised standards) allow comparison of conflicting issues in relation to business objectives’.

An important finding, though, was that asset management tended to be practised at a site level rather than strategically at a portfolio level where, potentially, most benefits could be gained. In one case, it was not practised at all. There appeared to be little strategic effort to align an organisation’s assets with the kinds of new service demands described earlier in this paper.

4.3 IS THERE COMMITMENT TO IMPROVING ASSET MANAGEMENT?

As shown in Appendix B, some minor improvement was evident when the levels of understanding and application of performance management were compared with those ascertained through the 2002 self-assessment.

An important aim of the 2004 survey was to examine performance management ‘culture’ - to ascertain what would motivate agencies and their asset managers to make the effort to improve their knowledge and application of performance management. Did they possess the will, desire and commitment to ‘raise the performance bar’ from their current status (often operational, tactical and reactive) to the higher strategic level? Or was a fundamental change in culture required?

In this regard, one agency perceived ‘there is an awareness and desire within the organisation to implement the tools, although no action had been instigated to make it occur as yet. It was difficult to draw any general conclusions as to whether they had any real commitment to performance improvement.

Whilst the respondents acknowledged the importance of gaining the commitment of the corporate and executive management levels of an organisation, perhaps the answer lies in the pertinent comment that ‘assets exist because of people’. The requirement for essential services such as health and education was seen to drive the asset or facilities management solution – not the other way around. As Strategic Facility Services (2004) asked, ‘Should we link and compare the performance of the assets to the performance of the organisation?’ This may be the key to motivating agencies to improve their asset management knowledge and practices.

5. DISCUSSION

The challenge faced by Building Management and its other state government counterparts is to raise the level of understanding of strategic asset management and performance approaches – including business drivers such

as improved service delivery – among government agencies. An important mission of Building Management is to ‘work with agencies to achieve measurable asset management improvement across government’.

Without an improved understanding of asset management, the introduction of the strategic asset management information system (SAMIS) may be jeopardised. Agencies may not perceive the value of committing resources and time to introduce improved asset management practices accompanied by a new system, in a climate of funding restraints for some core services. As they are primarily concerned with maintaining these core businesses, the connection needs to be made between this and their assets – to show how better alignment can support service delivery. Furthermore, the uptake of asset performance approaches may be increased if performance management cultures and processes are applied to achievement of business outcomes. To date, asset performance has been viewed largely in isolation.

The survey revealed that asset management is applied largely at an *operational* level and the benefits of applying this at a wider *strategic* level have yet to be realised. One example of what can be achieved is the work of state health departments in delineating service requirements for various health services, with some early attempts to develop related ‘statements of asset requirements’ (DHS and DAIS, 2002). These can then be used as a basis for differentiating the requirements for various health assets that, taken together, may deliver more effective health services.

The basic improvement and reporting frameworks developed by Building Management and the students have already shown the potential for gaining a snapshot of asset management performance across government, for identifying the gaps, for planning actions towards achievement of targets, and for reporting on progress. However, to date, agencies have not made the link between these initiatives and recognised best practice standards and frameworks including ISO 9004: 2000 and the Australian Business Excellence Framework. Similar to its European counterpart, the latter includes key criteria for business success, including: leadership and innovation; people development and involvement; customer focus; continuous learning, innovation and improvement; and systems.

There is considerable scope for developing more sophisticated frameworks, along the lines suggested by Byrne, Edwards and Wilson (2002) and Woodhouse (2001), and incorporating the principles of ISO 9004: 2000. Stedman has developed a stepped pathway to improvement, with attainment at each level of an ‘Organisation Improvement Framework’ being related to relevant standards and accreditation (Stedman, 2004). A similar framework could be developed for asset management improvement, with training requirements, competencies and the like being linked to each level of attainment.

Importantly, such frameworks can provide a useful basis for discussion with agencies on how to ‘raise the bar’ – including the nature of any barriers, how these may be overcome, and how this may be worth the effort in terms of improved business outcomes. The guidance provided in Annex B of ISO 9004: 2000, hitherto untapped, could provide valuable assistance. This states that continual improvement by either the breakthrough or small-step,

gradual methods involves identifying the reason for improvement, problems with the current situation, and possible solutions.

Similar improvement frameworks using 'scorecards' and the above principles of gap analysis may be applied at the level of assets. Thus, a performance management culture may permeate government agencies, starting with their business outcomes, then extending to the assets that support these and to the systems (eg SAMIS) that underpin sound asset management and reporting.

From an educational perspective, the students appreciated the opportunity to meet asset managers face-to-face and gain an understanding of the application of asset management principles. Feedback from the group, though, indicated that the learning outcomes of the survey could have been clearer and the short time frame of only one month for the whole exercise inhibited a more thorough survey and in depth learning. Despite such difficulties, the findings have provided a useful platform for further surveys by the SA Government.

6. CONCLUSIONS

Although the 2004 survey was conducted using a sample of only ten organisations, these represented some key agencies such as health, education, police and arts. The findings are therefore considered to provide a good indication of the status of asset performance management across government. An attempt was also made to compare the levels of understanding and application with those that had been ascertained through the 2002 self-assessment, and some minor improvement was evident.

However, the main value of the 2004 survey by means of interview was that it provided greater insight into the barriers to implementing performance management within agencies and how these might be overcome. Whilst performance approaches may undoubtedly have benefits in improved asset management and better allocation of funds to areas of most need, this is offset to some extent by costs in terms of increased resources (time, financial, human) to improve systems, the need to improve general understanding and knowledge, and to demonstrate that there are business benefits. To achieve a change in culture, it was critical to focus on the deficiencies of current practices, the reasons for improvement, and the benefits of the new approaches. For agencies to become committed to practising asset performance management, it was critical that they first embraced *business* performance management. In other words, it was necessary to have business drivers in place.

Whilst the performance improvement matrix developed in 2002 - later adapted for the 2004 survey - is rudimentary in nature, the results to date have indicated that it would be worthwhile to develop a more refined version which is more aligned with ISO 9004: 2000.

Whilst this paper is focussed on government agencies, the philosophies of performance management and improvement are seen as applicable to the private sector, although profit may loom larger than service delivery as a driver for improvement.

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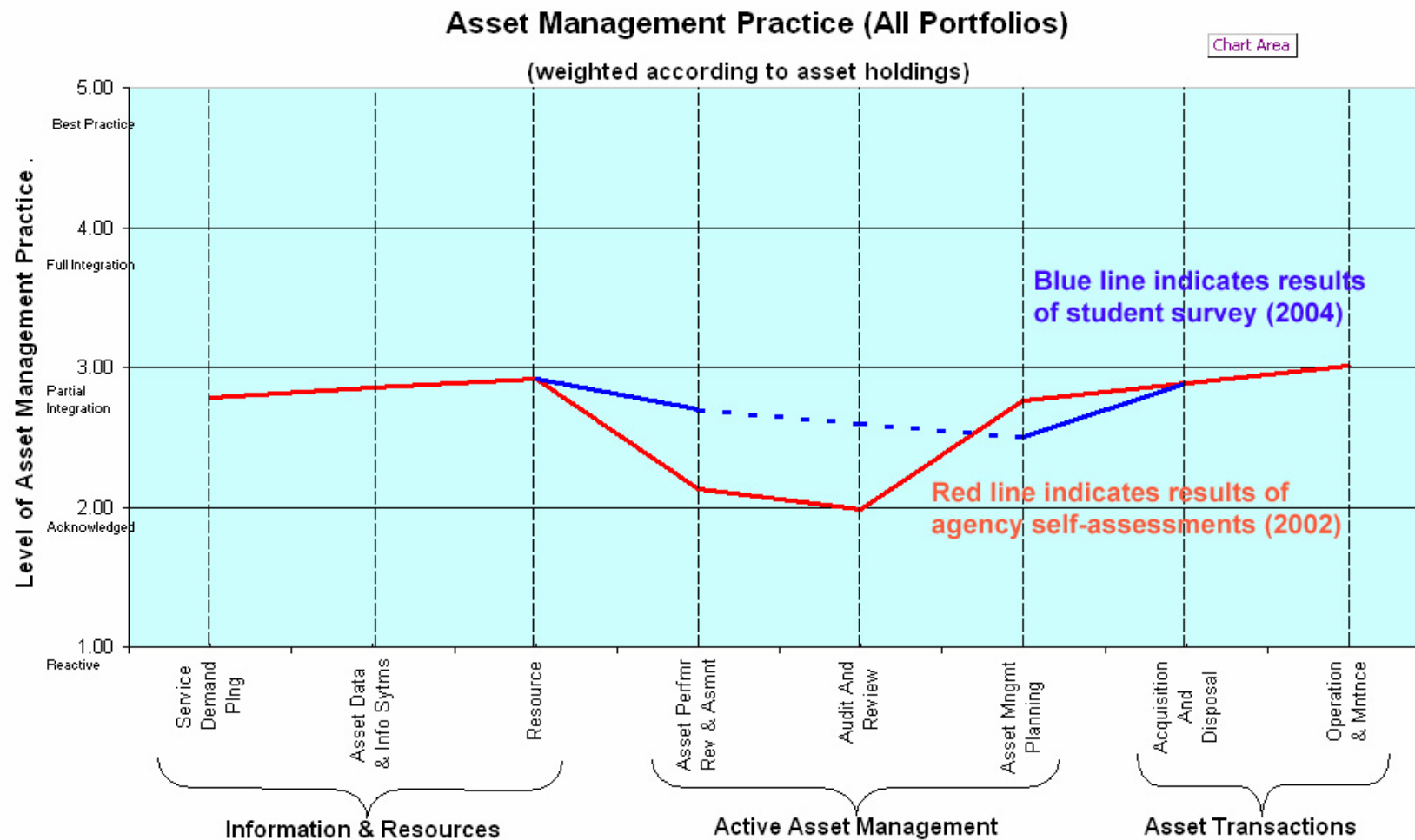
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APPENDIX A: ASSET MANAGEMENT CONTINUOUS IMPROVEMENT MATRIX

	SERVICE DEMAND PLANNING	ASSET DATA & INFORMATION SYSTEMS	RESOURCE	ASSET PERFORMANCE REVIEW	AUDIT AND REVIEW	ASSET MANAGEMENT PLANNING	ACQUISITION & DISPOSAL	OPERATION & MAINTENANCE
 5 BEST PRACTICE A.M.	Proactive asset management anticipating future requirements influencing demand	Common data bases exist; Data information is correct & timely; Data/ information accessible to all levels of management/ ops	Flexible partnership relationships across agency, other agencies, central govt; Partnership arrangements with private sector as benefits.	Exemplary review process; Generates economic value & advancement.	Able to achieve benchmark efficiency/ effectiveness; Independent audit encouraged.	Continuous improvement activities are fully integrated with planning life cycle; SAM incorporated into corporate strategies.	Portfolio plan/ corporate plan outcome driven.	Individual asset ops. & mtce. strategy based on performance & evaluated against returns on assets; Preventative mtce. primary focus.
 4 A.M. FULLY INTEGRATED INTO MANAGE'T	Asset management linked to service demand & building service delivery strategy	There is no duplication of info; Integrated info systems.	External partnership relationships; Packaging of work; Accountabilities set at asset level; People proficient in measurement, aggreg'n & analysis of data.	Strategic review based on importance/ criticality; Analyse trends/ cause/ effect; Full lifecycle benefits measured and optimised	Systemised & integrated audit process.	KPIs linked to strategic & business plans; Long term asset plans in place; Risk plans; Portfolio asset planning integrated with business plans.	Acquisition strategy set by existing long term asset plans; Processes ensure value for money, transparency of process.	Based on business & performance objectives; Effort for assets based on strategic ranking; Risk management.
 3 PARTIAL INTEGRATION OF A.M. INTO MANAGE'T	Development of service demand strategy & implementation of asset performance requirements/ measurements.	Focus on, quality, completeness & timeliness of information; Recognise need to link asset related information systems; Identification & collection of strategic asset performance data	Well defined roles & responsibilities; Internal resources for strategic planning; Site level personnel trained in SAM; Outsourcing packages.	Level of service vs. cost of service reviewed regularly; Strategic asset performance measures described Applied asset valuation methodology; Operational performance measures applied	Business/ market oriented; Unnecessary risks avoided; Close monitoring; Continuous review of supplier performance; Post occupancy evaluation	Business oriented Performance based Consistent project evaluation process in place Use gap analysis techniques including risk assessment Planning & partial implementation of portfolio asset plans.	Implementation of procurement processes; Application of analytical tools & techniques; Project risk management.	Integrated financial / ops & mtce. Plans well documented; Ability to contract out aggregated packages; Asset condition & backlog maintenance identified.

 2 A.M. NEED ACKNOWLEDGED 	Identified need to define service demand & asset performance requirements.	Asset register exists & is maintained; Need for asset management info system recognised, together with more proficiency in use of information.	Corporate facilities manager with well documented relationship with site managers; Skills/ training needs Identified; Relationship with key public sector service providers.	KPIs identified & communicated: capacity, suitability, condition; Process responsibilities established.	Well documented/ prioritised processes & practices; Formal audit plans.	Need for SAM recognised; LCC for major capital investments; Site asset plans being developed; Some risk analysis.	Planned asset replacement not linked to service demand; Decisions based on business case; Formal delegations.	<i>Maintenance strategy for major assets only;</i> Some consideration of condition, risk, cost benefit.
1 REACTIVE A.M.	Ad-hoc service demand & asset requirements information.	Asset register does not exist; No centralised data base; Data collection ad-hoc.	Corporate facilities manager.	Corporate focused; Performance/ cost management for major assets only.	Reactive/ unplanned.	Based historical trends; No strategic asset planning process; Technical aspects, ad-hoc data only	Ad-hoc; Informal; Price sensitive; Decision at line level	Based on historical trends; Reactive maintenance; No performance monitoring.

APPENDIX B: ASSET MANAGEMENT PRACTICE (ALL PORTFOLIOS)



CONFERENCE THEME: VISUALISATION AND INFORMATION

Full Paper

AUTOMATED CODE CHECKING

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ABSTRACT

Most buildings constructed in Australia must comply with the Building Code of Australia (BCA). Checking for compliance against the BCA is a major task for both designers and building surveyors. This project carries out a prototype research using the EDM Model Checker and the SMC Model Checker for automated design checking against the Building Codes of Australia for use in professional practice.

In this project, we develop a means of encoding design requirements and domain specific knowledge for building codes and investigate the flexibility of building models to contain design information. After assessing two implementations of EDM and SMC that check compliance against deemed-to-satisfy provision of building codes relevant to access by people with disabilities, an approach to automated code checking using a shared object-oriented database is established.

This project can be applied in other potential areas – including checking a building design for non-compliance of many types of design requirements. Recommendations for future development and use in other potential areas in construction industries are discussed.

Keywords: Code Checking, Design Verification, Domain Knowledge, EDM, SMC

1. INTRODUCTION

Buildings are required to meet various criteria from organisational, financial, environmental and social perspectives. An important social perspective is the equity of access to buildings by all members of the public. The requirements for access are defined in the Building Code of Australia (BCA). The BCA is a performance-based code, which allows the use of a range of solutions to requirements. Australian Standard (AS) 1428 "Design for access and mobility" is accepted as a deemed-to-satisfy solution within the BCA. This project takes AS 1428 as a focus of our application.

Express Data Manager™ (EDM) and Solibri Model Checker™ (SMC) are two major systems currently available that provide object-based rule engines. EDM provides a shared data repository and is compatible with the Industry Foundation Classes (IFC). SMC provides automated "design spell-checking" to a building model and is capable of directly interfacing to an object-based architectural CAD system.

This project uses EDM and SMC for the automated assessment of designs against AS1428. Two prototype systems using EDM and SMC are implemented for a comparative analysis. The fundamental issues that we deal with involve the:

- Capability of automating design checking process;
- Flexibility of modelling design information;
- Flexibility of encoding building codes and domain knowledge;
- Capability of interfacing to object-based CAD systems;
- Capability of providing friendly reporting systems and 3D visualization;
- Capability of integrating with other applications.

Section 2 and Section 3 of this paper describe the functionality of EDM and SMC for encoding building codes and domain knowledge. They are followed by a demonstration of the performances of the EDM prototype and SMC prototype in Section 4 and Section 5. Section 6 presents an approach of using a shared EDM database for storing comprehensive design information and encoding domain-specific knowledge to support automated code checking and discussions on future development.

2. DOMAIN KNOWLEDGE AND EDM RULE BASE

Checking a building design for compliance with a given set of design requirements from building codes requires a process of design verification (Balachandran, Rosenman and Gero, 1991). The design verification demands the interpretations of design information and performance requirements supported by domain knowledge. This section describes the functionality of the EDM database for encoding domain knowledge and design requirements to support design verification.

The EDM database contains data models and schemas, Figure 1. The schemas include a model schema for defining data models, rule schema for validating data models and query schema for producing a specific view of a

data model. This project focuses on the development of the EDM rule schema.

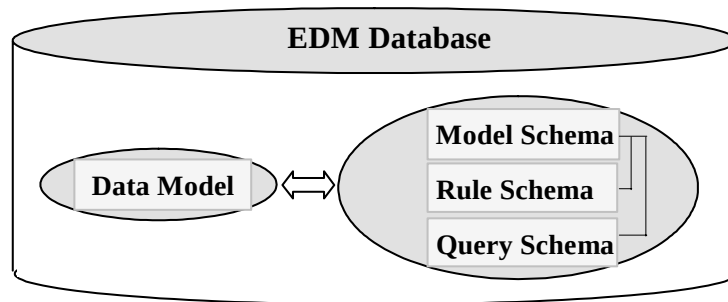


Figure 1. An illustration of the EDM database.

The EDM rule schema consists of the declarations of entities, rules, functions and procedures used for defining various rules to data models. We develop the EDM rule schema to accommodate the performance requirements and domain knowledge from building codes for design verification, Figure 2.

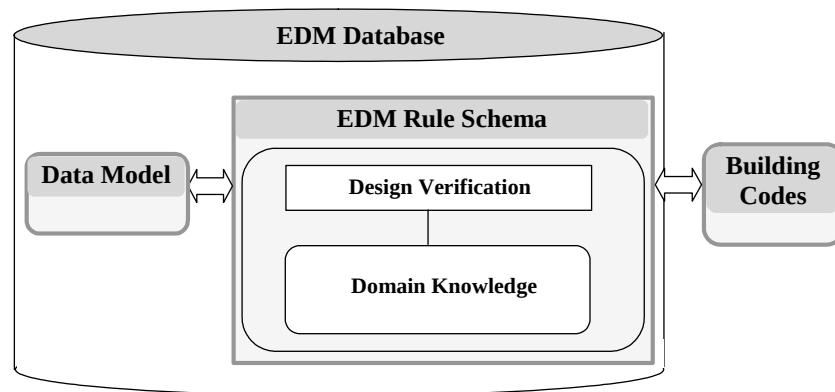


Figure 2. An illustration of using EDM rule schema for code checking.

We present an example of encoding a clause in AS 1428 Part 1 with the EDM rule schema. The clause, from 7.1 Provision of Entrances, is described as: 'accessible entrances shall be incorporated in an accessible path of travel'. Design checking against this clause requires an interpretation on 'accessible entrances' and 'an accessible path of travel'.

We develop an object-based interpretation and define it with the EDM rule schema. The object-based interpretation consists of: Descriptions, Performance Requirements, Objects, Properties, Relationships, and Domain-specific Knowledge for Interpretation. Figure 3 shows the object-based interpretation for the clause from 7.1 Provision of Entrances. A process of encoding a clause of building codes to an object-based interpretation and then to an EDM rule schema is illustrated in Figure 4.

CLAUSE 7: DOORWAYS, DOORS AND CIRCULATION SPACE AT DOORWAYS

Clause 7.1 Provision of Entrances

Description:

The requirements for entrances to buildings are as follows:

- (a) Accessible entrances shall be incorporated in an accessible path of travel.

Performance Requirements:

There is an uninterrupted path of travel from an accessible entrance to an accessible space required.

Objects:

{Space, Door}

Object Properties:

{Door_exterior, Door_accessible, Door_type, Door_width, Space_accessible, Space_identification, Space_area}

Object Relationship:

{Contain (Space, Door): Space contains Door}

Domain-specific knowledge for Interpretation:

(to be implemented with functions and procedures)

AssessibleExteriorDoor (Doors)

{IF Door_exterior and Door_accessible are found, THEN return AssessibleExteriorDoors}

AccessibleEntranceSpace (AssessibleExteriorDoors)

{IF AssessibleExteriorDoors are contained by Spaces, THEN return AccessibleEntranceSpaces}

AccessibleSpaceRequired (Spaces)

{IF Space_accessible is found, THEN return AccessibleSpacesRequired}

A_Path_from_AccessibleEntranceSpace_to_AccessibleSpaceRequired (Spaces, Doors)

{IF Spaces and Doors are located in the path from AccessibleEntranceSpace to AccessibleSpaceRequired, THEN return a set of the Spaces and a set of the Doors}

Criteria_for_anUninterruptedPath

{IF Spaces and Doors located in the path satisfy the requirement of Door_width, Door_type, Space_area, etc. THEN return TRUE}

Figure 3. An example of an object-based interpretation for a clause of building codes.

3. DOMAIN KNOWLEDGE AND SMC RULE BASE

Compared with EDM, SMC provides a Constraint Set Manager (CSM) for managing and configuring constraint sets as the rule base to support design spell-checking.

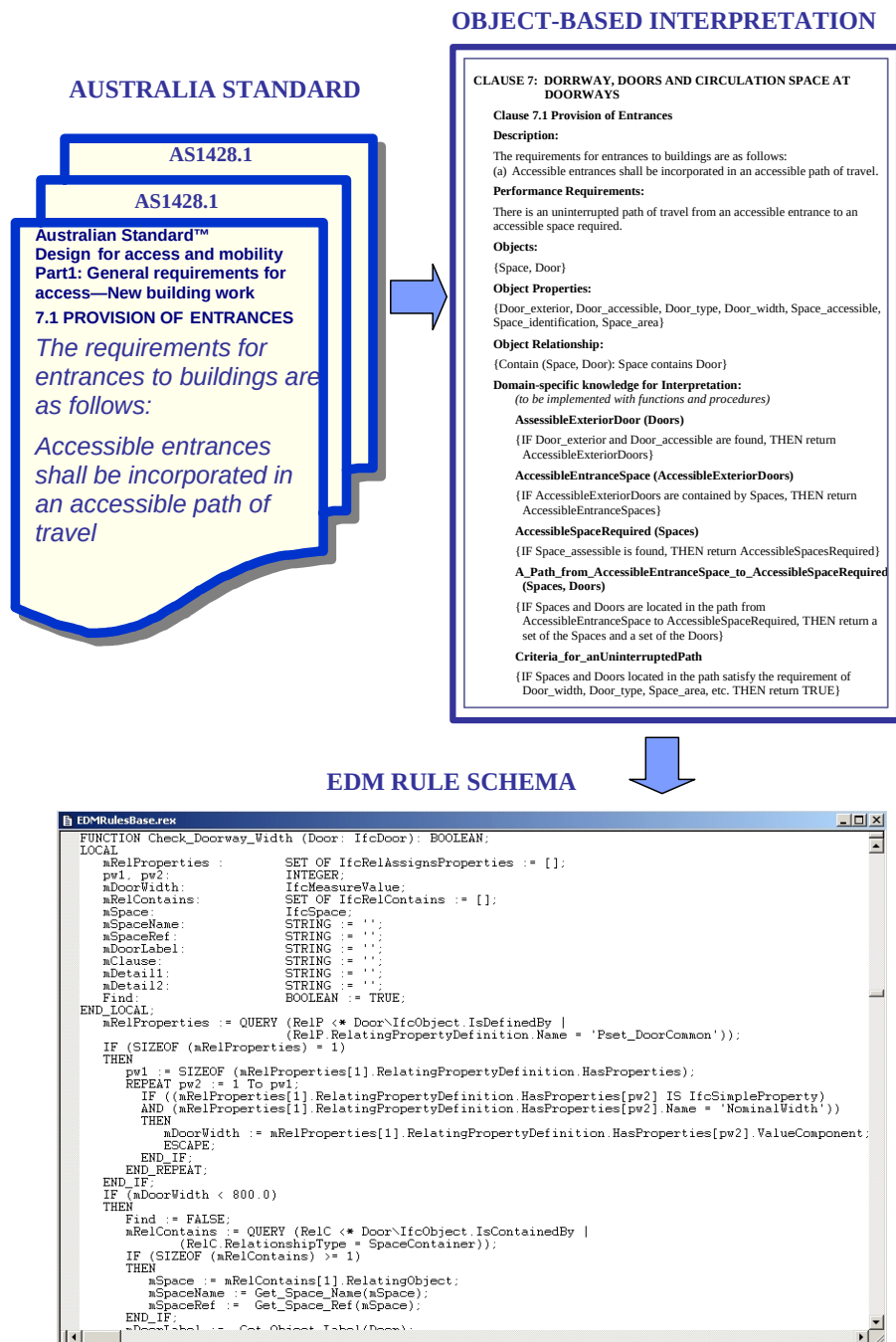


Figure 4. An illustration of the process of encoding a clause of building codes to an object-based interpretation and then to an EDM rule schema.

CSM is a Java-implemented schema that defines a rule base displayed to the user as constraints. There are over 150 different constraints defined within the Constraint Libraries and Constraint Sets of CSM 1.0/1.1. Constraints can be divided into ten main groups containing unique constraints for constructing specialised rules, including: Construction Constraints, Legacy Constraints, A Precheck of the Model (CAD components), Checking for Quantity Take Off

Purposes, Escape Routes, Interference Checking, Construction Type, Space Checking, Typical Modelling Errors and Visualisation Constraints, Figure 5.

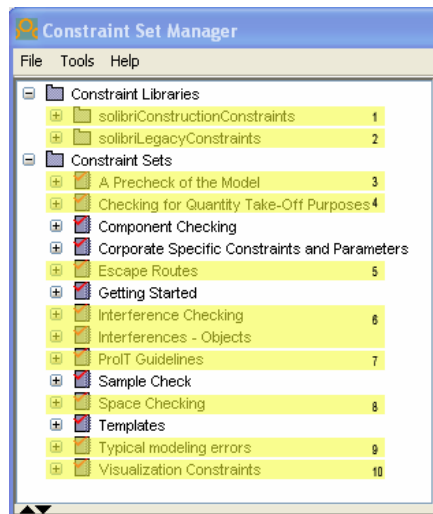


Figure 5. An illustration of the constraint groups provided by CSM 1.1.

The capability of the CSM rule base to encode the performance requirements and domain knowledge from building codes was investigated. CSM allows structuring of new constraints to be composed from generic constraints available in libraries. Control of constraint behaviours is possible by setting parameter values for specific performance requirements from building codes. Figure 6 illustrates how CSM is employed for encoding building codes and operated in conjunction with SMC.

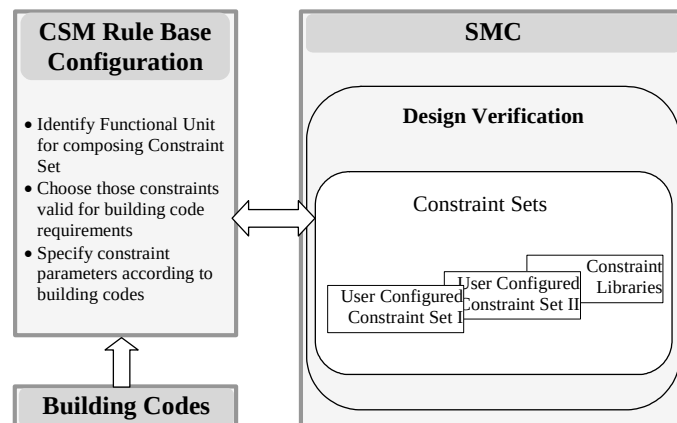


Figure 6. An illustration of developing CSM rule base for code checking.

SMC defines highly focused constraints with the CSM for encoding design requirements and as a result, descriptions are inflexible. Some flexibility is provided by the ability to set parameter values, however, the parameters are narrow and not available for all components and across all types of constraints. When design verification requires an interpretation of the performance requirements, e.g. an interpretation of a complex building code clause where domain-specific knowledge is demanded, SMC lacks a mechanism for encoding such interpretations.

4. EDM PROTOTYPE SYSTEM

This project implemented an EDM prototype system based on a proposed framework illustrated in Figure 7. We used ArchiCAD as an example object-based CAD system and chose a small 3 storeys building from SMC for testing.

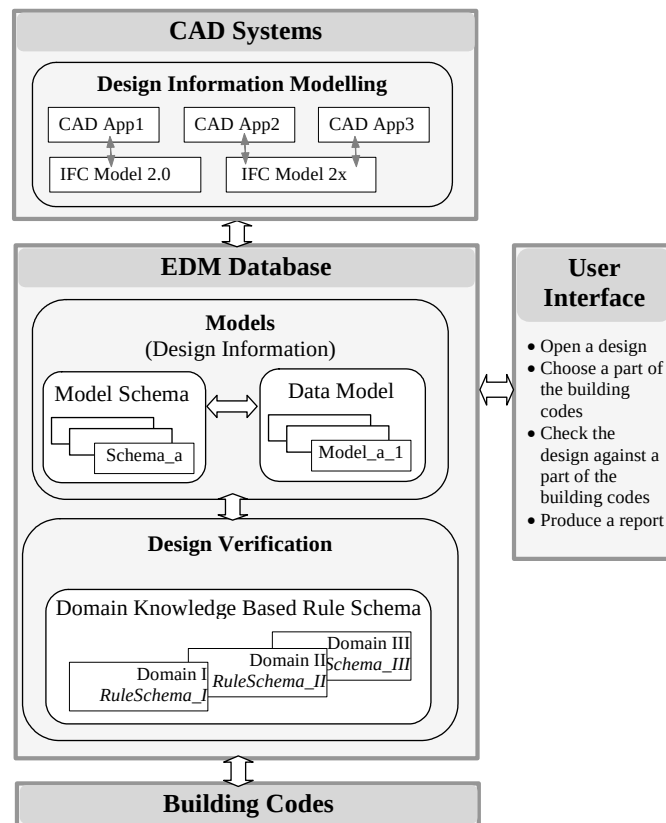


Figure 7. An illustration of a framework for the EDM prototype system.

4.1 MODELLING DESIGN INFORMATION

The process of automating code checking requires that one begins with an adequate building model. ArchiCAD supports object-based information modelling while ArchiCAD IFC add-ons provide a way to define and export extensible and interoperable model data. This project uses the IFC conversion and property extension mechanisms to achieve extended design information for ArchiCAD objects. An example of converting an ArchiCAD object into an extensive IFC object is presented in Figure 8, where a Ramp object was converted into IfcRamp with extended information specified as properties.

Mappings between CAD, IFC and building code models require uniform object identification and description. The information requirements for a complete mapping schema between models are fundamental to the task of automating code checking. The following general requirements have been considered for such mappings:

- Defining uniform building objects ID descriptions;
- Defining semantics of object properties;
- Structuring extended objects and properties;
- Instantiating definitions and parameters.

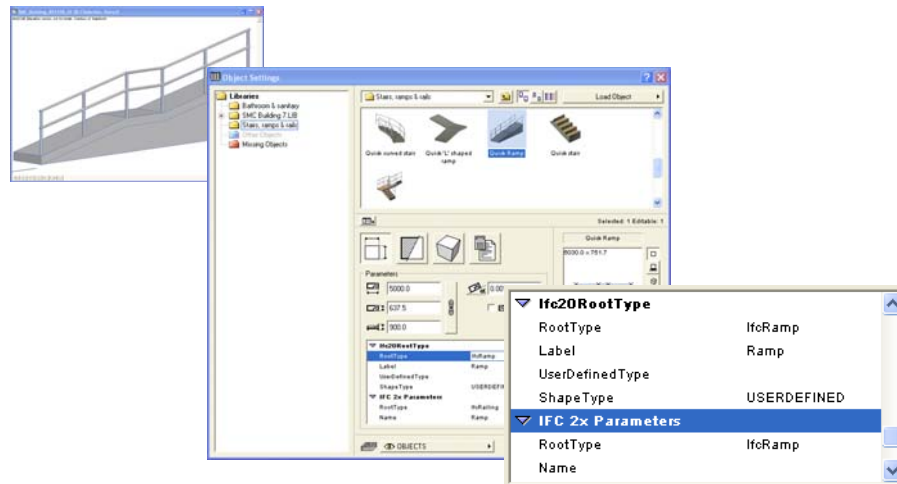


Figure 8. An example of converting an ArchiCAD object into an IFC object.

Table 1 outlines examples for object mappings between CAD, IFC and building codes models.

AS 1428.1 Building Object	ArchiCAD Element/ Object	Mapping to IFC Object
Walkway	Create Zone	IFCSPACE
Path of Travel	Create Zone	IFCSPACE
Circulation	Create Zone	IFCSPACE
Ramp	Library Object = Ramp	IFCRAMP
Kerb Ramp or Step Ramp	Create Object / Library Object	IFCRAMP
Landing (Stair or Ramp)	Create Object / Library Object	IFCSTAIRFLIGHT or IFCRAMPFLIGHT
Handrail	Library Object = Handrail	IFCRAILING
Door / Single Swing Door	Element = Door	IFCDOOR SINGLE_SWING_LEFT SINGLE_SWING_RIGHT
Door / Single Sliding Door	Element = Door	IFCDOOR SLIDING_TO_LEFT SLIDING_TO_RIGHT
Door / Revolving	Element = Door	IFCDOOR REVOLVING
Entrance Door	Element = Door	IFCDOOR ISEXTERNAL
Gate	Create Object	IFCPROXY

Table 1. Examples of object mappings between CAD, IFC and building codes models.

In order to provide a building model that tests AS 1428 Part 1 clauses, building elements are selected and re-modelled in ArchiCAD so as particular attributes and properties do not comply. Figure 9 presents the building model that we used for testing, where the illegal building elements are circled in red. For example, in the Lobby space in Figure 9, it shows that a revolving door is installed but there is no hinged or sliding door installed. This is not compliant with AS 1428 Part 1 Clause 7.1 (a).

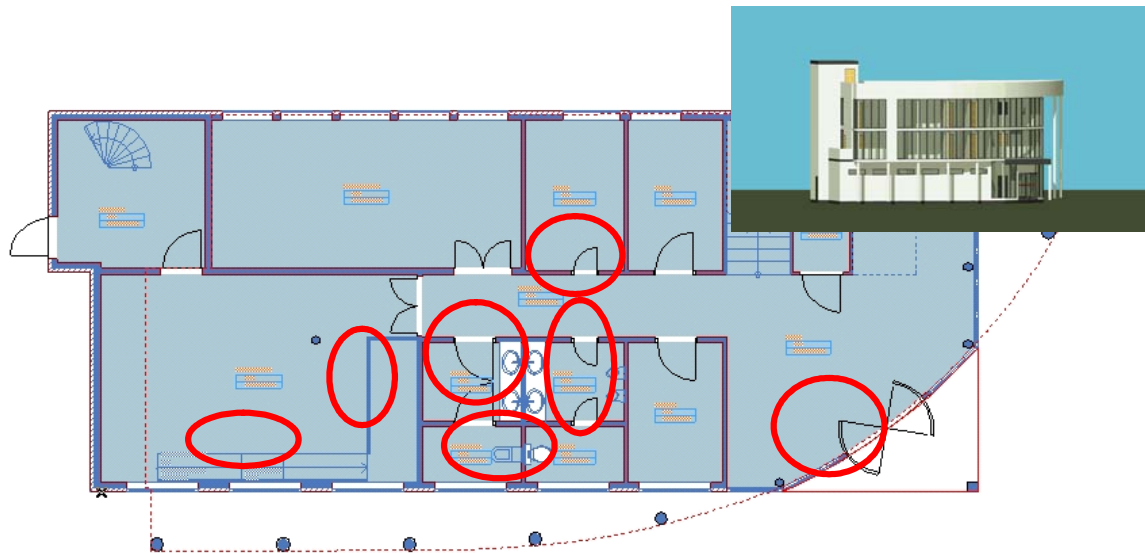


Figure 9. An example building model with illegal building elements circled in red.

4.2 IMPLEMENTATION OF EDM DATABASE AND RULE BASE

An EDM database was created /opened to store the IFC-based building models from ArchiCAD. The building models consisting of object, properties and relationships were translated into the EDM database files.

There are seventeen clauses in AS 1428 Part 1. This project encoded the clauses where the objects and properties are supported by the current object-based CAD systems and IFC models. Table 2 presents an example of encoding a part of Clause 5 Walkways, Ramps and Landings.

Performance requirements in different areas are able to be encoded with a number of rule schemas which are supported by domain knowledge. Figure 10 illustrates a set of EDM schemas for encoding building codes in different areas such as Fire Safety, Roof and Wall Cladding, etc.


```

ENTITY IfcRamp;
WHERE
  Handrail: Handrails_BothSides(self);
  Landing: Landing_Length(self);
  Ramp: Ramp_Width(self);
END_ENTITY;

FUNCTION Handrails_BothSides (Rmp: IfcRamp): LOGICAL;
LOCAL
  Find: BOOLEAN := FALSE;
  RampRelationProperties: SET OF IfcRelAssignsProperties := [];
  cont1,cont2: INTEGER;
  mObjValue: IfcMeasureValue;
  mObjName: STRING := ' ';
  mObjLabel: STRING := ' ';
  mObjRef: STRING := 'N/A';
  mClause: STRING := ' ';
END_LOCAL;
Find := True;
RampRelProperties := QUERY (Ramp <* Rmp\IfcObject.IsDefinedBy |
                          (Ramp.RelatingPropertyDefinition IS
                           IfcExtensionPropertySet));
IF (SIZEOF (RampRelProperties) = 1)
THEN
  cont1 := SIZEOF(RampRelProperties[1].
                  RelatingPropertyDefinition.HasProperties);
  REPEAT count2 := 1 To cont1;
  IF ((RampRelProperties[1].
        RelatingPropertyDefinition.HasProperties[c1] IS
        IfcPropertyList)
      AND (RampRelProperties[1].
            RelatingPropertyDefinition.HasProperties[c1].Name
            = 'LIBPARAM'))
  THEN
    ---

```

Table 2. An example of encoding a part of Clause 5 Walkways, Ramps and Landings.

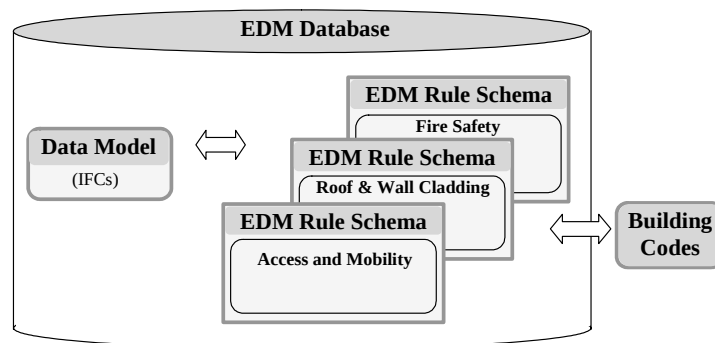


Figure 10. An example of encoding performance requirements in different areas with a set of EDM rule schemas.

4.3 EDM REPORTING SYSTEM

The EDM rule checking engine was tested for checking the building model against the new rule schema encoding clauses from AS 1428 Part 1. The system was designed to automatically generate a report listing the objects

that were not compliant. The original report was in a text format without detailed features for viewing and analysing.

In this project, we developed a user friendly reporting system that allows detailed information and issues to be analysed. A new reporting schema was implemented with XML and HTML and interfaced to the EDM rule checking engine. Detailed issues involve: object identification, clause description and failed object features.

Figure 11 illustrates the issues from a typical run of checking the building design. We see the information for the Lobby object includes: a reference number of the Lobby object in ArchiCAD, identification for Door object contained in the Lobby that resulted in failure to comply, a description of Clause 7.4 and failed features.

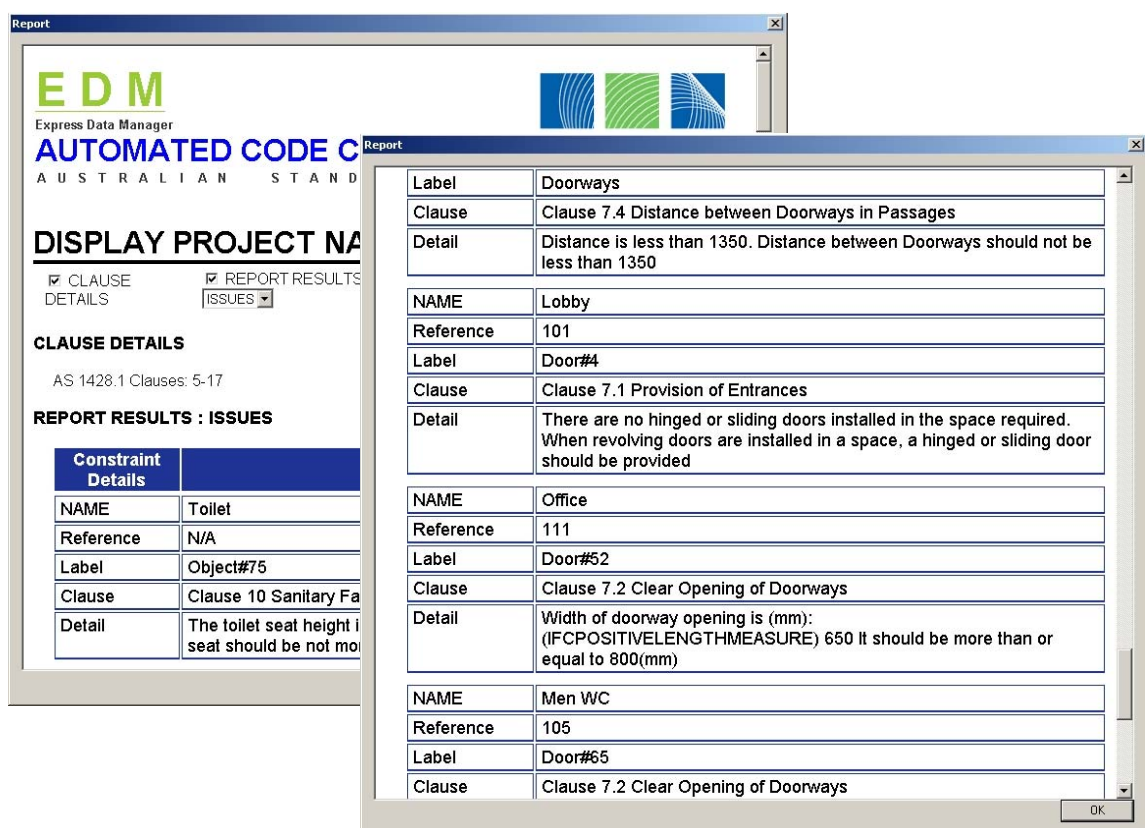


Figure 11. Some issues from a typical run of checking designs.

5. SMC PROTOTYPE

A framework for implementing the SMC prototype is illustrated in Figure 12. Different from EDM, SMC provides ArchiCAD SMC add-ons so the building models in ArchiCAD can be converted into IFC models or directly exported into SMC models for design checking.

SMC provides a direct interface to ArchiCAD that will allow designers to modify designs in conjunction with compliance with building codes at real time.

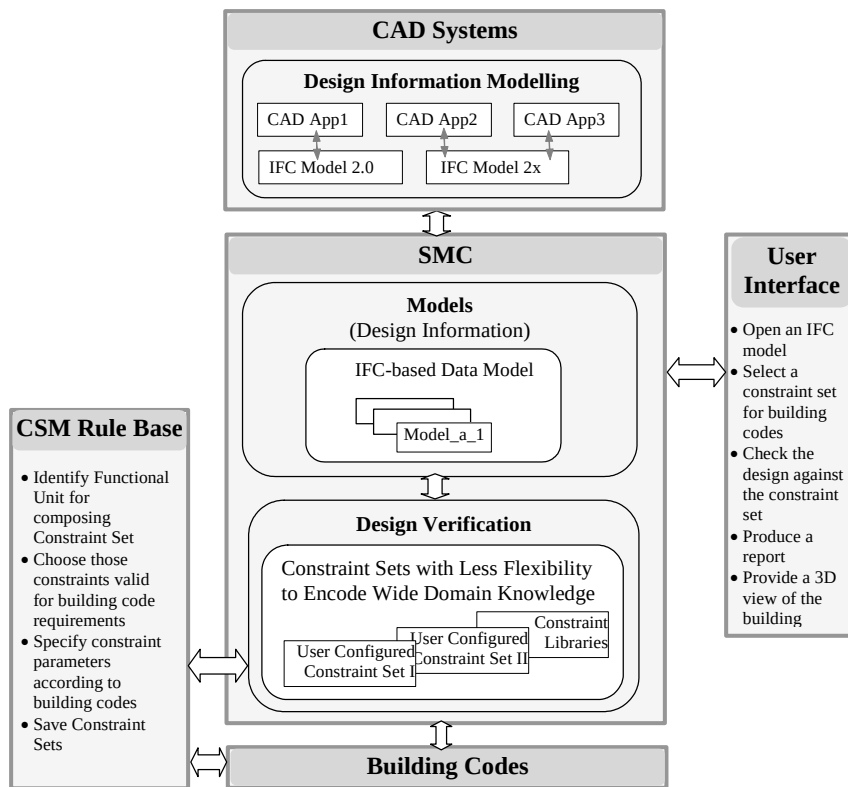


Figure 12. An illustration of a framework for the SMC prototype system.

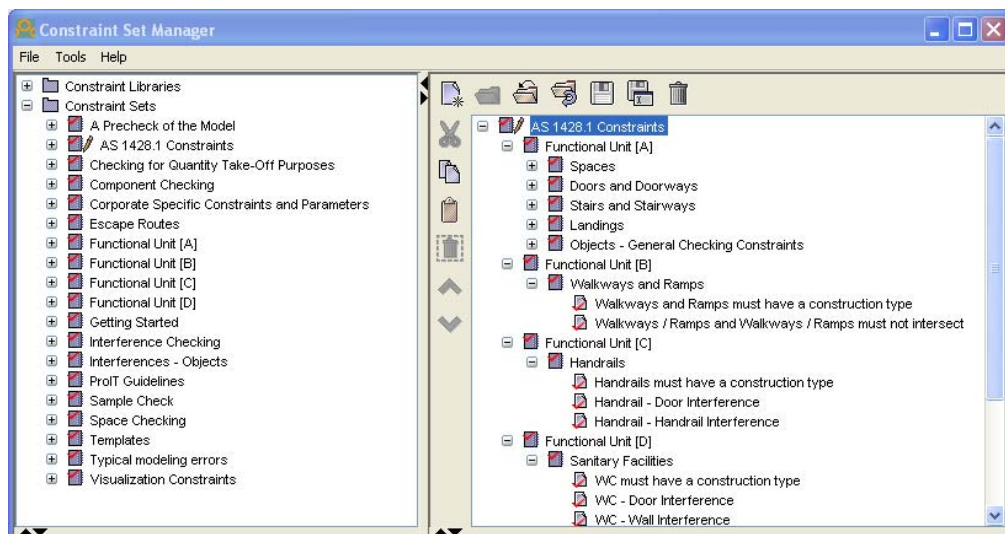
The SMC rule base provided by CSM is adequate for the purpose of checking how proficiently a building design is modelled in CAD systems and the precision in which various CAD objects have been represented. However, it shows less flexibility when used for the purpose of code checking.

5.1 IMPLEMENTATION OF SMC RULE BASE

A set of constraints were chosen from the SMC rule base for encoding clauses of AS 1428 Part1 and the constraint parameter values were set mapping onto specific performance requirements from AS 1428 Part 1 clauses. The following six groups were selected for mapping on to AS 1428 Part 1 building requirements:

- Construction Constraints;
- A precheck of the Model (CAD components);
- Checking for Quantity Take Off Purposes;
- Interference Checking;
- Construction Type;
- Spacing Checking.

These constraints were composed into Functional Units to check individual AS 1428 Part 1 building objects. Where CSM constraints map onto AS 1428 Part 1 clauses, the parameter values are adjusted to match the attributes of building objects. A detailed explanation of the constraint description and parameter specification is presented in Figure 13 (a) and (b).



(a)

4.3.1.1 Space [A]

Spaces must have a name

- DESCRIPTION: This constraint checks that the name is set for all spaces in the model.
- PARAMETERS: Space Property - **Name**.

Space numbers must be unique

- DESCRIPTION: This constraint checks that there are no duplicate space numbers in the model.
- PARAMETERS: Space Property - **Space Number**.

Spaces must have an access

- DESCRIPTION: This constraint checks that each space can be accessed through a door.
- PARAMETERS: -

Spaces must not intersect other spaces

- DESCRIPTION: This constraint checks intersections of spaces.
- PARAMETERS: Component types to be checked - **Space** + **Space**.
Interference Type: ☒ Duplicate
☒ Inside
☒ Overlapping
Horizontal Interference: ☒ Smaller Dimension = **0.01m**
Vertical Interference: ☒ Intrusion Height = **3m**

Airlock etc must not be too small

- DESCRIPTION: This constraint checks too small spaces.
- PARAMETERS: Component Type - **Space**.
Property Value Constraints: Property = **Width**

(b)

Figure 13. (a) An illustration of constraints composed into Functional Units to check individual AS 1428 Part 1 building objects and (b) A detailed explanation of the constraint description and parameter specification.

The SMC rule base does not contain constraints that check relations between building elements other than constraints for Interference Checking. Nor does it allow encoding of interpretations for performance requirements. The rule base can only be controlled by choosing among a number of building objects, library constraints and constraint parameter values. As a consequence, it has less flexibility to encode domain-specific knowledge.

5.2 SMC REPORTING SYSTEM

SMC provides a well developed reporting system with 3D visualization. The reporting interface allows designers to view the constraints being checked, update constraints as well as toggle between the reporting results and constraint specifications. Checking results can be grouped into four categories: All, Passed, Irrelevant and Issues.

For analysis purposes, the SMC reporting system allows: navigation of the building model from a 3D view port, identification and highlighting of the building elements that are not compliant as well as active links among reported issues, constraints, building components and their properties, Figure 14.

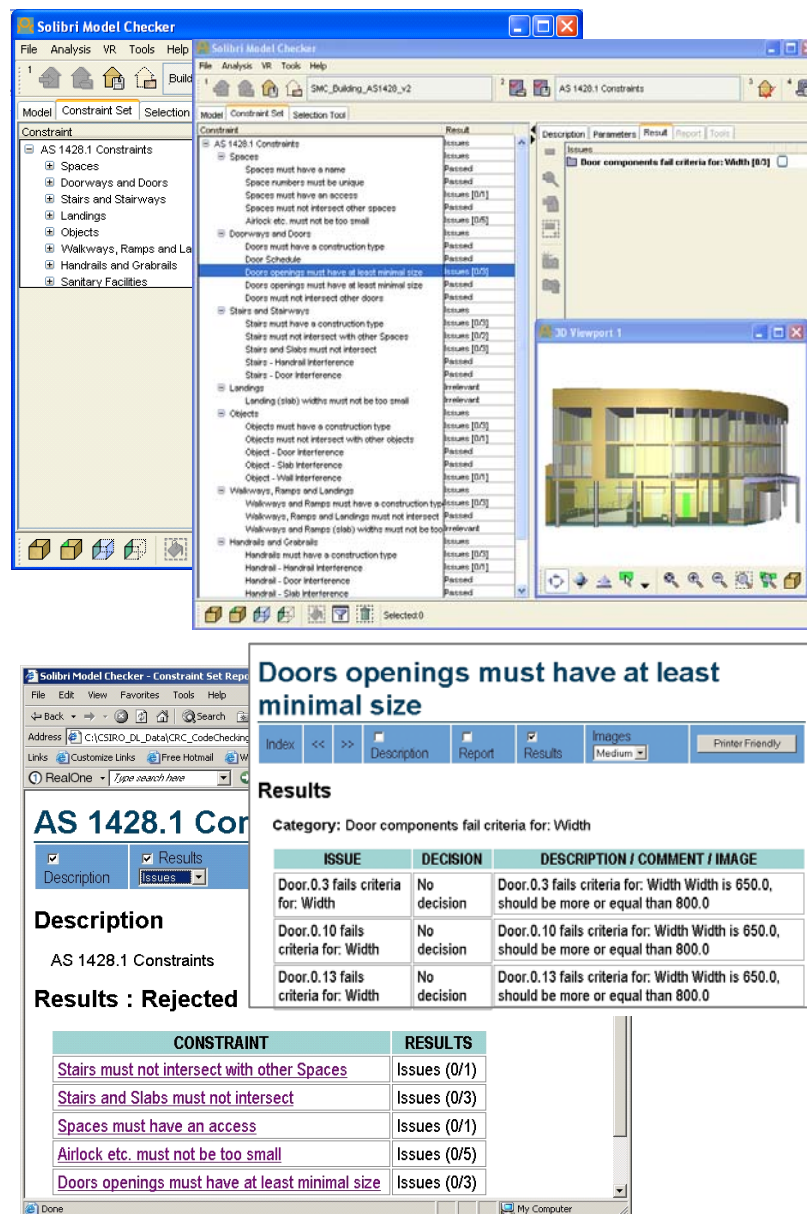


Figure 14. An illustration of the issues from the SMC reporting system.

6. FUTURE DEVELOPMENT

6.1 A SUMMARY OF EDM AND SMC PROTOYPES

This section summarises the EDM prototype and SMC prototype through a comparative analysis.

The EDM prototype shows flexibility in modelling extended design information and encoding of wider domain-specific knowledge. The EDM database allows definitions of own model schema for building models that contain comprehensive design information as well as identical descriptions that map more directly onto building codes.

Compared with SMC, EDM doesn't provide a direct interface to CAD systems. However, it can be developed through the Application Program Interface of CAD systems when necessary.

The EDM prototype demonstrates an automated checking process comprising: importing building models into the EDM database, checking building models against defined EDM rule schema and reporting a list of the objects that failed to compliance. However, there is no user friendly reporting system for analysing issues. The system also lacks a user friendly interface for designers to monitor the information flows.

In testing the SMC prototype, the SMC rule base proved inadequate for checking building regulations and specific building codes since constraints were not able to encode design requirements at the required level.

SMC 2.0 has increased its component capability by including Stair object and general Objects for Interference and Construction Type checking. However, the parameters for Stair object and the general Objects do not support the range of checking procedures defined for existing components. In general, the SMC building model shows less flexibility in extending objects properties as well as mapping descriptions onto building codes.

The SMC prototype also demonstrates an automated checking process. It has shown its advantage of directly interfacing to CAD systems and excellent performance from its reporting system.

From the point view of application development, the EDM prototype provides a central object-based database containing a common model, which facilitates data sharing and communication with other applications. The SMC prototype provides building models based on a specific version of IFC. When the IFC standard is updated, the SMC models must also be upgraded.

6.2 AN APPROACH USING A SHARED OBJECT-BASED DATABASE

Since the EDM prototype provides more flexibility and capability for automating code checking, we consider this system as a focus for future development.

The EDM approach is able to provide a shared object-based database to contain design information and domain-specific knowledge. The EDM database has the Standard Data Interfaces, early /late bindings in Java, C++, XML, etc. to support data exchange and information communication with various applications including CAD applications.

The future development of the EDM approach lies in extending its ability toward defining extensive design information into the EDM Data Model as well as interpretations of performance requirements and domain knowledge into the EDM General Rule Base, Figure 15. This will fundamentally support the design verification required by automated code checking. The EDM Data Model will be defined to contain adequate design information mapping onto building codes. The EDM General Rule Base will be developed to encode domain- knowledge for general interpretations of design performances. Once specific criterion from building codes are updated, it is not therefore necessary to modify the whole EDM rule base.

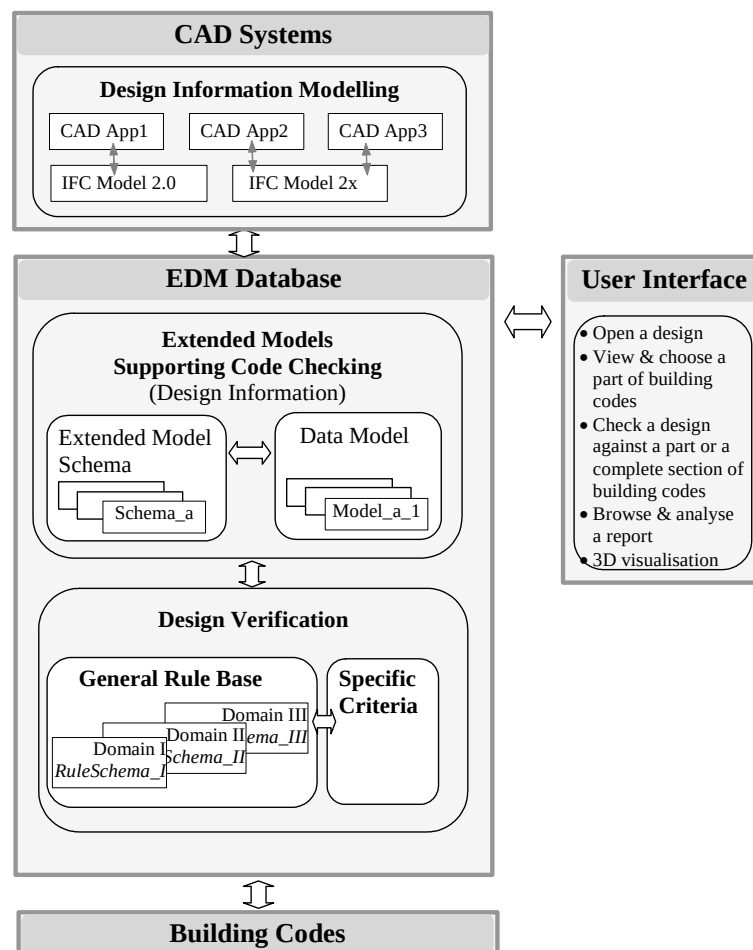


Figure 15. An illustration of the EDM approach for future development.

EDM's approach to the checking process will be improved through considering different levels of design checking in conjunction with different stages of design and different focuses on building objects or clauses of building codes.

6.3 POTENTIAL APPLICATIONS

This project can be applied in other potential areas in the construction industries. For example, when domain-specific knowledge in relation to project management or fire safety assessment is encoded to the EDM rule base, it can then be applied to check a building model against project management or fire risk analysis.

From this project, a prototype research for automated code checking has been completed. Future works will be towards improving the prototype for applications in AEC in Australia.

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PROCUREMENT AND RISK SHARING

Full Paper

SUSTAINABLE SUBURBS – THE DEVELOPER’S CHALLENGE

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ABSTRACT

As our cities expand, developers are transforming more and more land to create our suburbs of the future. Developers and government bodies have a golden opportunity to design suburbs that are not only great places to live, but also are environmentally sensitive and sustainable. This is a unique opportunity, as significant changes after development are constrained by the configuration of the subdivision, and then by the construction of the dwellings.

This paper explores some of these issues by presenting initial findings from the CRC-CI, Sustainable Subdivisions Project. The Project examines the drivers and barriers that land developers face when trying to achieve sustainable subdivisions. This paper will review the results from a series of industry interviews and workshops and explore possible ways forward. In addition, the possible effect on the way future land subdivision is managed and planned as a result of recent changes in the energy efficiency provisions of the Building Code of Australia will be explored.

This paper highlights problems that both builders and land developers may face through poor subdivision design. Finally an innovative program being driven by a major land developer will be introduced. The program aims to deliver over 400 energy and water efficient homes through a series of compulsory and voluntary schemes that the developer is designing, funding and implementing. This program is the first large-scale development in Australia that demonstrates how developers can help achieve environmentally sensitive and sustainable suburbs of the future.

Keywords: Subdivision, sustainable, orientation, energy efficiency ratings, regulations.

INTRODUCTION

As our cities expand, developers are transforming more and more land to create our suburbs of the future. Over the last year Australia has seen an 8.2% increase in the number of dwelling units approved (Australian Bureau of Statistics, 2004) although this increase is now slowing. This growth has been a boom for land developers with many finding that demand for land is exceeding that available and they have had to adopt lottery style methods for land sales. As a result of this buying frenzy it is perhaps understandable that factors such as environmental considerations and sustainability may be overlooked. However, developers and government have continued to pursue these areas resulting in new Australia wide energy efficiency regulations for residential buildings and the development of energy efficient housing projects and estates.

The new energy efficiency regulations within the Building Code of Australia (Australian Building Codes Board, 2003) require all houses to achieve a certain performance level, although these vary from state to state. Attaining the required Energy Efficiency Ratings (EER) and addressing other sustainability factors has been the responsibility of the designer. At present, designs are deemed to comply with the mandated requirements through the inclusion of specified construction requirements or through performance evaluation. With this focus on the construction, the role of the subdivision in this process has largely been ignored. However, the expectation is that regulations will continue to be toughened. For example, in Victoria, the present minimum EER rating of 4 (which also requires water efficiency measures) is set to increase to 5 Stars in July 2005. More stringent standards will mean that allotment size and orientation will become increasingly important.

In Queensland, the new dwelling trend is increasing at a faster rate than the Australian average. Indeed, the 2003 December quarter saw a 15.1% increase in dwelling commencements, the highest for nine years (Australian Bureau of Statistics, 2004a). Energy Efficiency Ratings on domestic dwellings only became mandatory in Queensland on 1 September 2003 (Australian Building Codes Board, 2003) and at present a minimum Star rating of 3.5 is required. The effect of this Standard has been to raise awareness of the issue of sustainability and developers, builders and consumers alike are looking for information and tools.

This paper explores some of these issues by presenting initial findings from the CRC-CI, Sustainable Subdivisions Project. The paper examines the drivers and barriers that land developers face when trying to achieve sustainable subdivisions and reviews the results from a series of industry interviews and explores possible ways forward. In addition, the possible effect on the way future land subdivision is managed and planned as a result of recent changes in the energy efficiency provisions of the Building Code of Australia is explored, and finally an innovative energy efficiency program being driven by a major land developer is introduced that demonstrates how industry can drive change.

TRADITIONAL SUB-DIVISIONS

To gain an understanding of the drivers and barriers considered important by land developers, the researchers undertook a series of interviews in Southeast Queensland (SEQ) (Mead and Wales 2004). Key informants were asked to discuss traditional subdivision design and then to address industry and market demand for sustainability practices. The original intention was to hold a number of workshops,

but following industry discussions this was changed to individual interviews as it was believed that this method would facilitate more open discussions. For this reason, the interview participants were not identified. In all, some twenty-two interviews were held with representatives from a range of government and industry associations, project and development managers, urban planners and designers from both large and small development companies, developers and marketing representatives. The following reviews the results from the key informant interviews.

YIELD

Not surprisingly, key informants overwhelmingly identified yield as the most important driver when configuring allotments within development sites. In greenfield developments, yield takes into account factors such as the;

- Cost of the initial site purchase,
- Projected return,
- Time necessary in which to gain the return, and
- Legislation, local mandates and regulations.

Development involves significant investment and the financial outlay and the projected timeframe for return are paramount. Where possible, staggered land settlement payments are tied to conditions and approvals. This effectively maximises the developer's liquidity and lessens the period between the period of financial outlay and return. Other factors affect yield, including location, topography, zoning requirements, allotment size, and market competition and consumer perceptions.

LOCATION

The location of the development site for market demand is of prime consideration. To make the development financially viable, the location of the site has to be perceived as attractive within the market. This is achieved in part through the associated services at, or near, the development site. While larger developers will provide amenities and facilities within master-planned community developments, those with less resources, or with smaller development sites, will use locations near existing 'draw cards', such as schools, child minding and shops.

TOPOGRAPHY

Topography is one of the physical elements of a site that most influences yield as it presents environmental and engineering constraints unique to each sub-division development. Topography can dictate the development layout - the steeper the terrain, the more constraints the site will impose on form of development that can occur. As a result, areas with gradual terrain are more desirable.

ZONING

The preference is for land that is self or code assessable. Although zoning can be changed, sites that are impact assessable and require community notification are avoided as they attract public attention. If objections are lodged with the local regulatory body, the delays to the development approval process can significantly reduce profit and may render the development economically unviable.

ALLOTMENT SIZE

Another issue related to zoning is local authority requirements that the developer provide low-density development while also providing services that cannot be easily supported by a low-density population. Other factors affecting density (or allotment size) include investors' financial viability factors, consumer requirements, expectations and affordability, the range of residential dwelling types available, and locational factors. However, increasingly, regulatory bodies are insisting on greater densities. While this provides greater opportunity for the developers to fund the required infrastructures, developers are also aware that the same residents who expect infrastructure and close proximity to ongoing services, often do not want their suburb to look overly dense.

COMPETITION

Competition between developers has played a significant role in how developments are subdivided. As an example, one developer may have 600m² allotments at \$180,000 each. Then to secure the market, a rival developer will sub-divide with 700m² allotments for a lesser price of \$175,000. Both are gambling on which alternative the market will support. In Queensland's recent development boom, competition has not been as critical. However, as developers discussed the downturn in recent months, it became apparent that competition would become more important and influence the manner in how a subdivision takes place.

AESTHETIC APPEAL

All informants discussed the aesthetic appeal of mature vegetation and landscaped their developments as a financial investment to compliment allotment sales. Even when all existing vegetation had been completely removed, it is normal practice to re-introduce vegetation for entry, procession and parkland appeal. Only two informants were including native plants for environmental benefit.

SUPPLY AND DEMAND

Traditionally, land developers supply a familiar product to a familiar market – that is the project home and land package. Sustainability has not been a factor and has only recently entered the process and usually as a result of a change in regulations. While the BCA requirements are universal, at present local government authority requirements vary from area to area, effectively allowing developers who are not prepared to alter their methods to 'leapfrog' to areas with fewer requirements. Fewer requirements translate to lower costs and consumers, especially first homebuyers, buy wherever they can maximise the return on their investment.

SUSTAINABLE SUB-DIVISIONS

Despite these dominant drivers, there are a growing number of proactive developers who are aware of sustainability issues, who engage sustainable principles in subdivision outlays and in construction, and promote this to their clients as being desirable. Some developers even go as far as providing environmental plans and site analysis recommending layout for a home suited to each specific site. These developers realise that pressure to develop sustainably is growing. They are also aware that as clients become more knowledgeable of sustainable principles, they will start demanding sustainable practices and these developers will be able to respond appropriately. However, even these interested and proactive developers identified numerous barriers that need to be overcome in order to achieve sustainable suburbs.

DEFINING SUSTAINABILITY

Sustainability is a complex issue that is open to numerous interpretations and definitions. What does the word 'sustainability' mean? How is the meaning interpreted in practice? How can it be measured? Who recognises the measures? While the long term cost of avoiding addressing the issue may be clear, in the short term, who pays? How can developers implement a concept that is not clearly defined, that most fear will involve additional financial outlay that the consumer may not want or be able to afford? In this sense, use of the word 'sustainability' is a significant barrier to its implementation.

SUSTAINABLE SUBDIVISIONS

It could be argued that it is impossible to have a truly sustainable suburb, as all subdivisions and suburbs consume finite resources. However a more pragmatic approach is to view sustainability as a method of actively reducing the impact that today's subdivisions - tomorrow's suburbs - have on the environment.

Within the development of subdivisions, there are numerous aspects related to sustainability, including environmental degradation, waste and pollutants, construction methods and materials and developer and consumer energy consumption and water use. To limit and focus the discussions, the interviews focused on energy use - specifically, the energy efficiency of dwellings as this is now incorporated into the BCA. To achieve the required EER and to predict how dwellings may perform in future, it is important to understand the relationship between subdivisional layouts and the energy efficiency of the dwelling.

MEASURING SUSTAINABILITY

The current 3.5 rating for residential construction in South-East Queensland can be met with no reliance on appropriate subdivision orientation. However in order to meet higher sustainability criterion, all informants commented on the need for tools or methodologies in both subdivision development and construction. Regulations were viewed as dictating the minimum standard required, but benchmarks are needed to enable developers so they know what they have to do, and how to do it – without losing any competitive edge in the market. A tool is needed that can measure design options of elements such as orientation, natural ventilation and light. This would enable all parties to understand what 'sustainability' covers, and how to measure it, within the level playing field of industry.

REGULATORY BARRIERS

At present, there is little reward for implementing sustainable principles within developments. Developers trying to incorporate sustainable innovation often find that it does not fit under the criteria of the local planning authorities that will then not approve the development application. Of the regulatory bodies interviewed, some were more receptive to sustainable initiatives, while others were not. For example, Figure 1 shows two subdivisional layouts. The layout on the right is regarded as the better for solar orientation. However, one regulatory body would not allow such hammerhead access, preferring the more familiar cul-de-sac layout shown on the left.

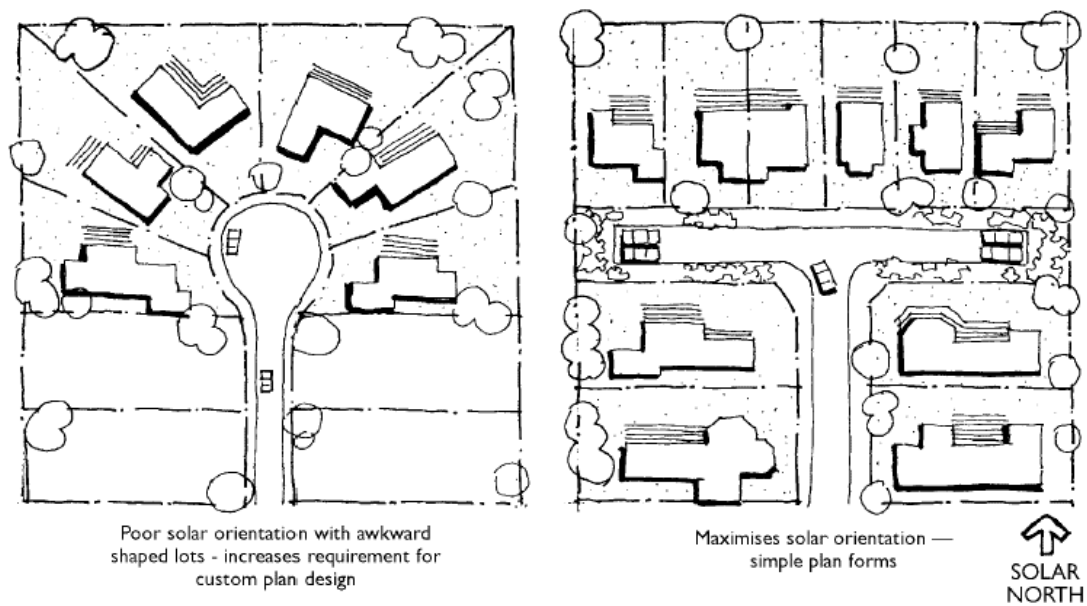


Figure 1 Maximising solar orientation in subdivisions. Source: (Commonwealth Department of Housing and Regional Development 1995).

Other regulatory barriers identified included the instance where a developer included water tanks and a sewage treatment system in their development, and then was not rewarded with reduction to land rates from local regulatory bodies for the provision of these services. Town plans often do not have any guidelines in place for 'innovative', 'sustainable' or a 'new' type of development and the development process does not take into account that innovative solutions are often untested. Consequently, the cautious nature of regulatory bodies can restrict innovation to avoid incurring the uncertainty of unknown maintenance and replacement costs. One developer summed this attitude with the statement: '(planning) regulations do not keep up with innovation'.

MARKET BARRIERS

Valuers also play a critical role. Valuers assess the value of a home on comparative residences in the immediate area, but do not take into account factors such as allotment orientation, or that a home with large eaves and access to natural light and breezes has on-going economic benefits. This has significant implications for financiers who will not recognise the additional costs involved and only finance homes to the valuers' assessments. Without market recognition, developers who finance and implement innovation that is not supported by the market are the first to be impacted upon. The second impact falls on the consumer, who has to pay for innovation without the support of a financier. Sustainable factors are effectively devalued.

DRIVING SUSTAINABLE DESIGN

Traditionally, the house buying public has looked to the builder as the expert when it comes to energy efficiency. However, with large estate developments, the land developer is also able to influence a client's buying habits. Consequently, these professions can have a significant influence on the decisions that homebuyers make.

Energy efficiency of dwellings is influenced by material choices, design layout and orientation. Subdivision design has little impact on material choice, but can affect design layout and impacts directly on orientation. Correct solar orientation of a dwelling will help in maximising winter sun penetration and minimising solar gain in summer. Poorly orientated blocks make achieving these results difficult. This is especially true for project homes that typically have limited scope for design changes.

RATING SUBDIVISION LAYOUTS

As has been noted, a methodology for rating sustainability within subdivisions is required. A rating methodology was developed several years ago by Sustainable Energy Authority of Victoria and was later modified by Sustainable Energy Development Authority (SEDA 2003). The Sustainable Subdivisions project is looking at the appropriateness of adopting this rating scheme for SEQ.

The SEDA methodology is a simple three-step process;

1. Determine the orientation of an allotment along its long boundary. To achieve the highest rating of 5 Stars, the long boundary must be oriented so that one axis is within 30° east and 20° west of true solar north, as shown in Figure 2. Allotments outside these orientations receive a 1 Star rating.
2. Determine the width of the block by measuring at right angles to the long axis. East/west allotments have a greater width requirement than north/south allotments to allow for set back of the dwelling along the northern boundary.
3. Determine the star rating by finding which width band an allotment falls into. The allotments are rated on their ability to accommodate a dwelling with good solar access. Corrections can be made to allow for the slope of the allotment, which will either improve or hinder solar access. Allotments with a slope in excess of 20% receive a 1 Star rating. Concessions are made for allotments that have guaranteed open space to the north or are larger than 1000m^2 .

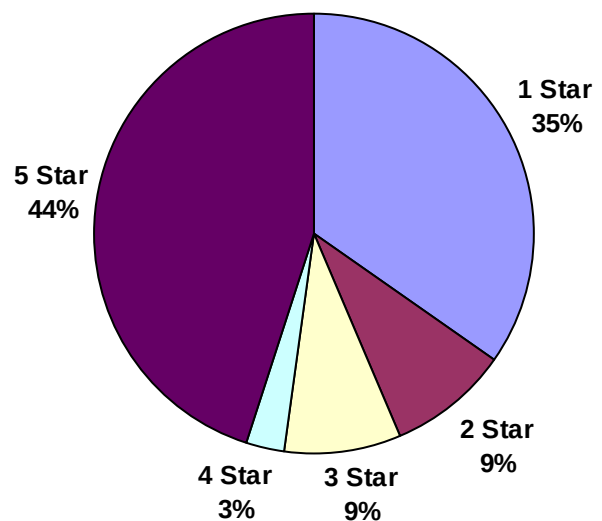
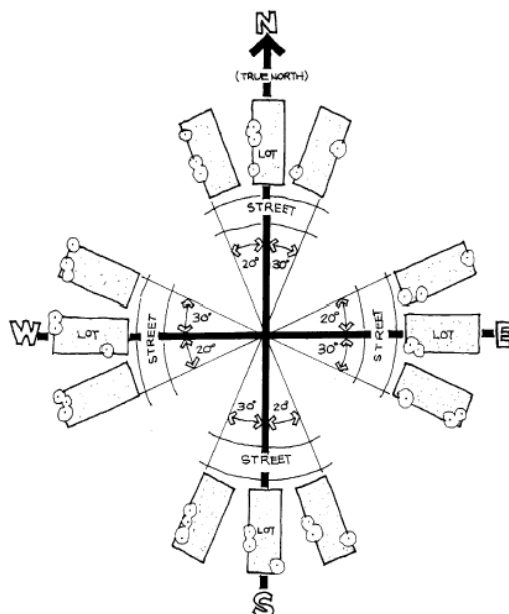


Figure 2 Preferred orientations of allotment.

Figure 3 Trial rating of subdivision

Source: (Commonwealth Department of Housing and Regional Development 1995))

An initial trial of this methodology has been undertaken on a new subdivision in SEQ. Of the 69 allotments surveyed, 35% of allotments within the subdivision rated at one star, while 44% rated at the maximum 5 Star (Figure 3). SEDA in their design guidelines, aim for performance criteria of at least 80% of allotments rating 5 stars with the remainder rating either 4 or 3 stars. The initial findings suggest that current subdivision practice is falling well short of the mark.

DEVELOPERS DRIVING INNOVATION

Despite the barriers that exist for the uptake of sustainable development, some developers are still keen to trial innovative ideas and encourage their clients to adopt many of the principles of sustainability. One such development is Sanctuary Pocket, a 400 home site, 33-hectare village located 20kms west of the Brisbane's Central Business District. The development will require homeowners to include specified energy and water-saving features into their homes. In return, each block sold will come with a pre-negotiated arrangement for the supply of a solar hot water system and a rainwater tank (Delfin, 2004). Residents must demonstrate the inclusion of these (or other) systems and also select a minimum of six additional energy and six water saving devices from a range suggested by the developer. Energy choices cover orientation, increasing ventilation, limiting low-efficiency lighting and improved insulation while water saving choices include irrigation control devices, AAA rated shower roses, mixer taps, pervious areas for car washing and gutter guards for increased flow to the rainwater tanks. The developer acknowledges that many of the other features are relatively standard inclusions. The intent is to make features considered to be desirable from a sustainable point of view and readily identifiable and clearly linked to a range of benefits. Residents will also be eligible for a discounted home loan rate that has been negotiated by the developer.

The developer estimates that the 400 homes built will save 1,740 tonnes of greenhouse gas emissions per year (the equivalent to taking 350 cars off the road) and 108 million litres of water per year. The developer is also running workshops for home owners and builders to improve design and orientation for a better performing home and sponsoring builders to undertake accredited sustainability courses through a local industry association.

Brisbane City Council is using the development as their first Trial Rainwater Tank Community in Brisbane, which will determine the viability of rainwater tanks in urban environments. This development provides a case study of collaboration between developer, builders, product suppliers, local authorities and financiers to include a series of compulsory and voluntary features to encourage a higher level of sustainable development that is consistent throughout the entire development.

The first allotments were released for sale in March and by the end of May; around a third of had been sold indicating that consumers are responding to the concept. The developer is considering including covenants that require solar hot water and water tanks as benchmark for all future releases. However the developer is closely monitoring consumer choices to ensure that it is the sustainable features and not just the rate of development in SEQ that is fuelling the sales.

CONCLUSIONS

Although the momentum towards energy efficiency is slow, it is multi-directional, encompassing elements such as energy and water. However, the industry representatives interviewed believe it is only a matter of time before momentum builds, and increased sustainable energy efficiency becomes the standard. To encourage this growth, there are several key areas that need to be taken into consideration.

- Required and desired sustainability practices need to be clearly articulated and consistent to retain the competitive nature of industry. There is a need for collaboration between local authorities, agencies, developers and consumers – to share a vision that is of benefit all parties
- Where possible, incentives need to be introduced into the industry to make sustainable practices more attractive to the developers, suppliers and the homeowners, as well as emphasise the importance of the practice.
- Tools that measure energy efficiency need to be site specific, apply to the whole of industry, and take into account factors such as orientation, adjacent built forms, deciduous and evergreen vegetation, and a broad range of construction materials.
- Sustainable practices in development need to be recognised by the valuation and financial industry to overcome the financial barrier.
- There is a need for research to demonstrate that new and innovative models of sustainable development are more affordable than traditional models of development.

Regardless of these challenges, some developers are leading the way and demonstrating how sustainable suburbs can be incorporated into the current marketplace. Developments such as Sanctuary Pocket are acting as real world examples of what can be achieved and are providing the necessary driver that will enable large-scale adoption by the industry of sustainability practices in subdivision developments.

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CONFERENCE THEME: INNOVATIVE ASSET MANAGEMENT

Full Paper

IMPROVING THE MANAGEMENT OF BUILDING LIFE CYCLE: A DATA MINING APPROACH

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ABSTRACT

The construction industry has adapted information technology in its processes in terms of computer aided design and drafting, construction documentation and maintenance. The data generated within the construction industry has become increasingly overwhelming. Data mining is a sophisticated data search capability that uses classification algorithms to discover patterns and correlations within a large volume of data. This paper presents the selection and application of data mining techniques on maintenance data of buildings. The results of applying such techniques and potential benefits of utilising their results to identify useful patterns of knowledge and correlations to support decision making of improving the management of building life cycle are presented and discussed.

Keywords: Building Life Cycle, Data Mining, Management

1. INTRODUCTION

The construction industry has adapted information technology in its processes in terms of computer aided design and drafting, construction documentation and maintenance. The data generated within the construction industry has become increasingly overwhelming. The growth of many business, government, and scientific databases has begun to far outpace our ability to interpret and digest this data. This issue becomes critical when the high degree of complexity of work flow is taken into account in the decision making process during the lifetime of a building. Furthermore, past experience often plays an important role in building management. Therefore, applying data analytic techniques to efficiently deal with information at different stages of a building life cycle has the potential to improve the maintenance management of building assets. Traditional methods of data analysis such as spreadsheets and ad-hoc queries are not adequate since they can only create informative reports from data, but can not analyse the contents of these reports. Hence, there is a significant need for a new generation of techniques and tools with the ability to automatically assist humans in analysing a large amount of data to provide useful knowledge within the construction industry. The increasing use of databases to store information about facilities, their use and maintenance provides a platform for the use of data mining techniques. Knowledge Discovery in Databases (KDD) and Data Mining (DM) are tools that allow identification of valid, useful, and previously unknown patterns so that building managers can analyse a large amount of project data. These technologies combine techniques from the areas of machine learning, artificial intelligence, pattern recognition, statistics, databases, and visualisation to automatically extract concepts, interrelationships, and patterns of knowledge of interest from large databases.

The work in this paper is motivated by several observations of the current situation in the building industry. The design of new buildings and facilities tends to focus on short-term cost and immediate needs of the building owner to meet a set of business and functional requirements. Current technologies such as Computer-Aided Design (CAD) have focussed on the needs of designers to develop designs without giving much attention to the management of the life cycle of buildings. Current information technology applied to facility maintenance utilises databases to keep track of information and notification of maintenance schedules. However, these databases are not well linked with interactive 3D models of buildings and are mostly presented in tabular formats.

Applying data mining techniques to the records of existing facilities has the potential to improve the management and maintenance of existing facilities and the design of new facilities. This will lead to more efficient and effective facilities maintenance and management through better planning based on models developed from available maintenance data, resulting in a more economical life cycle of buildings. Furthermore, designers and maintenance managers will be better equipped to achieve higher performance by utilising appropriate techniques of information technology at their workplace.

This paper presents the selection and application of data mining techniques on maintenance data of buildings. The paper addresses potential benefits of applying such techniques to identify useful patterns of knowledge and correlations within the existing building maintenance data to support improving the management of future maintenance operations.

2. INCORPORATING DATA MINING INTO BUILDING LIFE CYCLE

Building systems should always be available to support building functions. The maintenance objective for a building is that the cost of any maintenance activity should be less than the expected marginal value of production enabled by the planned activity. To support this objective, it is essential to tackle the maintenance from multiple facets including interpretation of observed data, diagnosis of problems, planning repair and maintenance, and business evaluation of the value-added from different repair and maintenance options.

Past experience often plays an important role in building management. “How often will this asset need repair?” or “How much time is this repair going to take?” are the types of questions that project managers face daily in their planning activities. Failure or success in developing good schedules, budgets and other project management tasks depends on the project manager's ability to obtain reliable information in order to be able to answer these types of questions. Other aspects of building management include improving available scheduling algorithms, estimating spreadsheets and other project management tools. However, even with the best of such tools, low quality input information will produce inaccurate output of schedules and budget.

Data mining, as an extraction of implicit, previously unknown, and potentially useful information from data (Frawley et al, 1992) provides useful tools that help to explain how building systems that were once thought to be completely chaotic have predictable patterns (Peitgen et al, 1992). By applying data mining to identify novel patterns, project managers will be able to build knowledge models that may be used for the recurrent activities of on-going building projects, and activities of future projects to avoid unanticipated consequences (Soibelman and Kim, 2002). Data mining presents a significant potential for addressing the problem of transforming knowledge implicit in data into explicit knowledge for decision makers.

2.1 A DATA MINING APPROACH FOR BUILDING LIFE CYCLE

The approach, presented in this paper, views the process of building design, maintenance, and replacement as a process that generates high volumes of information. While current practices address only parts of this information generation and management, this approach attempts to account for the life cycle flow of this information. The cost of designing and building structures can be much smaller than the costs of operating a building or other structure over the course of its life span. Data mining enables building owners, designers and facility managers to make important decisions about the building life cycle cost in advance, thereby significantly affecting and improving design decisions.

The rich set of building data generated or accumulated during the design and documentation phases of buildings remains relevant even after the building is constructed. Building data becomes richer as maintenance data is included and updated regularly. Architects, interiors designers, engineers, contractors, marketing and sales personnel, building managers and owners can extract useful information from the databases for building renovation, maintenance, and operation. Figure 1 illustrates a proposed model of the information flow in building design and maintenance. The bold arrows depict the new functions provided in this model while the dashed arrows present current approaches to building information management.

The integration of data mining within the process of information flow provides the opportunity to increase the value of building data and to feedback and improve the processes of building design and maintenance.

Data mining techniques can be used effectively on data stored in a Building Maintenance System (BMS) by extracting useful knowledge that can be used for future management and design decision making. Knowledge that implicitly resides in BMS databases and corresponds to Figure 1 includes:

- Components that frequently need maintenance and therefore need to be inspected carefully.
- Historical consequences of maintenance decisions that may inform future decisions.
- Components of buildings that significantly determine maintenance cost and therefore may inform future building designs, as well as refurbishment of the building in question.

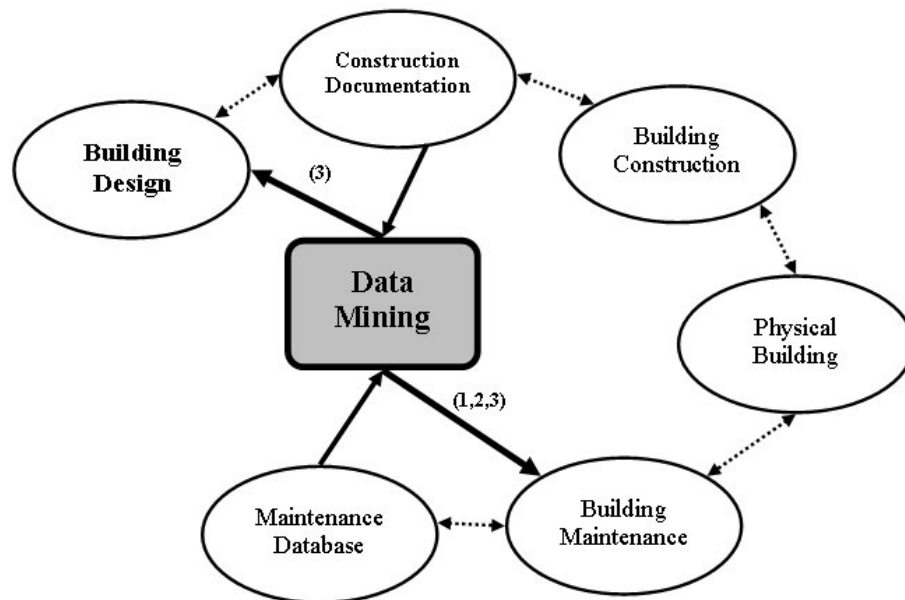


Figure 1. Integrating data mining within the life cycle of buildings.

It has been shown in the AEC (Architecture, Engineering and Construction) industry that major factors contributing to construction quality problems include inadequate information and poor communication (Burait et al, 1992; Arditi and Gunaydin, 1998). The detection of previously undiscovered patterns in BMS data can be used to determine factors such as cost effectiveness and expected failure rate of assorted building materials or equipment in varying environments and circumstances. These factors are important throughout the life cycle of a building, and such information could be used in the design, construction, refurbishment, and maintenance of a building, representing a substantial decrease in cost and increase in reliability. Such knowledge is significant for saving resources in construction projects. In order to examine the feasibility of the proposed approach, a prototype of the data mining system has been developed and tested using an industry building maintenance database.

2.2 DATA MINING PROCESS

Data mining involves going from problem specification to the implementation of tools, and monitoring of the model. Successful data mining requires several collaborative expertises such as; subject area expertise, data expertise, and data analysis expertise. Data mining is an explorative process since new knowledge is discovered and new hypotheses can be formed. The data mining process for extracting hidden knowledge from large databases can be depicted as shown in Figure 2. The process focuses on finding interesting patterns that can be interpreted as useful knowledge and consists of seven steps (Hui and Jha, 2000).

- Establishing the mining goals. This involves the understanding of building maintenance process and its acquired database.
- Selection of data. This step identifies a subset of variables or data samples, on which mining can be performed. There are many tables in the database not all of which are suitable for mining since they are not sufficiently rich.
- Data pre-processing. This step aims to remove the noisy, erroneous and incomplete data. The presence of too many different categories of data makes visualisation of the displayed information very difficult. Hence, those categories with only a few records are eliminated. Moreover, all the records with missing values are deleted to avoid potential problems in visualisation. Since the proportion of such records is normally quite small, their deletion will have little effect on the results.
- Data transformation. The data stored in the various tables are required to be in a specified format. Sometimes, it is useful to transform the data into a new format in order to mine additional information.
- Data warehousing. Data warehousing is the process of visioning, planning, building, using, managing, maintaining and enhancing databases. The data suitable for mining are collected from various tables of customer service database and stored in WEKA's data warehouse. WEKA is a collection of machine learning algorithms for solving real-world data mining problems. The algorithms can either be applied directly to a dataset or called from your own Java code. WEKA not only contains tools for data pre-processing, classification, regression, clustering, association rules, and visualisation, but is also suitable for developing new machine learning schemes.
- Data mining. WEKA is used to perform the data mining functions, including summarisation, association, classification, prediction and clustering.
- Evaluating the mining results. The information obtained is analysed.

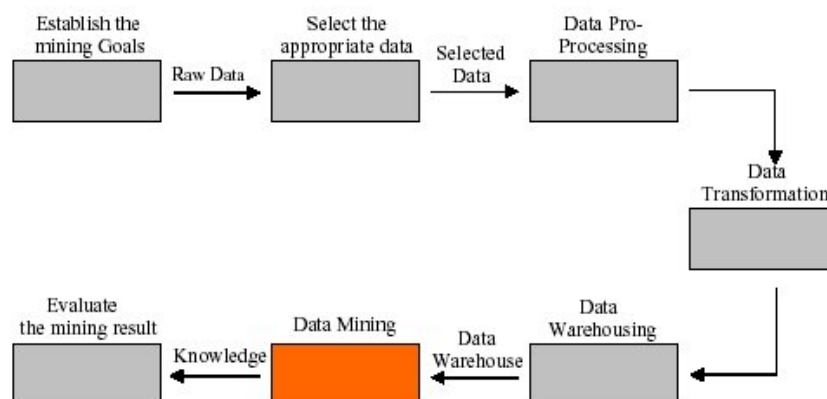


Figure 2. Stages of data mining process.

3. APPLYING DATA MINING TECHNIQUES ON INDUSTRY MAINTENANCE DATA

The maintenance data in this paper is provided by the Engineering Division of the Central Sydney Area Health Service (CSAHS) for one of their hospital buildings. This building is a five-storey building and referred to here as Building 10. Maintenance data for the last two and a half years is available in SQL format and contains data that is highly detailed and structured. There are approximately 5,000 work orders recorded for Building 10 in the period from 1 January 2001 to 9 December 2002.

3.1 DATA MINING USING VISUAL ANALYSIS APPROACH (STACKED HISTOGRAM)

In a histogram, data is collected and sorted into categories. Histograms focus on the frequencies and distributions of one particular attribute, for example, the Priority description for the entire data set is illustrated in Figure 3 wherein the High Priority is 49 instances; Medium Priority is 48 instances and Low Priority is 10 instances. Therefore the figure does not illustrate percentages but rather no. of instances. In order to find out correlations between various attributes, there is a need of an interactive visualisation rather than a static view of histogram.

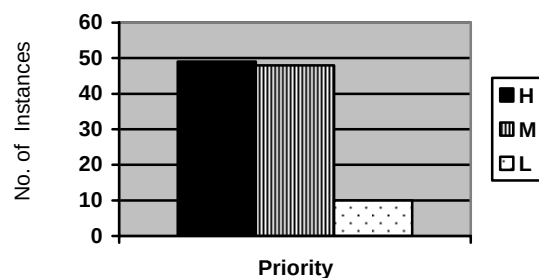


Figure 3. A standard histogram of the “Priority” attribute.

WEKA incorporates a stacked histogram which allows three judgments: (i) the trends on the total height of the columns, (ii) the proportion of each category within each column and (iii) the trends in the lowest category (Dix and Ellis, 1998). This interactive stacked histogram solves the problem of cross comparison of standard histogram by allowing different trends to be analysed using the same graph. Thus, the correlation between attribute “priority” and “cause-of-repair” can be visualised as shown in Figure 4. A rule can be learned from this interactive stacked histogram, that is about 94% of A/C (Air/Condition) malfunction belongs to high or medium priority jobs.

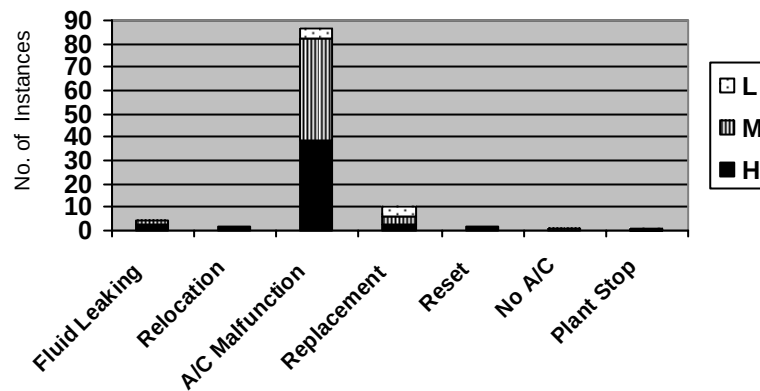


Figure 4. A stacked histogram of correlation between “Priority” and “Cause-of-repair”.

A number of rules were generated by analysing the correlations between various attributes using WEKA's stacked histograms function. Stacked histogram is capable of handling both numeric and nominal attributes, but it does not perform well in analysing date and continuous numeric values.

3.2 DATA MINING USING THE CLUSTERING ALGORITHM

Clustering techniques are applied when there is no class to be predicted but rather when the instances are to be divided into natural groups (Witten and Frank, 2000). Based on a number of trials with all available clustering algorithms provided by WEKA, it was found that the classic SimpleKmeans which employs the K-means algorithm generates meaningful clusters. This clustering method is effective in generating similar collections that simplify the representation of data sets. Simplification plays a significant role especially with very large scale of data with multi-dimensional attributes. From a practical perspective, the clustering algorithm can help to identify the critical attributes in a multi-dimensional space. For example, applying this data mining technique of clustering using SimpleKmeans on available industrial data, the data set was found to be divided into two clusters centred at two major types of A/C malfunction: too_hot in March, and too_cold in January with an approximately even distribution around 50% as shown in Figure 5. This is potential knowledge which could be used to guide future maintenance and building management. However, K-means have proven to be one of the most popular clustering algorithms because of its simplicity and effectiveness, it is time-consuming for relatively massive data sets due to the numbers of iterations involved in the process of clustering.

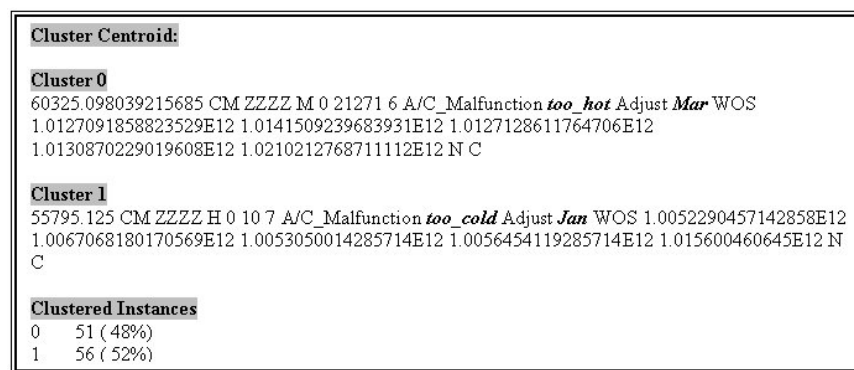


Figure 5. A clustering result generated from applying the SimpleKmeans algorithm on the maintenance data of Building 10.

3.3 DATA MINING USING THE CLASSIFICATION TREE ALGORITHM

A decision tree is a tree-based knowledge representation methodology used to present classification rules. The leaf nodes present class labels. Various classification algorithms offered by WEKA have been applied and it was found that several algorithms were not able to deal with the maintenance data sets available due to some limitation in processing certain data types. For instance, some algorithms were not able to accommodate numeric values while others failed to accommodate nominal variables. The C4.5 algorithm (built on the top of ID3 proposed by Quinlan (1993), was selected because of its ability to deal with numeric and nominal variables, and to handle missing values and pruning. The latter can be done by replacing a whole sub-tree by a leaf node if the expected error rate in the sub-tree of a rule obtained is greater than it in the single leaf.

The C4.5 algorithm generates a classification-decision tree for a given data-set by recursive partitioning of data. Once the tree is constructed, rules can be generated by traversing each branch of the tree and collecting the conditions at each branch of the decision tree. For an instance, the rules associated with decision tree from applying C4.5 on the “month” attribute of “thermo static mixing valve” on the maintenance data of Building 10 is described in Figure 6. All monthly high priority maintenance works were carried out in the later part of the year, July to November. All 6 monthly maintenance works happen to be in December.

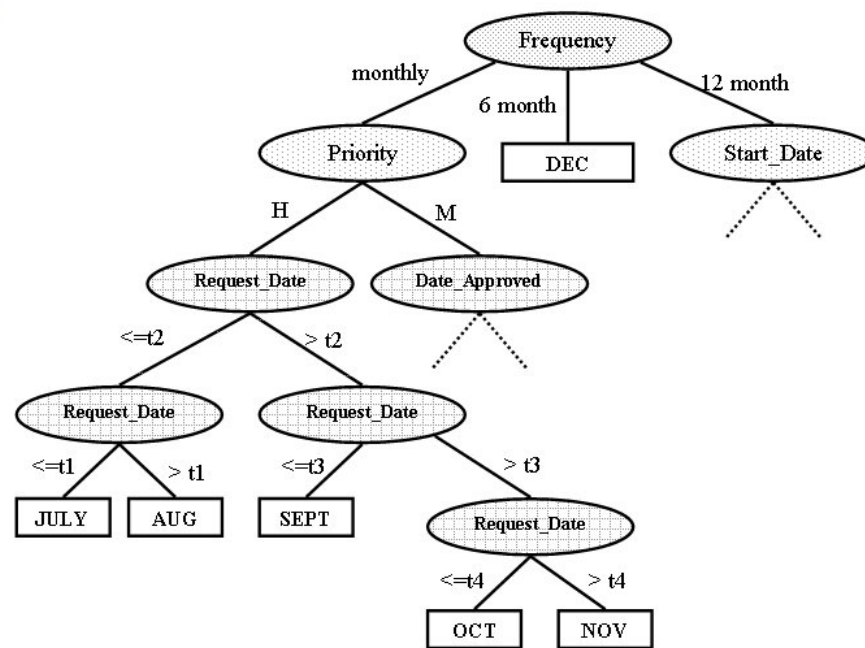


Figure 6. Part of decision tree generated from C4.5 on the “month” attribute (where $t1 < t2 < t3 < t4$)

C4.5 is a powerful classifier that is robust to noise but its performance relies on the data sets on which it runs. For instance, C4.5 is applied to the maintenance data of air handling units of Building 10 in which some attributes have unchanged values, such as “job_subtype” with 105 “zzzz” out of 107 and “workorder_status” with 105 “C” out of 107. The performance of the classifier was not that effective and its results were less meaningful.

3.4 DATA MINING USING THE ASSOCIATION RULE

The association rule technique involves finding frequent patterns, associations, correlations, or causal structures among sets of items or objects in transaction databases, relational databases, and other information repositories (Han and Kamber, 2001). The association rule algorithm adopted in WEKA is “Apriori” which is developed by IBM’s Quest project team. Apriori finds all associations that satisfy a set of criteria with minimum support and minimum confidence. Support (also called coverage) refers to the number of instances predicted correctly. Confidence (also called accuracy) is the proportion of the number of instances that a rule is correctly applied to them (Witten and Frank, 2000). Rules with high support are of interest and some rules are pruned out due to their low coverage. The basic idea of Apriori is to generate item sets that are combinations of attribute-value pairs with the minimum coverage. Apriori is efficient in searching the associations and correlations between attributes. However, to avoid having a great number of less meaningful rules, there is a need to filter out all irrelevant attributes and find the groups of correlated attributes prior to applying the algorithm. WEKA provides an attribute evaluator in which some search methods such as the “BestFirst” can be used to sort out groups of correlated attributes. After applying this filtering process on the available maintenance data of the Air Handling Units at Building 10, the association rule algorithm “Apriori” was later applied and meaningful relational rules were obtained. Some of these rules include: “for floor 5, 6, 7, workOrder_Status was always completed”; “for all too_hot and too_cold descriptions, workOrder_Status was completed”; and “all works in floor 7 and in department 26462 belongs to A/C

malfunction". Unfortunately, "Apriori" deals only with nominal attribute values. Numeric, date, string data types are not applicable to most of the associative rule algorithms.

4. POTENTIAL BENEFITS OF UTILISING DATA MINING TECHNIQUES TO IMPROVE THE MANAGEMENT OF BUILDING LIFE CYCLE

Visual data analysis and data mining techniques were applied on two selected data sets: air handling units and thermostatic mixing valves at Building 10, Royal Prince Alfred Hospital, Central Sydney Area Health Service. The evaluation of the results obtained from mining the maintenance data of the above two asset types and their potential benefits on improving the maintenance of existing buildings and the design of future facilities are shown in Tables 1 and 2.

Table 1. Applying data mining techniques on maintenance data of air handling units and potential benefits of improving the maintenance management during its life cycle.

Data Mining Technique	Acquired rules	Potential benefits on improving the management of building life cycle
Visual Analysis	Approximately all "A/C malfunction" belongs to high and medium priority.	A/C malfunction" is of a major concern in guiding the allocation of maintenance resources.
	"A/C malfunction" is concentrated on the problems of: <i>too_hot</i> 32%, <i>too_cold</i> 28%, <i>not_working</i> 7.5%.	Temperature should be automatically adjusted and a provision of self-reporting faults equipments should be considered.
	The lowest levels of "A/C malfunction" took place in August followed by June and April while other months share similar high rate of "A/C malfunction".	Correlations between seasons and malfunction rates should be considered in guiding maintenance resource allocation.
	The maintenance work at 4, 5, 6, 7 th floor constitutes most of the reports of A/C malfunctions, with 86% of A/C malfunction reported from these floors.	
	Approximately all the descriptions of <i>too_cold</i> or <i>too_hot</i> were associated with high or medium priority.	The appropriate temperature is of high priority from users' perspective.
Visual Analysis + Association Rule Algorithm	All 7 th floor jobs were of high and medium priority and the cause of repairing was "A/C malfunction".	Investigate the possibility of poor design or maintenance of air conditioning function in 7 th floor. A special attention in the design should be given to a specific floor due to its high demand of corrective or preventive maintenance or special design of A/C.

Visual Analysis	Higher percentage of user dissatisfaction in terms of work completed not meeting expectations is associated with maintenance work of high and medium priority.	Seeking feedback from users is important in order to improve the efficiency of building maintenance and achieving user satisfaction.
	Higher level of unhappiness related to completion not meeting expectation with a focus at <i>too_hot</i> and <i>too_cold</i> adjustment activities.	Paying attention to temperature adjustment in maintenance and design phrase may improve users' happiness.
	Cost centre 0 has the highest percentage of maintenance not meeting expectations (44%)	A special attention should be directed to certain places in the building wherein maintenance work is more likely to consume more time and effort than expected compared to normal places.
Decision Tree Algorithm –C4.5, Association Rule Algorithm	Department 26462 only reports A/C malfunction. (all 18 cases)	A special attention should be directed to certain places in the building wherein maintenance work is required more often.
	96% jobs for cost_centre = 0 is CM (corrective maintenance).	
Association Rule Algorithm	For floors 5, 6 and 7, the workOrder_Status was always completed.	Benefiting from successful maintenance practices including both equipments and labour is useful to achieve a high level of an overall maintenance performance.

Table 2. Applying data mining techniques on maintenance data of thermostatic mixing valves and potential benefits of improving the maintenance management during its life cycle.

Data Mining Technique	Rules Obtained	Potential Impact on Facility Maintenance and Design
Visual Analysis	The percentage of high priority work constitutes of 55% of monthly work, 22% of 6mthly work and 24% of 12mthly work.	These percentages should direct the allocation of maintenance resources at the appropriate time of the year to achieve better planning and scheduling of maintenance work.
Analysis + Decision Tree Algorithm	12mthly work occurred during the middle of the year – June-Sept, while all 6mthly occurred in December.	
Visual Analysis	All outstanding works took place in December	The 6mthly maintenance work should be thoroughly analysed to identify the actual reasons of incompleteness.
	All monthly and 12mthly works were completed. Parts of 6mthly works (50%) were outstanding.	
	All high priority works were did not meet the expected completion date.	Maintenance job required with high priority should be investigated in relation to maintenance labour and the practicality of initial expected date of completion that has not been met.
	All works between August and December did not meet the completion data.	
	All medium priority works were completed on the expected completion data.	Analyse this phenomenon to help identifying the deficiency of not meeting the expected completion with high priority works.
Decision Tree Algorithm (C4.5)	All monthly high priority works are carried out in the later part of the year – July to November.	Distribution of priority of maintenance work is important in planning and scheduling maintenance work and resources.
Association Rule Algorithm	There is an incremental relationship between the work priority, the estimated time to complete the work and associated budget.	A better planning and scheduling will help to advance this pattern of relationship.

5. DISCUSSION

Facility managers and building owners are more concerned with highlighting areas of existing or potential maintenance problems in order to be able to improve the building performance, satisfy occupants and minimise the operational cost of maintenance. Applying data mining techniques on the available industrial maintenance data has helped to discover useful rules that allowed locating some critical issues that have substantial impact on improving the management of building life cycle.

The distribution of useful rules extracted from applying data mining techniques on two data sets of Building 10 is shown in Figure 7. The outcomes of applying data mining on industrial maintenance data can be enriched by including cost-related information and complete description of the task carried out on site and cause of repair.

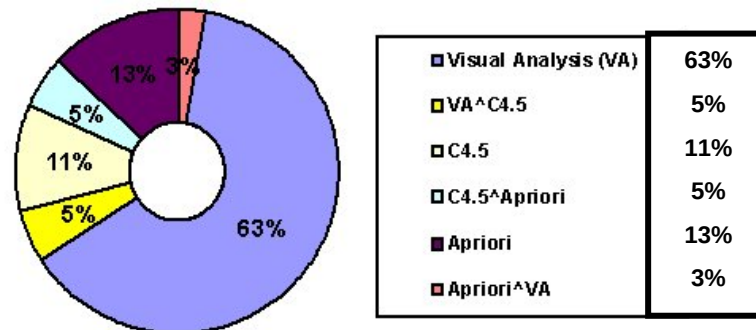


Figure 7. Percentages of rules extracted using various data mining techniques applied on Building 10.

Data mining techniques assisted in identifying critical cost issues. For instance, discovering that corrective maintenance accounts for approximately 55% of all work orders implies a high level of unplanned maintenance that contributes to increasing the operational cost. The maintenance services required for the air conditioning system were related to thermal sensation complaints (too_hot 32%, too_cold 28%, not working 7.5%; total 67.5%). Federspiel (1998) found that thermal sensation complaints in buildings account for 75% of all environmental complaints from occupants and estimated that the labour cost associated with HVAC maintenance could be decreased by 20% by reducing the frequency of thermal sensation complaints that cost \$2 billion annually in the U.S. (Martin et al, 2002). The “cost of discomfort” or “unsolicited complaints” is associated to increasing the operational cost of buildings due to the unexpected maintenance service (Federspiel, 2003). Hence, applying data mining techniques assists facility and building managers to identify the crucial maintenance issues and directs the improvement of strategic planning to add value to the life cycle of buildings.

Other benefits include constructing predictive plans based on correlations obtained from applying data mining techniques on the maintenance data sets of buildings. For instance, considering the role of potential correlations between seasons and malfunction rates in guiding the allocation of maintenance resources. Also, investigating any abnormal phenomenon discovered from the maintenance data set such as “all outstanding works took place in December”. An investigation is required to study the relationship between the cause of increasing the outstanding maintenance jobs taking place in December the Christmas holiday or any the other causes. Appropriately addressing this problem will lead to better activities to improve the maintenance management of existing facilities and will guide the design of future facilities.

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INTERNATIONAL INNOVATION

Full Paper

IMPLEMENTING INNOVATION ON COMMERCIAL BUILDING PROJECTS IN AUSTRALIA

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ABSTRACT

Since the 1950s, economic theory has highlighted the 'central importance of technological progress for maintaining long-term, continuous increases in real national income per head' (Hall 2003, 498). Empirical work since that time has reinforced the importance of innovation to industry growth and national economic welfare. Hence, innovation can be considered a key means of improving construction industry performance. Yet, a recent study of efficiency improvement in construction reminds us that the industry has yet to embrace the value of innovation (Yiu et al 2004). That this is particularly so in the Australian context is evidenced by the findings of the recent Cole Royal Commission (2002b).

The industry in Australia and globally is slow to embrace change and there are powerful cultural reasons why this is so. The reason addressed by this paper is concern by industry participants about the risks associated with innovation and lack of information about appropriate implementation strategies. In order to improve this situation the key players and dynamics behind successful implementation of innovation are explored here.

The paper is based on three innovation case studies in the Australian commercial building industry undertaken in 2003. Each case involves innovation undertaken on a commercial building project by clients, contractors, consultants and/or suppliers.

The paper reviews the industry's performance in Australia, before outlining the methodology and conceptual framework. Data from the case studies is then described and analysed. The evidence presented points to four key participants

driving innovation processes; clients, regulators, technical service providers and consultants.

Keywords: innovation processes, client-driven innovation, regulators, technical support providers, consultants, Australian commercial building industry

INTRODUCTION

This paper addresses the research question 'who are the key players in implementing innovation on Australian commercial building projects and what roles do they play?' The aim of this paper is to demonstrate the nature of successful innovation implementation processes in this context. The paper makes an original contribution to the literature by examining the roles of project participants in project-based innovation, in the Australian commercial building context. The need for the study arose from widespread evidence of poor performance in the sector in Australia and globally (Gyles 1992, Egan 1998, Cole 2002a), and local evidence suggesting that many industry participants, particularly SMEs, were unsure about how to go about implementing innovation (Manley and Blayse 2003). This evidence about innovation is concerning, given the established links between innovation and economic growth (OECD 2000). This relationship exists regardless of whether the innovation is an original development, or whether it involves the adoption of best practice, which already exists, but is new to the adopting firm.

Historically, there have been few incentives for the construction industry to undertake innovation, due to the absence of strong competitive forces (Seaden 1996, 1). However, since the 1990s the industry has been under increasing pressure to improve efficiency and effectiveness. The drivers of industry improvement that emerged last decade still apply pressure today. These include the emergence of more demanding clients as public sector resources decline; the challenges of increasingly global competition; and the demands of strict environmental legislation (Seaden 1996, 3). In Australia, as in other developed countries (particularly the UK), significant government programs have been introduced to remove the obstacles to industry growth. Since the Gyles Royal Commission in 1992, considerable attention has been paid to improving the industry's performance. This culminated in a partnership between the Commonwealth Government and the industry to develop an Action Agenda, with government funding of \$3.6 million devoted to a comprehensive suite of initiatives to promote industry growth. These activities ran between 1999 and 2002 and an evaluation of the program in 2004 found that innovation performance had improved, but that better outcomes were possible given a better demonstration and diffusion effort (DISR 2004, 2-3). The current paper responds to the opportunity to further improve innovation outcomes revealed by the evaluation.

Despite the contributions of a range of authors on the broad topic of innovation success factors (eg. van der Panne et al 2003, Gann 2001, Winch 1998), there remained an opportunity to extend the literature by exploring different types of participants as innovation implementation drivers on Australian commercial building projects.

Perhaps the most relevant academic work to the current study is Ling (2003), Slaughter (2000) and Gann and Salter (1998). Ling's (2003) study is a quantitative study of the factors that support innovation benefits. The case study work undertaken here helps to flesh out her results and provides a different focus by examining the roles of particular types of project participants.

Slaughter (2000) conceptualises the implementation stages for construction innovation, as a component of a business's innovation strategy. The current study adopts a broader approach by looking beyond intra-firm processes to examine innovation as the result of inter-organisational relationships. This builds on recognition of the collective nature of innovation process generally (Manley 2003)

and the project-based nature of production in the building industry (Gann and Salter 1998). Gann and Salter (1998) provide a useful framework for mapping participants and dynamics as part of an innovation system, which forms the conceptual background for the present study.

METHODOLOGY

A case program was adopted to determine the types of participants in the industry who were most active in driving effective implementation of Australian commercial building innovations. The resources available to the program dictated that three case studies in this sector could be undertaken over nine months, between April and December 2003.

The case studies were nominated by industry partners associated with the research. The industry partners comprised key repeat clients and key consultants. The case studies they nominated were considered best-practice examples of innovation. Only examples with measured benefits from innovation were eligible for inclusion in the program. The innovation examples showing the greatest benefit to a construction project were selected for study. The examples covered innovation arising from the contractor, consultant, client and supplier sub-sectors.

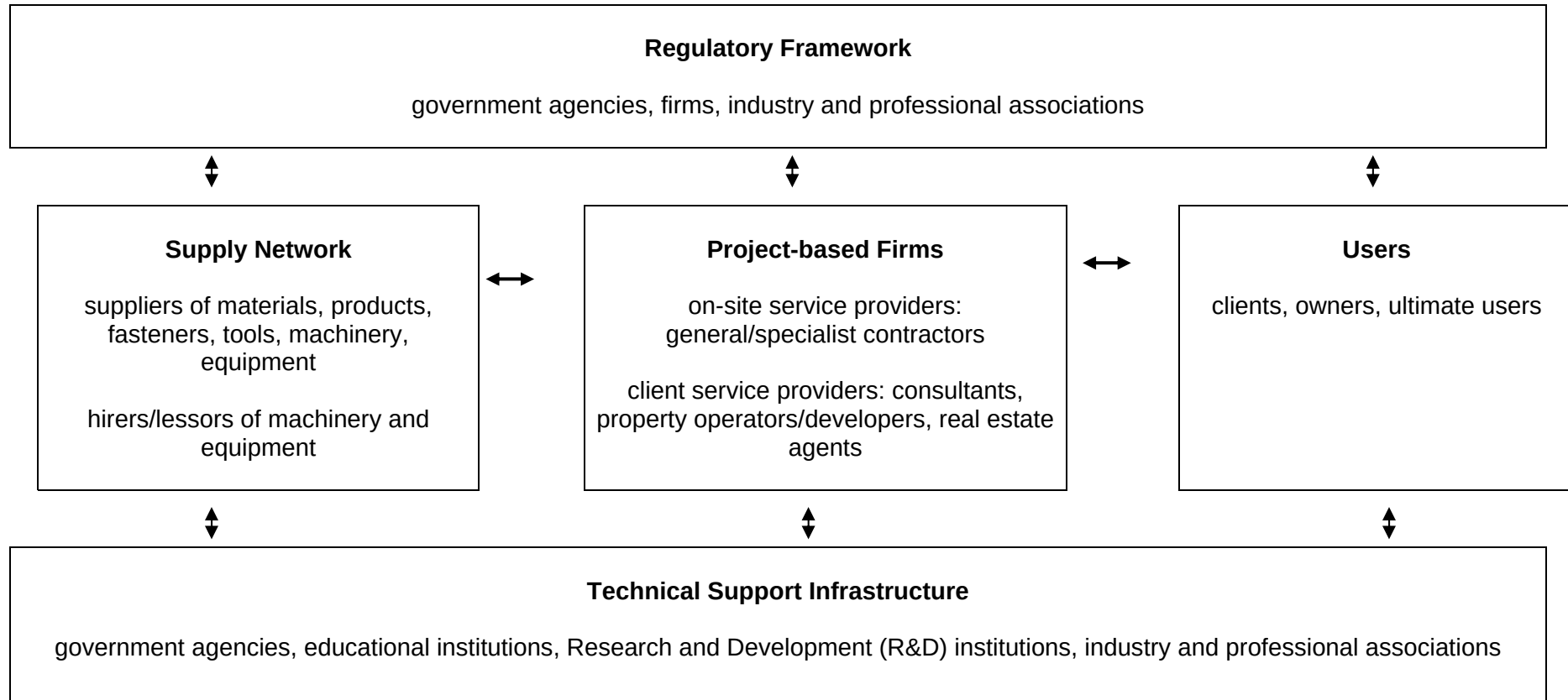
The program reviewed innovative projects in Queensland, New South Wales and Victoria. The focus on building and construction (B&C) projects arises because most readily identifiable innovation takes place there, rather than within particular organisations. The focus on the three states was driven by the fact that they account for 80 per cent of Australia's B&C activity (Cole Royal Commission 2002b, 16).

The case studies were based on semi-structured interviews, and background documentation including award submissions, academic papers, magazine articles, internal reports and workshop presentations. Each case involved multiple interviews covering at least two of the organisations on the project. Each interviewee was a senior technical or management representative and the range of interviewees covered all types of industry participants including clients, contractors, consultants and suppliers.

CONCEPTUAL FRAMEWORK

The case studies were interpreted according to the influential work of Gann and Salter (1998). These authors emphasise the non-linear and highly interactive nature of innovation processes, taking a broad view of the boundaries of the B&C industry. Figure 1 is based on their approach:

Figure 1 The Context for Innovation: Participants and Relationships in the Building and Construction Industry



(Based on Gann and Salter 1998)

Figure 1 provides a good summary of the relevant participants in the B&C industry. It helped in structuring the case studies and positioning key relationships, and provided a useful analytical tool to assist in thinking about the audience(s) for the results of the study, as part of the research dissemination process.

The diagram shows five key classes of participants: project-based firms, suppliers, users, regulators and technical support providers. Sub-classifications are also shown. Relationships between the participants are multi-directional. There is no starting point in the innovation process, as it is not linear. Innovation may be championed or implemented by any of the participants. The empirical work undertaken by the present study aims to further define the roles these participants play in innovation on Australian commercial building projects.

Figure 1 guided qualitative analysis of the case studies. This analysis identified four key innovation participants and their roles in influencing implementation processes. Prior to discussing these findings, the innovation implementation processes are examined.

CASE STUDIES OF INNOVATION IMPLEMENTATION PROCESSES¹

This section describes three case studies of innovation on projects in the Australian commercial building sector, focussing on implementation processes and the way in which obstacles were overcome. The next section interprets the findings according to the conceptual background of the study and summarises the key learnings from the exercise.

WILLIAM MCCORMACK PLACE: CASE A

William McCormack Place is a 4,568m² (net lettable area) four-storey commercial office building in Cairns, Australia. It was built for a public sector client by a private sector construction manager under a two-stage, design and construct, guaranteed maximum price contract with an overall budget of \$A17.5 million including fit-out and public art. The building was opened in September 2002, delivered on time and within budget, after an 18-month design and construction program.

The innovation profiled on this project involved a suite of advanced air-conditioning components, including the use of a chilled water thermal tank and a total enthalpy thermal wheel. The thermal tank eliminated the need for a low-load chiller and the associated prolonged periods of inefficient low-load operation of the chiller sets. The moisture-absorbing thermal wheel was used to recover cool and dehumidified outside spill air energy to precondition incoming hot, moist ventilation air. Both these advanced technologies have been employed to a limited extent in Australia and overseas, and their rate of uptake is expected to rapidly increase as the benefits they can deliver become more established.

The Implementation Process

¹ Readers requiring more detail about the case studies are referred to Manley and Blayse (2003). This report provides greater detail about the technology and discusses the benefits they delivered.

A key driver for adoption of the thermal tank and wheel was the client's desire to improve the energy efficiency of its buildings, while the mechanical and electrical consultant was motivated by the potential improvement to its reputation and the belief that this would enhance its competitive position in the marketplace. Both were strongly motivated by the opportunity to enable the building to win the first 5-star energy rating, awarded under the Australian Greenhouse Rating Scheme, for a commercial office building. This aim was achieved.

Thermal Tank

The client's original brief suggested that three chiller sets be installed to manage air-conditioning requirements. However, the consultant advised that it would be more efficient to replace the third low-load chiller with a thermal tank to get maximum efficiency from the chillers. The consultant designed the first large-scale tank in Australia in the late 1990s, roughly a decade after the first use of tanks overseas, and was motivated to do so after having monitored their performance through industry association newsletters and international networks involving R&D conducted by the university sector.

The consultant understood the technology and had proved its effectiveness and the accuracy of payback periods. The client's audit engineers reviewed the design and agreed that energy performance was likely to be significantly improved by the thermal tank. The adoption decision took into account the climatic conditions of the building. The heat and humidity in Cairns is quite extreme, demanding the use of innovative technologies to minimise environmental impacts.

Thermal Wheel

The consultant introduced the first total enthalpy thermal wheel into Queensland in 1986 and has since designed several hundred. They were early adopters of this technology, as such wheels only emerged globally in the mid 1980s.

The company's ability to encourage clients to use the wheels was assisted by its review of developments overseas. Its knowledge and experience enabled it to strongly champion the use of a thermal wheel on the William McCormack Place project, and the client was able to confirm the value of the technology with internal mechanical engineers who knew the wheels were widely used in Europe.

The Queensland Government had an interest in local employment for this regional project through its Local Industry Participation Policy, which provided the consultant with the opportunity to be involved. The consultant was a local firm with considerable expertise, and experience with the often extreme local weather conditions, whilst also having linkages with technical experts in Australia, America and Europe. The success of this project shows that regional firms can be technology leaders and that knowledge can be gained *from* them, rather than merely imparted *to* them.

Overcoming Obstacles

Obstacles to the adoption of environmentally friendly technologies, such as the thermal tank and wheel, have traditionally been high up-front costs and risk aversion. However, this case has shown that:

- the cost element is circumventable when addressed in the overall design and construction of a building; and
- clear objectives and design can reduce the risks for both managing contractors and clients to acceptable levels.

Another problem has been that building users are unaware of the negative environmental impacts of conservative approaches to building. However, as concerns about energy and other conservation issues become more prominent, building users are demanding energy-minimising buildings and creating the need for appropriate project delivery mechanisms. William McCormack Place illustrates the positive impacts of this trend.

The client's traditional method for delivering new office buildings was for a specialist unit to manage the design and construction of a building and then hand it over to the property management area on completion. There were few drivers within this system to maximise building performance, particularly in terms of user-needs and whole-of-life costs. In the case of William McCormack Place, senior management decided that the team responsible for the ongoing management of the building would deliver the project.

This meant that project decisions could be made on the basis of time, budget and quality, and also on the functionality and manageability of the property, based on the building life cycle from a *facility management perspective*. This was the first time the client had managed a major contract in this way, with the facility manager playing such a significant role. The client's role as an informed buyer was enhanced, with the required awareness to encourage the adoption of advanced technologies.

The adoption of advanced technologies was also facilitated by the construction management style of contract, which involved the builder very early in the design process. There were no 'rude shocks' when the advanced technologies were incorporated into the design. The guaranteed maximum price element of the contract ensured that the design was as thorough as possible, to reduce the builders' risk, and to ensure that the final design was 'buildable'.

Finally, there are often obstacles to adoption of advanced technologies and practices when tender selection is based solely on cost, as innovation is rarely associated with the lowest cost tender. In this case, the mechanical and electrical consultant was selected on experience and ability, not just on competitive cost. This approach was critical to adoption of the thermal tank and wheel.

SUNCORP STADIUM: CASE B

Suncorp Stadium is a 52,500-seat, world-class football facility, constructed by a private sector managing contractor under a two-stage, document and construct, guaranteed maximum price contract, with a project budget of \$A280 million. The stadium was opened in June 2003, delivered on time and within budget, after a two-year documentation and construction program.

The innovation examined by the study was a new method of manufacturing concrete planks and connecting them to supporting steel beams. Formed rebates were designed for the ends of the pre-cast pre-stressed polystyrene-voided concrete planks.

Complementary design of concrete topping and reinforcement details ensured a crack-free, reliable composite connection between the steel beams that support the grandstands.

Polystyrene-voided planks and formed rebate details had only been combined on a few occasions globally in the building industry. The particular planks and the particular rebate, and associated details, were unique to the Stadium project.

The Implementation Process

The 'clever plank' innovation arose in part from the opportunities for designer and contractor interaction inherent in a document and construct contract. The engineering consultant noted that:

... the contractual arrangement was not like a lump sum fully documented contract, where the contractor is basically given the design and told to go away and build it. Here, the Joint Venture was encouraged to look at alternative forms of construction

The preliminary stadium design on which the managing contract was tendered incorporated a structural system assessed as the lowest cost option by quantity surveyors, that is, conventionally formed concrete beams and slabs. When the Joint Venture was appointed, the joint venturers agreed that the conventional approach was the cheapest in direct costs; however, they pursued the idea of a steel beam and plank design, based on advantages related to time, risk and management of sub-contractors. The Joint Venture asked the consultants to explore the technical feasibility of such an approach. The consultants found that, while the components were more expensive for beam and plank construction, the timber and sub-contractor savings related to the absence of formwork more than offset the extra expense.

Formwork is very material and labour intensive. The advantages of not requiring formwork for the stadium included:

- a less congested site without large numbers of form workers;
- reduced car parking and concrete truck access problems in the inner city location;
- no concreter delays/disputes to hold up following trade work (previous experience with highly unionised workforces and industrial action fed into the decision-making process);
- no obstruction of the areas underneath the grandstand with temporary propping, which restricts trade work;
- lower safety risk because there is no need for scaffolding, planks and ply; and
- easier quality control and guaranteed standards when concrete planks are manufactured off-site.

The above advantages result for either extruded or voided planks employed in a conventional non-composite way, although voided planks can be more efficiently attached to supporting beams by adjusting the pattern of voids to create solid ends for more robust fixing. The consultant looked beyond these advantages in response to the contractor's request to find further savings.

The contractor's interest in savings was driven by the form of contract. The contract allowed for the development of alternative designs and for shared benefits between the contractor and client if the project was delivered below the guaranteed maximum price. It seems this contractual driver helped to create an environment where innovative ideas were explored and embraced.

The consultant's study of a series of steel and precast plank options found that there were potential cost savings with lighter steel beams, if a reliable and practical method of achieving composite connections between planks and beams could be developed. After consulting with leading international researchers in the field of composite steel connections, it devised the innovative rebate design. It then calculated the theoretical capacity by extrapolating from available theory and codes, and arranged for full-scale prototype testing to verify the accuracy of the design calculations and the efficiency of the connections. The construction program dictated that the manufacture of the clever planks commenced before the prototype testing was completed, but the designers were confident that the results would be positive. Their confidence in the design has subsequently been borne out by the prototype test results and the faultless performance of the planks and concrete topping on site.

The implementation of the clever plank innovation will not end with this project; both the consultant and the supplier intend to use the innovation on future projects. The consultant will maximise these opportunities by publicising clever planks on its internal skills network, which is a formalised knowledge-sharing system operating across the organisation's global operations. The company also plans to submit a paper for publication with the Institution of Engineers, Australia and is currently providing advice to colleagues considering similar plank and beam approaches. Further, the clever plank innovation has been submitted to the consultant's innovation competition, which feeds into the organisation's marketing efforts. Such initiatives encourage employees to take the time to write up the benefits of their innovations, an activity that can otherwise be marginalised in the project-to-project rush of work.

Overcoming Difficulties

A large part of a consultant's role is to provide ideas to clients and contractors, which benefit these two parties, but not necessarily the consultant in a direct sense. Certainly, reputation is important for consultants, especially reputation for money-saving innovations, and the consultant on the project profited in this sense. Nevertheless, the benefits from construction innovation are not evenly spread along the supply chain, nor does the proponent/inventor necessarily profit directly. This problematic incentive structure is likely to constrain innovation efforts.

In the clever planks case, the consultant was aware of recent changes under the Queensland government's prequalification system for building industry consultants, which have seen 'innovation history' added as a criterion. Such moves help to make the benefits of innovation to a company's reputation more tangible, by recording and valuing the extent of the organisation's innovation activity.

Overall, there were few obstacles to the implementation of clever planks on the Stadium project, due to the positive drivers established by the form of contract, which encouraged the contractor to seek and support money-saving innovations.

AUSTRALIAN ART BUILDING: CASE C

The NGV (National Gallery Victoria)-Australian Art Building is a centrepiece of the Federation Square development in Melbourne. Federation Square is one of Australia's civic and cultural icons, incorporating multi-media, art, museum and office buildings. The NGV-Australian Art building was constructed by a private sector managing contractor and was completed in 2002 for approximately \$A65 million.

The innovation on the NGV-Australian Art Building examined by this study has three main elements: use of the performance-based Building Code of Australia (BCA); use of Quantitative Risk Assessment (QRA); and use of unprotected steel while meeting fire safety requirements.

The Implementation Process

The key to the benefits achieved by the use of unprotected steel was the QRA, which, in turn, was made possible by the recently implemented performance-based BCA. The managing contractor drove the design shift from concrete to steel, based on its experience of the benefits of steel. The design team drove the use of *unprotected* steel, reaping time and cost benefits, principally by employing QRA.

Risk assessment techniques, such as QRA, are used to evaluate the frequency and probability of threatening events such as fires. Once risks are assessed, options to reduce the risks can be examined and costed, and the most effective option adopted.

There are a number of approaches to risk assessment for fire safety decision-making. One of the most complex of these approaches is QRA, which is based on fault and event scenarios. Fault scenarios can be used to identify mechanisms of failure leading to fire starts. Event scenarios can then identify the probability of the fire advancing from ignition to the various stages of fire development and define the levels of threat to occupants and property. In Australia, this approach is known as an Evaluation Extent 3 or System Risk Evaluation approach, as defined in the Australian Building Codes Board Fire Safety Engineering Guidelines.

In the case of the NGV-Australian Art Building, the concept of five states of fire growth was used to assess the probability and consequences of various times-to-activation of the fire safety systems and human intervention. Further, a number of events and factors were incorporated into the analysis and the associated probabilities enumerated in order to determine the overall probability of fire development and damage to property. These three features – the five fire states; the application of QRA to property; and the method of probabilistic analysis – are cutting-edge. They have been used only rarely globally, and were adopted by the fire engineers on the project through their linkages with international experts, such as engineers conducting R&D with the National Research Council of Canada.

Overcoming Difficulties

One of the primary challenges in the adoption of the fire engineering/unprotected steel innovation was addressing the safety concerns of a number of stakeholders, including the client, about the new approach. One of the key reasons for concern, particularly for the client, was that the QRA approach to fire safety engineering is an analytical process,

as opposed to a physical testing-based approach. Acceptance of the QRA results requires an understanding of its theoretical underpinnings, and of the logic that leads to the outcomes. These can be more difficult to communicate than results based on physical testing of materials. However, members of the design team were able to effectively use fire engineering tools, and a cooperative approach, to educate the stakeholders about the relative risks and allay their fears.

QRA is a significant departure from *prescriptive, rule-based* approaches to building construction, and this may also have been a reason for concern. Despite the capacity of QRA to arrive at what are, in many cases, safer and less expensive construction methods, there is still a residual tendency for many stakeholders to prefer uncomplicated rules prescribing conventional building materials and methods. Indeed, QRA is harder to understand than prescriptive rules and this can result in risk-averse responses to its adoption. However, as this case demonstrates, it is possible to reduce this problem using education and a cooperative approach.

DISCUSSION AND CONCLUSIONS

The cases highlight the active role taken by four key types of industry participants in promoting innovation on projects: clients, regulators, technical support providers and consultants. To some extent, these are the likely suspects, although such a list, if it were comprehensive, would also include suppliers. Indeed, suppliers are shown to be significant in research related to that described here (Manley and Blayse 2003).

The literature highlights the importance of the four types of participants emphasised here: clients, regulators, technical support providers and consultants (Briscoe et al 2004, Gann 1998, Nelson 2004, Hislop 2002, Salter and Torbett 2003). This paper adds value to that existing knowledge by investigating in detail the roles of these participants in the implementation phase of innovation on commercial building projects in Australia.

From Case A, it has been shown that informed clients can facilitate the adoption of advanced technologies and practices by expertly cross-checking innovative proposals. For public sector agencies, this creates a driver for retaining skill bases within the agency, and reduces the likely benefits of outsourcing. It was also shown that clients who are willing to entertain acceptable risks can lead the industry in demonstrating the benefits of innovation. This 'entertainment of reasonable risk' is a best practice approach to risk. Unfortunately, the public sector is still dominated by a culture of risk aversion (Manley 2001). Indeed, the findings of Case C provide an example of a risk-averse client, which potentially created an impediment to innovation. In that case, consultants played a key role in allaying fears by educating the client. Yet, there remains a need for tailored programs across Australian public sector agencies to encourage greater risk-taking.

On a more positive note, Case A revealed that innovation can be prompted by clients who invite users to be involved in project scoping and management. User involvement tends to create pressure for minimisation of long-run operating costs and results in more functional buildings. The action of the client in this case responds to calls in the literature for client-led strategies to improve supply-chain integration (Briscoe et al 2004). Indeed, the findings here support the view that clients are 'key drivers of performance

improvement and innovation and are the most significant factor in achieving integration in the supply chain' (Briscoe et al 2004, 193).

Case B illustrated other roles government clients can play in shaping the industry's innovation opportunities, through prequalification activities and contract types. Prequalification systems designed in part to measure innovation performance create a strong innovation driver, while the selection of contract types that involve as many parties as possible, as early as possible, lead to synergistic benefits and innovation. This last point is reinforced by the work of Ehrenkrantz (1998), which explores the links between procurement systems and innovation. Indeed, an emerging focus in the literature is the design of incentive systems within contracts to promote goal alignment between clients and construction industry participants, encouraging the flexibility that allows change and innovation (see Rose 2004 for a recent summary). This follows from the view that clients have a better chance of achieving their goals if they view their contractors and consultants as 'employees' and seek to motivate them accordingly (Turner 2004, 75).

Building regulators are also very instrumental in driving innovation through the supply chain. In Case C, it was shown that performance-based building codes encourage innovation, reinforcing the findings of Gann (1998), while in Case A, environmental standards were set just beyond current industry capabilities, creating a strong driver for innovation and efficiency gains. Nevertheless, the literature warns that regulators and standard setters need to have a good grasp of current industry capabilities so that they are able to effectively set regulations and standards at levels that are appropriate to encourage innovation (Gann 1998).

The case studies support findings in the UK 'that, in general, performance standards allow firms the freedom to innovate while prescriptive standards stifle creativity' (Gann 1998, 291). The same study concludes that 'clarity and simplicity is needed in the regulatory process to enable the uptake of good practice and encourage innovation. Failure to provide clear and enforceable rules is likely to have repercussions which damage industry's capacity to change, constraining future developments' (Gann 1998, 291).

Turning now to the role of technical support providers in driving innovation implementation, recall that international industry associations provided primary stimulus for the innovation in Case A, and university research played a central role in facilitating the innovation in Case B, while in Case C, the quality of the innovation was enhanced by international linkages with global experts. Further, the case studies indicate that technical support providers are particularly important when innovation relies on formal R&D. This is because the industry's structure and profit margins limit the extent to which other participants, such as contractors or consultants, can sustain formal R&D programs.

One of the important features of the knowledge base, which is managed by technical support providers, is the relative ease with which industry participants can access it. The case studies reviewed here show that industry networking with technical support providers still matters to competitiveness, however, the literature warns that this could be compromised by the increasing inaccessibility of public-sector science, with negative implications for national growth rates (Nelson 2004). This inaccessibility is associated

with commercialisation trends and associated patenting activity by public sector research organisations, which limits the diffusion of knowledge.

Finally, the role of consultants is reviewed. In some ways this is saving the best for last. It is clear that in all three case studies consultants were active drivers of innovation that was in turn facilitated by client behaviour, changes to regulations and relationships with technical support providers. Indeed 'there is widespread consensus that design is becoming increasingly important in determining competitiveness' (Salter and Torbett 2003, 573).

Consultant activity is pivotal on construction projects. Engineers and architects are responsible for translating technical possibilities into objects that respond to client needs and market opportunities (Salter and Torbett 2003, 573). However, the interviews conducted for the case studies revealed consultants that were not merely responding to 'demand-pull' pressures, but were proactively engaged in 'science-push' type activities. The consultants appeared to have the strongest links to international knowledge bases, compared to the clients, contractors and suppliers examined.

These four classes of participants – clients, regulators, technical support providers and consultants – stand out in the current context from all the participants reviewed in Figure 1. The effectiveness of these participants in promoting innovation is mediated by the type of contract employed on the project. Contracts that promote goal alignment, flexibility and integration are more conducive to innovation. There is an extensive literature on this topic and interested readers are referred to Turner (2004) and Briscoe (2004). Here, the underlying driver is discussed – effective relationships.

The case studies reveal the extent to which relationships between participants drive innovation implementation, particularly international linkages. Indeed, the need for strong industry networking is emphasised in the literature, in view of the fragmented and temporary nature of production activities in construction (Slaughter 1998, Blayse and Manley in print). The importance of an organisation's ability to absorb external information has been emphasised since the early 1970s (Freeman et al 1972) and has only been highlighted by the rapidly increasing pace of change as we move into the 21st century (Neville 1998).

The relationships reviewed in the case studies centred on the need for knowledge. The importance of knowledge in learning economies is highlighted by the literature on innovation and growth, which is marked by the view that knowledge has become the most critical variable in productive activity (Marceau et al 1999, 2-9). In the construction industry, Green et al (2004, 72) found that poor communication is a key factor in constraining innovation rates. This finding is supported by the case work reported here, where successful innovation is linked to active inter-organisational and inter-sectoral relationships involving the communication of knowledge.

The case studies also show that the networking activity resulted largely in incremental innovation, rather than radical innovation. Incremental innovation is characterised by the adoption, refinement and enhancement of existing innovations. The study by Green et al (2004, 67) showed that the diffusion of existing innovations through incremental innovation was a key factor in construction industry growth, partly because of the impact incremental innovation has on cultural change. Incremental innovation involves an

understanding of the need for continuous improvement, overturning the social norms in the industry that support complacency.

Yet, incremental innovation, like that demonstrated in the case studies, is typically problem-driven, reactive innovation. The lack of emphasis on more proactive innovation represents a relatively untapped source of industry growth. Incremental innovation helps in improving industry culture, however a 'blame-free' culture is even more important for proactive innovation and, as yet, opportunistic behaviour in the industry remains too dominant to allow this type of innovation to flourish.

The lack of emphasis on proactive innovation suggests fewer formalised R&D programs in organisations and hence less ability to access government programs that support R&D. Given this, a recent report suggests that programs supporting education and training initiatives can assist in promoting innovation rates. The same report argues that service industries, such as construction, need to be assisted in this way to match the support provided to manufacturing organisations through R&D programs (Thorburn and Langdale 2003, 38).

Overall, the experiences of innovators in the case studies emphasise the highly interactive nature of successful innovation implementation processes and the importance of robust business networking. Many construction industry participants are wary of sharing knowledge, reflecting a history of adversarial relationships. However, these case studies suggest that sharing knowledge pays. Cooperation is increasingly regarded as an essential component of self-interested growth. As the literature notes, 'knowledge sharing is not a zero sum game' (Green et al 2004, 12).

There are clear opportunities for further research. Indeed, in related studies, the authors are applying a similar perspective to a study of the Australian road and bridge industry, and are also undertaking a large-scale quantitative study of interactive innovation implementation processes in the Australian B&C industry. A number of specific issues raised in the present study warrant more attention and these include the relative merits of reactive and proactive innovation, and the policy implications of the relative inability of many construction organisations to conduct internal R&D compared to manufacturing organisations.

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QUALITY AND TRAINING - INTERACTION WITH INNOVATION

Full Paper

ACHIEVING RELEVANT CONSTRUCTION RESEARCH THROUGH INDUSTRY-UNIVERSITY PARTNERSHIPS

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ABSTRACT

This is to report an innovative work and study arrangement that has shown to be successful and has benefits to all parties involved. In short it involves an industry based Doctor of Philosophy (PhD) program whereby the student is placed into an organisation and undertakes full time study towards the PhD, as well as undertaking other research projects for the organisation. This has led to significant value added benefits for all parties that might otherwise have not been the case.

The Engineering Project Management Group (EPMG) at The University of Melbourne has developed the practice of industry focused engineering PhD's with several past graduates having spent significant time placed in government and industry. This specific case takes the theory one step further where the student is placed full time in industry through a collaborative arrangement with the employer, in this case Multiplex Constructions (Vic) Pty Ltd.

The University stands to gain excellent exposure through being closely involved with industry, whilst the industry organisation stands to benefit through having an in house researcher who has skills in searching for and disseminating relevant industry and academic material to the organisation. The student benefits by gaining valuable industry experience unlikely to be otherwise available to PhD students. The student has access to a wealth of information and expertise through both the University and the organisation, which is more likely to result in an industry grounded PhD of high academic merit.

This paper reports a specific case where the student has undertaken 18 months of candidature thus far, and has been able to maintain the balance between work and research, and is currently running to programme. It also lists the barriers that must be overcome for the programme to be successful, and contrasts Australian experiences with a similar programme in the United Kingdom. There is scope for this form of industry based PhD to become more commonplace.

Industry based construction research, PhD programme

1 INTRODUCTION

The concept of employer sponsored postgraduate study is not new. However, the majority of these programmes are based around coursework degrees such as a Master of Business Administration (MBA) or similar, with very few opting to sponsor a research based degree program such as a PhD. This is especially true in the Australian construction industry where research is not at the forefront of construction companies' priorities.

Difficulties arise from the perceived gap between industry and academia, with the commonly held view that academia operates in isolation. That is why this particular innovative arrangement merits further dissemination to dispel those views, and hopefully gain a more widespread acceptance of use within the engineering and construction industry.

1.1 INDUSTRY- UNIVERSITY PARTNERSHIPS:

The value of establishing effective industry-university partnerships has been realised by many construction engineering educators and industry leaders (Tener, 1996). Industry plays a large role in the co-operative model of education by way of development, management and work placements for students (Calway, 1994). Integrative collaborative project work for postgraduate students is suggested as a means of facilitating the broadening processes and also to promote the pooling of knowledge and experience from within the student group (Lowe, 1991).

The real educational issue however, is how to best prepare engineers and constructors to deliver a quality product to an owner (Schexnayder, 2003). Where full time students have been in industry placement, employers were often surprised at the contribution made by students and valued their contact with the university (Edward, 1998).

2 PROGRAMME OUTLINE:

Broadly speaking, the programme sees a PhD candidate placed full time in government and/or industry and undertaking work directly for the employer along with studying towards the PhD full time.

The employer, in this case Multiplex Constructions (Vic) Pty Ltd, employs the candidate as a "researcher", to perform research and report on any particular area of interest to the organisation. The candidate reports directly to the Managing Director, for whom the majority of research reports are performed, which are then disseminated to the appropriate directors or other nominated people.

The PhD thesis topic was determined at a joint meeting between Multiplex, the student and the university supervisors, which ensured the project was of relevance, not only to the organisation but also to the construction industry as a

whole. Whilst the organisation was consulted on what direction the research should take, it had no overriding say in the final topic, thus ensuring the academic rigour of the PhD is maintained.

The candidate is currently based full time at Multiplex, but spends 60% of time working directly towards the PhD, and the remaining 40% on Multiplex projects. This split can vary from week to week, as in the past there have been Multiplex projects which may have required a full week or 2 of work, however it is balanced out with the requisite PhD study later on. Residency requirements also state that 2 of the 3 years of PhD candidature must be spent at The University of Melbourne unless it is spent at an 'approved outside institution', which in this case it is not. Most of the first year of candidature was based at the University, and it is envisaged that portions of time in the following year will be spent back in the Department of Civil and Environmental Engineering in order to meet the residency requirements by the due date.

Whilst there are certain added pressures with this mix of work and study which could be detrimental to the success of the PhD, it is up to the individual candidate and supervisors to ensure the industry work doesn't interfere too heavily with the PhD programme. So far this has been managed successfully, with the PhD on schedule for completion by the due date.

2.2 ADVANTAGES TO THE PARTICIPATING PARTIES:

2.2.1 The University

The Engineering Project Management Group (EPMG) through which the student is supervised has pioneered the practice of industry focused Engineering PhD's with many past graduates having spent significant time placed in government and industry (Refer Table 1). This specific case takes the theory one step further where the student is placed full time in industry through a collaborative arrangement with the employer. The University stands to gain excellent exposure through being closely involved with industry, and confirms the EPMG as an industry focused group whilst still maintaining its academic integrity.

2.2.2 The Organisation

The organisation stands to benefit greatly through having an on site researcher who has skills in searching for and disseminating relevant industry and academic material to the company. In this case, much of the research towards the student's specific PhD topic has relevance to the company; therefore the student is able to provide a low cost information source on current industry best practice. The organisation also stands to benefit from the added incentive it has provided the student to stay loyal to the company once the PhD program is complete. No time periods have been set for compulsory work once completed, however it is much more likely the student harbours a greater desire to remain with the company. The program also provides tax benefits under Australian Taxation Laws through the provision of Research and Development.

2.2.3 The Student

Possibly benefits the most through the program, by gaining valuable industry experience not otherwise available to PhD students. The student has access to a wealth of information and expertise through both the University and the organisation, which is much more likely to result in an industry grounded PhD that retains its academic merit. The student also stands to benefit financially through the additional work for the organisation.

The student has recently embarked on a 3 month research trip to the United Kingdom to investigate a number of case studies of direct relevance to the PhD, as well as working within the London office of Multiplex Constructions, preparing research reports on various topics. Again this proved to be a good experience for all parties involved, whereby the student gained valuable international exposure, as did the university through increased links and collaborations with overseas institutions, and the organisation stands to benefit through increased knowledge transfer between international offices.

2.3 MAJOR BARRIERS TO SUCCESS:

2.3.1 Intellectual Property

The issues of ownership of the intellectual property arising from such arrangements can be viewed as being for the benefit of the industry as a whole, the benefit of the academic institution and for the benefit of the organisation.

The preferences of the three participants can generally be met by prior agreement without jeopardising the academic criteria fundamental to the degree granting institution. With the rapid advance in technology and the transient nature of the building and construction industry, intellectual property often has a limited sole ownership life span. It can also be possible in some cases to place a short-term embargo on public access to theses. The related issue of confidentiality is commonly addressed by academic institutions but may also be required by the placement organisations.

2.3.2 Remaining Impartial

As the student is based at the organisation, there may be a view that there are certain 'pressures' to report on projects involving the organisation in a different manner to their competitors. This impartiality is ensured by all PhD candidates from The University of Melbourne having to abide by a Code of Conduct for Research, or risk being removed from the PhD programme.

2.3.3 Confidentiality Issues

When investigating various case studies and performing industry surveys within the bounds of the PhD research, there is an obligation under the Code of Conduct to state all affiliations and sources of funding. In doing so, a number of organisations in the industry have questioned the nature of the confidentiality arrangements – that is how they can be assured of their confidentiality when information is being given to an employee of a competitor.

This is maintained in a number of ways; firstly all confidential information gained from any survey must be kept secured on University premises with access only to the named researchers. Any information which is then published from the data will be anonymous and have all connecting information to that company removed. Some cases have arisen however, where there are issues of anonymity through small sample sizes, which at the top end of the construction industry is quite evident. These issues are some of the points covered under the University Ethics Approval Process.

2.3.4 Ethics Approval

Research conducted at universities in Australia is obliged to be submitted to selected committees for “ethics approval”. This process is conducted under the stringent National Health and Medical Research Council rules. While these may be appropriate for research involving the health and welfare of individual personnel, they are not considered appropriate for the academic research discipline being undertaken by the EPMG. It is noted that such a process does not appear to be common outside Australia.

3 OTHER INDUSTRY BASED PhD PLACEMENTS:

The Engineering Project Management Group has had a number of very successful industry placements of PhD students in the past. Areas of previous research and associated government and industry participation are presented in Table 1.

Table 1: Previous industry based PhD placements

Research Topic Area	Placement Organisation	Researcher's Industry Participation	Year
Environmental management systems	Australian Antarctic Division	Engaged at Casey Station, Antarctica, establishing environmental reporting systems	2002
Construction project management in developing countries	AusAID, Orica	Conducted training needs analysis in Vietnam, and consulting work on an Indonesian project	2002
Privately funded infrastructure evaluation	State Treasury, Victoria	Developed agreements for the delivery and operation of a range of public private partnership projects, including risk management investigations	2001
Risk allocation in the private provision of infrastructure	State Treasury, Victoria	Employed in developing risk management criteria for Victorian Government PPI projects	2000
Housing delivery in less developed countries	Urban Land Authority, Victoria	Engaged in urban land residential developments in outer suburban Melbourne	1999
Estimating and tendering in the Australian civil engineering construction industry	John Holland Group	Employed in estimate & tender preparation, and tender review	1996

3.1 UNITED KINGDOM (UK) EXPERIENCES:

Despite its huge contribution to the UK economy, the construction industry still appears to view research and development with suspicion, a sentiment echoed in the Australian construction industry.

The Centre for Innovative Construction Engineering (CICE), based at Loughborough University, UK was launched in 2000 and offers a four year Doctor of Engineering (EngD) qualification which has set about overcoming difficulties of combining the needs of industry with research. The degree provides a more vocationally oriented doctorate in engineering, and is better suited to the needs of industry than a traditional PhD (Fleming, 2002).

Topics for research within this programme have so far included innovative procurement and management practices, advanced analysis and design, sustainable construction, novel construction techniques and innovative construction materials.

As distinct from a traditional PhD programme, EngD projects must demonstrate innovation in the application of knowledge to the engineering business. They therefore must make a significant contribution to the performance of the industrial partner and thus have to be in the mainstream, not a 'student' project performed on the side of little consequence.

Where a company or industrial partner has an interest in a certain area of research, they can approach the EngD programme at Loughborough University to obtain a suitable 'research engineer'. The industrial partner is involved in the selection of candidates, and together with academics and the newly selected candidate, jointly design the research and course work programme that the research engineer will undertake.

Doctor of Engineering students will be expected to spend at least 70% of their time with the industry partner, and therefore any benefits flowing from the ongoing research will be immediately seen by the sponsor, not years down the track as in more traditional programmes.

The course also involves a course work component comprising modules of study administered by the CICE. Should the candidate choose to complete the requisite amount of modules, an MSc (Master of Science) en route to the final doctorate qualification is then awarded as well. The advantage for companies is that they can undertake research in an area where they have real technical or business needs at relatively low cost, and have access to expertise across the whole of the university.

4 FUTURE POSSIBILITIES:

To make the programme more marketable to the construction industry, and to other related engineering disciplines, a rebranding must occur. That is the notion that an academic programme such as a PhD solely leads to academia and has no place in industry, must be overturned. This will not be as easy task, but dissemination of information regarding successful programmes such as the one outlined here can only help influence the industry into greater acceptance.

An alternative route to that of a full time research based programme may be to include a number of coursework subjects of direct relevance to the employer's field. These might be management, law, or any other area of potential benefit to the student or the organisation. It is very common for engineers who commence their careers in technical roles to move on to senior management roles, and may end up taking on management training then, whereas through this programme they would obtain similar training along the way.

This concept has been tried successfully in the United Kingdom through the Engineering Doctorate programme at Loughborough University, and there is significant scope for a similar programme to be established in Australia. This would also require a change in thinking from the Universities who run traditionally

academic PhD programmes, to understand the need for a more vocationally oriented degree.

5 CONCLUSION:

Successful programmes such as that involving The University of Melbourne and Multiplex Constructions provide evidence to the Australian construction industry of the benefits to all parties involved.

The University gains valuable exposure in the Construction industry, and keeps itself at the 'cutting edge' whilst remaining grounded in actual industry practices, which is a danger of more traditional PhD programmes. The industry organisation gains a valuable source of information, and can prepare research reports on any aspect of the organisation or industry which may not have been possible without a dedicated researcher, a person very few organisations would have. There are also significant tax incentives to supporting Research and Development programmes under current Australian Tax Laws.

Finally, the student stands to complete a PhD of high industry relevance. This could see the student progress much faster in industry than the traditional academic based PhD, simply because they have gained valuable experience along the course of study and will not be starting at a 'graduate' level, as other PhD students may find.

It is clear that there is significant scope for industry based research programmes, such as a PhD, to become more commonplace, but this does require a major shift in traditional thinking from all parties involved.

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PROCUREMENT AND RISK SHARING

Full paper

USE OF ALLIANCE CONTRACTING FOR DELIVERING LOCAL GOVERNMENT ENGINEERING PROJECTS

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ABSTRACT

Alliance contracts are designed to align the principal's and contractor's objectives to maximise performance, positively manage risk, reduce cost and achieve positive results.

They are best suited to contracts that require innovation, are complex, have tight constraints, or in which resources of both parties can be successfully combined. Successful alliance contracting requires commitment by both parties to achieving common goals.

The research described in this paper assesses the use of alliance contracting in local government and develops a management tool for local government organisations to use in assessing the appropriateness of alliance contracting in given circumstances.

A questionnaire was used to obtain information about alliance contracting experiences from five local government organisations in Australia that had used alliance contracting to deliver civil engineering projects. The questionnaire was also given to their alliance partners.

Criteria addressed in the questionnaire included project costs, relationships formed, quality, innovation, safety, administrative effort and the alliance experience itself.

A decision matrix based on risk management principles was developed to assist local governments assess the suitability of alliance contracting in a particular case. Assessment is based on operational, technical, financial, legal and social criteria.

Keywords: alliance, contract, local government, management, procurement, risk

1. INTRODUCTION

Alliance contracts are recognised for their ability to align the principal's and contractor's objectives to maximise performance, proactively manage risk, reduce cost and achieve outstanding results in principal key objectives (Alchimie Pty Ltd & Phillips Fox Lawyers 2003, p. 8).

There is increasing use of alliances in the construction industry (for example, Manley & Hampson, 2000, who examined relationship contracting in the Queensland Department of Main Roads). However, the use of this process is still developing, and alliances are still in their early stages of use in local government.

In this paper, the authors discuss research into the use of alliance contracting in local government civil engineering projects and propose a methodology, based on risk management principles, which local governments may use to assess if alliance contracting is appropriate for particular circumstances.

2. ALLIANCE DEVELOPMENT

Project alliances are “an integrated high performance team selected on a best person for the job basis; sharing all project risks with incentives to achieve game-breaking performance in pre-aligned project objectives; within a framework of no fault, no blame and no dispute; characterized by uncompromising commitments to trust, collaboration, innovation and mutual support; all in order to achieve outstanding results” (Alchimie Pty Ltd and Phillips Fox Lawyers, 2003, p.8).

One source of alliance contracting is the business alliance, which developed from the high risk, high capital option of business acquisitions or takeovers. In the past if a company wanted to break into new markets, or increase or secure market share they would conduct detailed research, raise capital funds and then purchase the company or companies that offered the investor the best leverage in the new market (Doz & Hamel, 1998, p.3). In alliancing, the concepts of interdependence, no contract, no term relationships and payment on performance, not unit price are just some of the paradigm shifts that need to be embraced (Lendrum, 2000, p. x).

Joint ventures were the next strategy to evolve from the acquisition process. They differ from alliances as described by Doz & Hamel (1998, pp.19-24) in that they involve the creation of fixed objectives and the commitment of creating a new joint venture company from the parent companies. The joint venture is a stand alone self contained business. Alliances take this principle further, through partner collaboration and the exploitation of unforeseen value creation opportunities.

Alliances take many forms and operate with various levels of complexity. Lendrum (2000, p.7) describes alliances as the cooperative development of successful, long term, strategic relationships, based on mutual trust and sustainable competitive advantage for all the partners.

3. PROJECT ALLIANCES

Project alliances are a special form of alliance with defined commencement and completion dates. They form part of the wider range relationship contracting family of project delivery arrangements.

One form of relationship contracting is partnering, described by authors such as Rigsbee (2000, p.23), who observes that the basic stakeholders in a partnering arrangement (owner, the designer, the main contractor and subcontractors) attend a workshop before the project starts to air their grievances and resolve their differences. This enables the stakeholders to write a partnering charter, signed by all parties, that commits each party to work together to complete the project on time, within budget and without litigation.

Rigsbee provides details of an Arizona Department of Transport project worth US \$52 million that realised time savings of almost 20 per cent and total project savings for all the partners in excess of US \$2million per annum.

Another author discussing the benefit of partnering is Lendrum (2000, pp. 53-54), who described the advantages experienced by the United States Army Corps of Engineers.

Lendrum indicated that according to the Construction Industry Institute partnering assisted clients to reduce costs by 8 per cent, and project schedules by 7 per cent. Contractors also reported an on average profit improvement of 10 per cent. Design costs were reduced by 10 per cent and administration costs were 6 per cent less.

The unique feature of a project alliance is the synergy created between the selection of the commercial participants, the core alliance principles, the clarity and alignment of project objectives and the commercial framework, which all drive the pursuit and delivery of outstanding results. Price is not typically a part of the selection process, participants being selected on capability, approaches and systems and more subjective assessments.

A suitable leadership structure that places the project first is fundamental to a successful alliance. Figure 1 shows such a leadership structure.

4. PROJECTS SUITABLE FOR ALLIANCING

Contracting is one method of risk transfer (shifting the responsibility or burden for loss to another party) (Standards Australia, 1999, p. 5).

However, the transfer of a risk may not diminish the overall level of risk to society. In addition, where risks are transferred in whole or in part, the organisation transferring the risk has acquired a new risk, in that the organisation to which the risk has been transferred may not manage the risk effectively (Standards Australia, 1999, p. 18).

Therefore, in selecting a project for delivery by an alliance, risk management is an important issue. Is it better to transfer the risk with a contract? Are there risks that cannot be effectively transferred to a contractor? Can the overall risk be minimised if an alliance, involving principal, contractor and other key participants, is formed? Is it possible to use the synergy of an alliance to maximise opportunity?

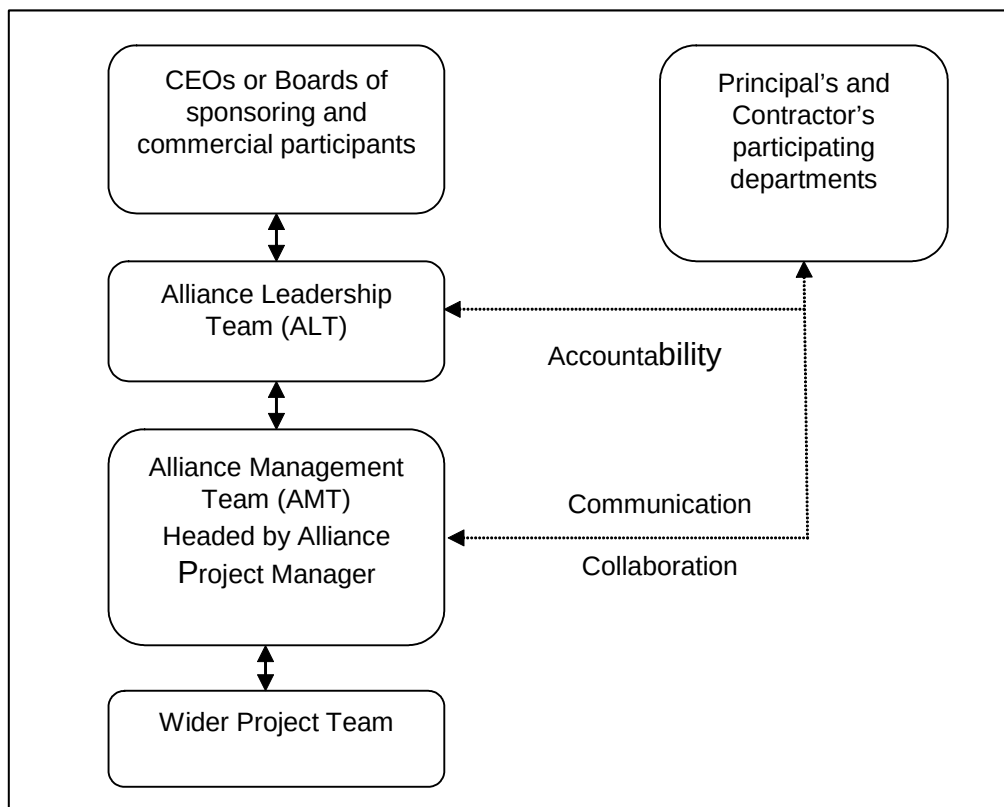


Figure 1: Project Alliance Team and Leadership Structure

Adapted from Figure 7-2, Alchimie Pty Ltd and Phillips Fox Lawyers (2003).

Alchimie & Phillips Fox Lawyers (2003, pp. 9-10) consider that the choice of any given procurement approach to deliver a project should only be made after a detailed and carefully considered risk analysis which considers all of the objectives, opportunities and risks involved in successfully delivering the project.

They note that not all projects are suited to an alliance approach. Project alliancing is best suited to those projects where the traditional risk transfer strategy is not appropriate, such as those involving elements of the unknown, having a high degree of complexity, having tight delivery constraints, or requiring the expertise of both parties to deliver the project

5. SUCCESS OF THE ALLIANCE

In order for alliances to be successful, all parties must agree on the objectives and share the principles processes and general information to gain your partner's initial and on going support and commitment Lendrum (2000, p. 183). The contractor must be involved to ensure a win/win long term relationship.

Both parties bring to the relationship a strategic and organisational context in the initial stages of an alliance. These contexts need to be discussed and recognised in an open and honest manner to eliminate any expectation gaps that may arise later in the relationship.

Walker, Hampson and Peters (2000, p. 26), observe that the essential features of partnering or alliancing are:

- Mutual objectives that firmly establish for everyone that their interests are best served on concentrating on the overall success of the project.
- Problem resolution using an escalation strategy to solve them at the lowest operational level possible.
- Continuous improvement, through measurement or analysis of performance and a commitment to learn from experience and to apply this knowledge to improve performance.

The context in which the alliance is framed can be critical to its success. Key factors in such a context include the strategic scope the partners see in the alliance, the reason why the parties want to commit themselves to it, the way in which it is framed, a consistent rule understood by both parties, the ambitions each partner hopes to fulfil, mutual assistance in achieving goals, and agreed objectives which become the basis of key performance indicators (Doz & Hamel 1998, pp. 142-151).

Trust in others and a belief in the alliance from the top of both organisations is crucial to the success of an alliance.

It is important not to fall into the traps that can cause failure of an alliance. Rigsbee (2000, pp.60 – 67) has identified many of these. They include conflict between core values of the partners, inflexibility, misalignment of goals, disloyalty, complacency, underestimation of the effort involved, overestimation of the ability of each partner to deliver agreed outcomes and high expectations of management.

6. RESEARCH METHODOLOGY

Local governments are responsible for large and complex public works. Their closeness to their communities and the largely urban nature of most major local government works exposes them to considerable political and environmental risk. Because few local governments have a large revenue base and all are accountable to higher government, they also have exposure to financial risk.

The research evaluated the use of alliance contracting in selected local government organisations. A decision matrix based on risk management principles was also developed to assist local governments assess the suitability of alliance contracting in a particular case.

A questionnaire was used to obtain and analyse information about alliance contracting experiences from five local government organisations in Australia that had used alliance contracting to deliver civil engineering projects. The questionnaire was also given to their alliance partners (contractors).

The research was conducted in the following steps, which are further discussed in the next sections:

1. Gather data on alliance experiences in local government.
2. Analyse the data collected
3. Develop the decision tool for assessing viability of an alliance

6.1 GATHER DATA ON ALLIANCE EXPERIENCES IN LOCAL GOVERNMENT

Data on alliance experiences in local government was gathered through a questionnaire to local governments that were either engaged in a project alliance at the time of the questionnaire or had previously been involved in such an alliance. The questionnaire was also sent to the alliance partners of the respective local governments to gain a complete picture of the alliance experience.

Information was requested on the following seven criteria, each of which addresses an aspect of the alliance:

1. Costs, selected because alliances should return cost savings to the principal and improved profit for the contractor.
2. Relationships, as it is through a strong and sustainable relationship that the true benefits of alliancing can be realised
3. Quality, as it represents an improvement in the value of the service provided.
4. Continuous Improvement, as to achieve results on time and to full specification requirements, innovation will always be required to improve the current process
5. Safety, as not only a commitment to safety must be evident in all services delivered by the alliance partners for legislative reasons, but also if an alliance manages their safety system well it shows commitment and alignment that is likely to be evident in other systems and processes the alliance teams adopt.
6. Administrative Effort, because of the resource intensive nature of selecting alliance partners and on-going information collection and dissemination requirements.
7. Lessons Learnt, which evaluates whether organisations have found the change to relationship contracting worthwhile, what respondents would do differently now they can look back on their process, and what they had achieved.

The expectation was that the questionnaire would highlight differences that would be addressed by the decision matrix.

Two basic types of questions were used. The first required a specific answer, ranked as follows:

- a. strongly disagree
- b. disagree
- c. neither agree or disagree
- d. agree
- e. strongly agree.

A typical question of this type would be “Have your costs improved since adopting a relationship approach to contracting?”

The second type of question was a discussion question. A typical question of this type was “Can you quantify the change?”

At least one dimension of each of the above criteria was addressed. In the case of relationships, five dimensions were addressed, while two dimensions were addressed for each of administrative effort and lessons learnt.

Five local governments and their alliance partners participated in this survey. These were local governments known to have participated in project alliancing at the time of the survey. While the number was small, the local governments involved represented a good cross-section ranging from larger city councils to smaller rural councils. They were located in Western Australia, Victoria (two) and Queensland (two departments of a large local government).

Initially, questionnaires were mailed to the respondents. As response through these was limited, the questionnaire was redesigned for use in a telephone interview. This was much more successful, all respondents preferring this method as they were able to clearly understand the context of each question and the whole process took about fifteen minutes to complete.

6.2 ANALYSE THE DATA COLLECTED.

The response for each of the criteria used for the questionnaire was given a score from one (representing “strongly disagree”) to five (representing “strongly agree”). Table 1 below summarises the questionnaire result.

Table 1: Summary of Questionnaire Results

Criterion	Question	Principal View Summary	Contractor View Summary
Costs	Costs improved	A : 3 N : 2	A : 5
	Comment	Two principals with alliances in early stages were unable to advise whether costs had improved.	All contractors agreed that costs had improved.
Relationships (with contract partner)	Collaborative	SA : 4 A : 1	SA : 2 A : 3
	Cooperative	SA : 3 A : 2	SA : 2 A : 3
	Tolerant	SA : 2 A : 3	SA : 2 A : 3
	Adversarial	D : 1 SD : 4	D : 2 SD : 3
	Untenable	SD : 5	D : 2 SD : 3
	Comment	Openness, teamwork, honesty were common feedbacks. Some minor areas needing improvement.	Openness, teamwork, honesty were common feedbacks. Some minor areas needing improvement.
Quality	Quality of service from contract partner improved	SA : 2 A : 3	SA : 2 A : 3
	Comment	Quality of service provided at least met requirements. Teamwork assisted quality result.	Happy with the quality of service they provided. Also agreed that teamwork was a factor in quality.
Continuous Improvement	Any notable innovation produced	SA : 2 A : 2 N : 1	SA : 1 A : 3 N : 1

Criterion	Question	Principal View Summary	Contractor View Summary
	Comment	Most alliances were producing cost saving innovations. Could have been more innovation. In one case "business as usual."	Most agreed that the alliance produced noticeable innovation. In one case not enough time yet.
Safety	Safety performance improved	N : 5	A : 1 N : 4
	Comment	No improvement as all organisations had mature safety systems at start of contract.	No improvement in most contracts as the organisations had mature safety systems at start of contract. One contractor had used psychological profiling techniques to select suitable team members from safety viewpoint.
Administration	Administrative effort to manage partner increased	SA : 1 D : 4	A : 4 D : 1
	This has had negative effect on organisation	D : 5	A : 1 D : 4
	Comment	Most considered that administration had not increased, nor had negative impact on organisation.	Most considered that administrative effort had increased, but did not have a negative effect on organisation.
Lessons Learnt	Would use relationship contracting again	SA : 2 A : 3	SA : 4 A : 1
	Local Government Authorities would benefit from relationship contracting	SA : 3 A : 2	SA : 3 A : 2
	Comment	All stated that they would use relationship contracting again. Some areas for improvement.	All stated that they would use relationship contracting again. Some areas for improvement.
SA = Strongly agree: A = Agree: N = Neither agree nor disagree: D = Disagree: SD = Strongly disagree.			

In summary, the results from Table 1 show that respondents were positive on the dimensions evaluated. The main exceptions were:

- In two cases it was too early in the relationship for the principal to tell whether costs had improved.

- One principal and one contractor (on different projects) could not identify notable innovations in the delivery of service. Both appear to be the result of it being too early to tell.
- Only in one case was it observed that safety performance of the contract had improved. This was probably due to the mature nature of the safety systems already in place.
- With one exception, principals did not report an increase in the administrative effort to manage their contract partner. On the other hand, four out of five contractors did report an increase in administrative effort. Only in one case (a contractor), however, did this have a negative effect on the organisation.

Radar (spiderweb) charts (see Figure 2 for an example) were produced for the responses to each question – one chart for the principal's response and one chart for the contractor's response. The radar charts illustrate in a qualitative sense what the respondents felt their experiences with alliance contracting has been thus far.

The five possible answers from strongly disagree to strongly agree are located on the vertices of the pentagon. Each answer is linked by concentric lines. Each concentric line represents the number of responses received for a particular answer. They are linked by lines between the responses to help illustrate where the trend of answers lie.

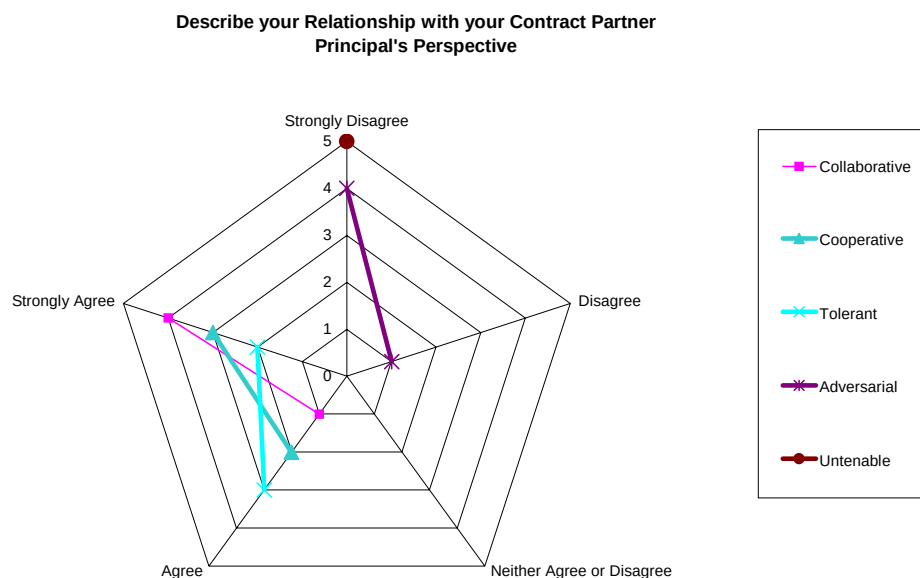


Figure 2: Radar Chart – Relationship with Contract Partner – Principal's View

Finally, responses to the questions requiring a specific answer were checked for alignment between the partners. Of 65 responses to these questions (13 per contract, each of which was answered by the principal and contractor), the number of responses were as follows:

Complete alignment - 29

Different by one answer rank - 31

Different by two answer ranks - 5

The answer rank difference refers to the distance between two answers. For example, a one answer rank difference would be when one party answers “strongly agree” and other answers “agree.”

No response differed by more than two answer ranks.

This alignment between responses (only 7.7 per cent different by two answer ranks, zero different by more than two answer ranks) was one indicator that the alliance partners were in close alignment on their opinions. A significant difference in perception about the results would have been an indicator that the alliance was under threat, and would also have caused some lack of confidence in the questionnaire results.

Questions in which the respondent could discuss the issue tended to support and explain these responses.

There were some significant innovations resulting from the use of the alliances researched. They included:

- A saving of \$3 million through eliminating a sewage pumping station.
- 20 per cent reduction in the delivery cost of a project through a team based approach that yielded efficient design, on time delivery, and no disruptions.
- Generation of a \$20,000 per annum profit for the alliance and employment of 20 disabled people through combining the resources of the principal, which owned the land, and the contractor, who provided \$1.6 million capital, for a regional waste material sorting system identified by the alliance team.

The lessons learnt showed areas in which the organisations would seek improvement in future alliances. These included:

1. Optimise the selection process.
2. Ensure the budget process is transparent.
3. Improve the outcomes of selection workshops to build stronger relationships earlier.
4. Pre agree the split of profits if more than two partners are involved.
5. Understand the implementation stages of an alliance.

There were also a number of areas identified that would prevent the creation of an alliance between a local government and a contractor. These included:

1. Contractor has something to hide or is not comfortable with the level of intrusion into its business.
2. Principal does not have staff with the suitable skills or culture to manage an alliance.
3. Contractor does not understand the principals needs or cannot meet them.
4. Perception of no openness or honesty in the relationship.
5. Upfront costs may be prohibitive.
6. Either party is not willing to take the “leap of faith.”

6.3 DEVELOP THE DECISION TOOL FOR ASSESSING ALLIANCE VIABILITY

Given the potential of project alliances to save money, deliver innovations and improve relationships, it is clear that they are desirable where they can be used.

To aid the evaluation of whether a project was suitable for the alliance method of delivery, a decision tool was developed based on the lessons learnt, the various checklists and issues raised in the references. Assessment is based on operational, technical, financial, legal and social criteria. While this tool is aimed at the needs of local governments, any organisation could use such a tool before considering whether to use an alliance contract.

The decision process is based on a qualitative analysis matrix, similar to that described in Appendix E of the Australian and New Zealand Standard for Risk Management AS4360:1999 (Standards Australia, 1999). This process qualitatively assigns a 1 to 5 rating (insignificant, minor, moderate, major, catastrophic) and a 1 to 5 (or A to E) similar rating to the likelihood (almost certain, likely, possible, unlikely, rare) of a risk. Various combinations of consequence and likelihood result in a low, moderate, high or extreme level for the risk. Numerical scores can also be used.

The risk with respect to whether the project is best delivered by an alliance process is “What can happen and how can it happen?” Each section of the tool addresses one of the alliance criteria described above. Within each section, questions are based on operational, technical, financial, legal, social and other considerations with respect to whether an alliance was the best form of project delivery.

An example risk could be “Not comfortable with agreed profit and reward model.” The assessor may rate the consequence of this as “major” and the likelihood as “unlikely.” A risk score or level (in this case “high”) would be obtained from looking up the analysis matrix.

Based on the risk assessment, and the answers to a range of other questions about the alliance, the principal would have an input into the decision as to whether to not to use alliancing for the particular project as the risks are too high, or to use it and manage the risks involved.

This tool has not yet been tested because of time constraints.

7. DISCUSSION AND CONCLUSIONS

This research has shown that alliance contracting is being used by local governments and is delivering good results. All the principals and contractors interviewed said they would definitely use alliance contracting again if the opportunity arose in the future. The team based approach, common goals and shared risk appears to create a positive work environment which many respondents claim to be the best way to do business.

The process used for the research was to review the business and project alliance process to assess the main criteria for a successful alliance project, develop a questionnaire around these criteria, seek out potential respondents to this questionnaire, obtain and analyse results, and evaluate from the issues raised in these results a decision matrix, based on risk analysis principles, for principals to use in deciding whether they should not use the alliance process for delivering projects.

One of major difficulties in conducting this research was to find organisations which had sufficient experience of using the alliance process to deliver projects. As relationship contracting becomes better known, it should be possible to extend this research to more organisations.

Of the criteria explored in the questionnaire, that of safety provided least information, probably because the organisations had mature safety systems. This criterion may need review in future research.

Informal feedback from principals suggested that the questionnaire covered all relevant issues and was not too long. Telephone interviews appeared to be the best way of gathering data.

The effectiveness of the change to alliance contracting was captured in the lessons learnt criterion of the questionnaire, from both principal and contractor. This use of both parties provided a balanced view of the process and an insight into what the contractors need to consider when they engage in relationship contracting.

The decision matrix using a risk management approach provide a useful starting point for any local government (or other principal) considering adopting alliance contracting. As it is based on a proven process of assessing risk, it offers flexibility to adapt the context, goals and objectives, and risk management criteria to meet each organisation's particular needs. It is intended to guide the principal to a point from which further analysis could be undertaken.

It is concluded that this research provides a methodology for assessing the usefulness of the project alliance process for delivering civil works in the local government context. The principles discussed, and the decision matrix for assessing whether or not to adopt the alliance process for delivering works projects, are applicable to any organisation.

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STAKEHOLDERS, INNOVATIVE WAYS OF DELIVERING IMPROVED SATISFACTION

Full paper

USE OF 'VIRTUAL REALITY WALKTHROUGH PANORAMA' TECHNOLOGY TO ASSESS PUBLIC PERCEPTIONS OF PERSONAL SAFETY ON RAILWAY STATIONS

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ABSTRACT

This project originated from the business need of Valley Lines, a UK Train Operating Company, to deliver growth on the rail network serving the city of Cardiff, capital of Wales. The network serves 67 stations handling more than 1 million passenger journeys per year. Spare capacity existed for journeys that customers were not making due to concerns about their own personal safety, whereas in fact across the network as a whole actual recorded crime is very low. Concern was also expressed about access routes to the station, which were outside the control of the company. Improvements would require a good business case if local authorities were to fund them.

The methodology was based on focus groups coupled with a questionnaire, providing a research environment with which the company was familiar. A series of focus groups was convened covering in total 47 respondents from a mix of gender, age and frequent and infrequent users.

The research tool was that of the 'virtual reality (VR) walk-through'. This technique allowed stations to be 'toured' in detail by respondents in a controlled environment, allowing a fully interactive panorama to be developed from the respondent's entry from public areas into the station itself. The respondents were able to view in and out and pan left and right at any stage of the journey and thus accurately mimic their

behaviour as a station customer. Each focus group was asked to suggest measures that could improve their *sense* of personal safety. Considerable preliminary work was undertaken to identify likely issues and to cluster the stations on the network into family groups with similar physical characteristics. From this analysis six representative stations were selected.

The groups produced a clear hierarchy of concerns and some very practical recommendations, mainly on the theme of improving visibility. As a result, the company has taken action: for example to clear away vegetation, improve lighting levels, and the design and installation of new, transparent shelters.

The project showed the VR walk-through tool was cost effective and versatile. This research tool has application outside the rail industry. Most importantly the research has delivered cleaner and safer railway stations to the people of south Wales, which they also *perceive* as safer place to be.

Keywords: personal safety, VR panorama, railway stations

1. INTRODUCTION

This project originated from the business need of Valley Lines, a UK Train Operating Company, to deliver growth on the rail network serving the city of Cardiff, capital of Wales, and its hinterland at times of the day and for journeys where spare capacity existed. This capacity existed at times and for journeys that customers were not making due to concerns about their own personal safety and that of their property. In order to deliver this growth and to sustain current levels of patronage there was also an objective to demonstrate to local and regional government, as external funding bodies outside the privatised rail network, that investment in environmental improvements was being undertaken on a sound and measurable basis. The project delivered this through an innovative visual research tool that led to investment in the network and further growth in volume.

This paper presents this work as a case study, starting with a description of the railway network, the company and the issues to be addressed. After a brief review of relevant literature, the methodology and results are described and discussed, followed by a summary of the changes made to the railway stations and the surrounding areas as a result. By way of amplification, a map of the Valley Lines railway network and a pair of 'before and after' photographs of an improved station are shown in an Annex.

2. THE 'VALLEY LINES' STATION CONTEXT

The Valley Lines network serves Cardiff, the Capital of Wales, with radial routes south to the coastal towns and north to some of the south Wales valleys. Cardiff and most of its immediate surrounding suburbs to the north and south are relatively prosperous. North of Cardiff two thirds of the routes serve the economically deprived valleys of the former South Wales coalfield, with deprivation levels being of such level that GDP falls below 74% of the European Union average.

The decline of the coalfield has meant that 73% of journeys take place into central Cardiff. Journeys are split almost equally between those made for leisure and commuting and tend to take place during the day. Growth in journeys of 40% over the last 3 years to ~7.5 million journeys per annum has led to significant constraints in capacity. An opportunity was identified to increase patronage levels in the evening and for journeys taking place against the peak flows into or out of Cardiff to other locations.

The network serves 67 stations of which 15 are staffed and only two can be considered large (handling more than 1 million passenger journeys per year). Vandalism at the smaller un-staffed stations had been endemic. To combat these issues, prior to commencement of this project, nearly half the stations had been equipped with CCTV, but with little in the way of a formal methodological approach to the assessment of risk prior to installation. Of significance, across the network as a whole, is the fact that *actual* recorded crime is and was statistically very low.

The impetus for the project originated with an advertising focus group in one of Cardiff's affluent northern suburbs served by a well equipped and newly refurbished station. Out of this came some surprising customer concerns. There was a generally high level of disquiet over travel after dark and to unfamiliar stations, particularly for lone females. Significantly, concern was expressed about access routes to the station which were outside the ownership and the direct control of the company. To

initiate improvements here would require a good business case if local authorities were to fund them.

The basic issue therefore was one of perceived personal safety, that appeared to be heightened by darkness, lack of familiarity and concerns over access routes to and within the station.

An extended period of growth and constrained capacity was leading to lack of capacity and consequent overcrowding during the morning and evening peak periods. Two opportunities were identified for potential growth: encouraging customers to consider the network for journeys other than into or out of Cardiff; and to consider using the network more in the evening. These were the two types of journey that the initial research suggested were causing customers the most concern with respect to their personal safety.

3. BRIEF REVIEW OF RELEVANT PUBLISHED RESEARCH

This paper is essentially a practice-based case study, but a brief review of some of the literature will provide a wider perspective.

There is a general need for more research into rail transport. Clarke (1996) has called for more studies to be funded by transit authorities and the Head of Rail Research UK, Keith Madelin (2003, p31), recently remarked that the rail industry "has ignored the potential benefits of academic research into new technologies and systems that could help to solve some of its problems". In terms of the design of the physical, built infrastructure of railways, there is a need to make more effort to take into account the views and needs of the customers; for example, the preferences of architects and design professionals have been studied and shown to differ from those of the ordinary citizen. (Groat 1982; Devlin 1990; Downing 1992; Purcell and Nasar 1992; Stamps and Nasar 1997).

Published work on crime and personal safety indicates the difficulties of definition and analysis. The British Crime Survey (BCS) (Mirrlees-Black *et al.* 1998) estimates that criminality is as much as four times higher than reported statistics indicate. Furthermore, the 'dark figure' of crime, that which is not reported or recorded, clearly exacerbates the problem of analysing recorded incidents of crime at the spatial level (Scott 1990; Maguire 1997). As a determinant of human behaviour, *perceptions* of exposure to personal risks of criminal activity are as important as the *actual* risk. Fear of crime can result in the withdrawal of the community from a location and a reduction in the number of people that might actively assist in the self-policing of a neighbourhood – known as "eyes on the street" (Jacobs 1961). Likewise, perceptions of crime on the railways have been shown to affect levels of usage and passenger confidence (Brantingham *et al.* 1991). Indeed, Crime Concern and Transport and Travel Research (1997) recently reported that 43% of women and 18% of men felt that rail travel in the UK was "unsafe". They also suggested that a 15% increase in all train journeys could be achieved if a range of communal security measures were successfully implemented.

Investigating how the design and management of stations affects public perceptions is therefore a worthwhile avenue for investigation. Indeed, the crucial role of perceptions in understanding crime and design has been highlighted with regard to residential housing (Tijerino, 1998; Ham-Rowbottom *et al.* 1999; Cozens *et al.* 2001) and public transport (Brantingham *et al.* 1991; Parliamentary Travel Safe Committee, 1998; Cozens 2002). Recently, the Legislative Assembly of Queensland (Australia)

commented that: "the public's perception of crime is an important determinant of people's usage of public transport" (Parliamentary Travel Safe Committee 1998, p16).

4. METHODOLOGY

The research methodology had to deliver against the commercial requirement that if these concerns were to be addressed, there would be need to attract external funding to make changes.

The Company's 'perception tracking studies' had proved too crude in their application and sample size to justify major improvements, but did raise some negative issues. Other existing methodologies used within the UK to tackle some of these issues consist of two schemes covering the Secure Accreditation of Stations and the Secure Accreditation of Car Parks. However, both of these have been designed to address issues at larger staffed stations and car parks and not the type of smaller and un-staffed stations that predominate on the Valley Lines Network.

The business case required to initiate the project was made on the basis that personal safety issues were being expressed by customers and that existing methodologies did not exist to justify the levels of investment being required. To put this into context the project lasted in total three years at a total cost of about £200k. The cost of a transparent waiting shelter - thought to be a major benefit and later proved as such - was costed at £20k, thus drawing in funding to install just ten of these gave a breakeven position, yet this was just one potential improvement. The installation of even a basic CCTV system costing in the order of £50k per location gave the potential for an even quicker break even position.

The University of Glamorgan was approached because it had a clear social advantage through its knowledge and location within the region and its interest in personal safety.

The research tool developed used the 'QuickTime' virtual reality walk-through. This technique allowed individual stations to be 'toured' in detail by respondents in a controlled environment in order to assess their perceptions of it. The use of photographs to test perceptions was ruled out at an early stage of the assessment phase due to the limitations inherent in trying to represent the complexity of the station environment, particularly when attempting to assess perceptions of unfamiliar locations. Video was considered as an alternative, but was also rejected because of the concerns that such an approach would only offer one fixed, linear visual journey to the respondent and would not allow them to move through the station in a way that they would do in reality, so running the risk of leading the respondent to draw conclusions driven by the prejudice of the author of the film.

The virtual reality (VR) walk-through allowed a panorama to be developed from the respondent's entry into the station, from public areas, into the confines of the station itself. Once within the station the respondent could then explore within it. The technique itself involved the photographing of a series of 360 degree panoramas at carefully chosen points outside and within the station. These individual panoramas were then linked together to create the 'virtual' journey through the station, the respondents being able to view in and out and pan left and right at any stage of the journey and thus accurately to mimic their behaviour in the field. (It should be noted that 'QuickTime' is not a full 'virtual reality' tool, using three-dimensional computer

generated models of the station, but is based on photographic panorama views on the actual stations).

Before the work was undertaken considerable study and analysis was undertaken to cluster the stations on the network into 'family groups' with similar physical characteristics. This stage took into account some of the early indications of where particular problems might be located, such as excessive overgrowth, general visibility and structural features such as underpasses.

From this initial sorting six representative stations were selected that ranged in character from isolated, un-staffed, single track stations with little in the way of security features through to urban stations that were staffed and had a range of security measures in place including CCTV. These stations, taken together, possessed all the characteristics that had been identified as potential causes of concern.

Focus groups were used to allow an open exploration of the respondents' views to be undertaken. It was also important from a Company point of view that this was a research method which it used routinely, so the benefits and limitations of the technique were understood. Respondents were recruited from users of the six representative stations. A series of 90 minute focus groups was convened covering in total 47 respondents (26 female and 21 male) from a combination of frequent and infrequent users, and ranged from 19 to 65 years of age. Each group was taken through a VR walk-through of 'their' local station and also of another representative station to which they did not normally travel – a 'home and away approach'. These walk-throughs included both the station itself and the immediate environment outside the station. The respondents could control 'where they went' and the level of detail that they saw. To assist in the codification of the results each respondent completed a questionnaire in which they were asked to state whether they had personal safety concerns relating to the various individual segments of the journey for a journey after dark as well as during daylight hours. They were then asked to suggest a range of measures that could be undertaken to improve their *sense* of personal safety.

5. RESULTS AND DISCUSSION

The focus groups produced some very tangible results with a clear hierarchy of concerns, as shown in Table 1. Female respondents exhibited a significantly higher level of concern for their personal safety across almost all the factors mentioned. This was particularly significant when approaching or waiting on the station after dark. Amongst male respondents the highest concerns related to security of their cars in station car parks both during the day and after dark.

Waiting on the platform after dark was also a significant area of concern, heightened by the infrequent nature of some evening train services causing extended waiting periods. Overall personal safety fears decreased during daylight hours. One of the overriding factors was the theme of visibility. Observation by nearby houses and those engaged in other activities near the station were particularly important.

Table 1. Personal Security Concerns at Stations

Personal Security Concerns	Females %	Males %	All %
When waiting for a train on the station platform after dark	93	53	75
When approaching the station after dark.	93	49	73
For the security of vehicle in car park after dark	78	58	66
For the security of vehicle in car park in the day.	72	58	63
When travelling on the train after dark.	80	37	60
When using the car park after dark.	63	58	60
Due to an infrequent service after dark.	57	36	51
When waiting for a train on the station platform in the day.	17	18	19
When travelling on the train in the day.	15	18	16
When approaching the station in the day.	20	6	16
Due to an infrequent service in the day.	13	12	15
When using the car park in the day.	0	22	12

The VR 'walk-throughs' were all undertaken during daylight hours, however the single most important factor in term of proposed improvements mentioned by both males and females was improvements to lighting, which reflected the universal concern by respondents of both gender to travel after dark. CCTV was mentioned by 62% of all respondents, although it was already in operation at 4 of the 6 stations where the walk-throughs took place. Transparent shelters were mentioned by 43% of the respondents as a suggested improvement, cleaner stations (38%), longer trains (34%) and cutting back vegetation (30%).

In interpreting the results it became clear that customer *perception*, given the low crime rates, was crucial. This very much reinforced the original focus group findings that indicated users had personal safety fears with a newly refurbished station in a prosperous suburb. What the further research did was deliver a series of action-orientated results, with a clear hierarchy of importance, as shown in Table 2.

6. IMPROVEMENTS TO THE STATIONS AND THE SURROUNDING AREAS

The first improvement to be undertaken by the company was vegetation clearance. Since the withdrawal of steam trains in the 1960's the necessity to reduce the risk of fire by regular vegetation clearance had diminished, leading to overgrowth that contributed to concerns of visibility at almost all locations sampled. This was an activity that the Company was able to undertake utilising its own maintenance teams with a small investment in plant and operator training. This gave an immediate impact at the locations identified in the six pilot locations and the lessons learnt were then progressively rolled out across the network.

Most local authorities in the UK now have their town centres covered by CCTV. The fact that respondents put CCTV at the top of their priorities for improvement assisted in reinforcing already held perceptions, but most importantly from a research based background. A progressive programme of CCTV is now being implemented with the majority of the stations outside of Cardiff now being covered.

Table 2. A Hierarchy of Proposed Improvements

Ranking of Improvements – Females	%	Ranking of Improvements - Males	%
More/better lighting	81	CCTV	62
CCTV	62	More/better lighting	52
Transparent shelters	58	More staff	48
More staff	38	Cleaner stations	43
Cleaner stations	35	Longer trains	43
Cut back vegetation	35	Less underpasses/better bridges	29
Longer trains	27	Cut back vegetation	24
Less underpasses/better bridges	27	Get rid of gangs/yobs	24
Better signage	27	More reliable service	24
Help points/panic buttons	19	Transparent shelters	24
Get rid of gangs/yobs	19	More frequent trains	19
More frequent trains	19	Clearer information	19
Coat of paint	15	Better signage	14
Better/easier access	12	Make platform more open	14
Better links to community	8	Better links to community	14
Demolish old buildings	4	Better/easier access	10
More reliable service	4	Help points / panic buttons	5
Busier trains/more people around	4	Coat of paint	5
Clearer information	4	More Spaces between seats	5
More Spaces between seats	0	Busier trains/more people around	5
Co-ordinated transport system	0	Co-ordinated transport system	5
Make platform more open	0	Demolish old buildings	0

Five years ago the company embarked on a partnership with Network Rail, the infrastructure provider, and a manufacturer of street furniture to develop a waiting shelter that would meet the criteria of visibility. The results of this research have assisted in the installation of these shelters on seven sites with more to follow, assisted by substantial funding from external parties – see Annex for photographs.

The depth and realism of the VR technique highlighted the very high concern amongst respondents of their personal safety after dark. There is no doubt that this is not something that would otherwise have become apparent. This led to a secondary phase of the project, again involving focus groups, partly conducted under controlled conditions, but also at stations at night in a controlled trial where luminance levels were raised at a pilot location. Whilst this was successful in confirming the role that lighting levels play in perceptions of personal safety, it also served to highlight the weaknesses of using a focus group in an external environment and the comparative strength of the controlled and standardised images of the VR. Further work on the VR technique in a night-time environment would be useful.

Two other factors were highlighted in particular by respondents. The first was the issue of train service capacity and frequency. The issue of frequency relates to the time spent waiting for trains. Under current UK funding arrangements, in a heavily subsidised urban network, making changes is a much more difficult proposition than might first appear and whilst improvements have taken place they have not as yet been entirely attributable to the research findings.

Secondly, station cleanliness is an issue for which the company has been able to take direct action itself as a consequence of the research. The results of this have been significant enough to be identified on the Company's tracking study.

7. CONCLUSIONS

The original research brief was orientated to find a commercial solution in order to deliver business investment and hence volume growth. The project met this objective by delivering a set of tangible, verifiable and applicable results. The outputs from the study in south Wales are of potential benefit to other parts of the urban rail network in the UK.

What also came out of the project was a research tool in the form of the VR walk-through and a comprehensive methodology for its effective use. This proved to be an extremely cost-effective and versatile solution, providing tangible benefits over other methodologies. This is a research tool that has application outside the rail industry. The technological solution proved to work particularly effectively within the focus group environment, providing a controlled visual stimulus through which to assess respondent's concerns and potential behaviours. It also demonstrated the flexibility and cost-effectiveness of this highly portable medium. This had a number of benefits. It allowed the walk-throughs to be captured easily in a wide variety of different station environments and to give respondents a very real spatial interaction with the environment. The use of focus groups coupled with questionnaires provided a research environment for the company with which it was familiar and also provided the opportunity for observation by members of the company. The technique delivered a set of results that indicated some clear courses of action to be undertaken to promote personal safety.

Most importantly the research has delivered cleaner and safer stations to the people of south Wales that they also *perceive* as safer place to be.

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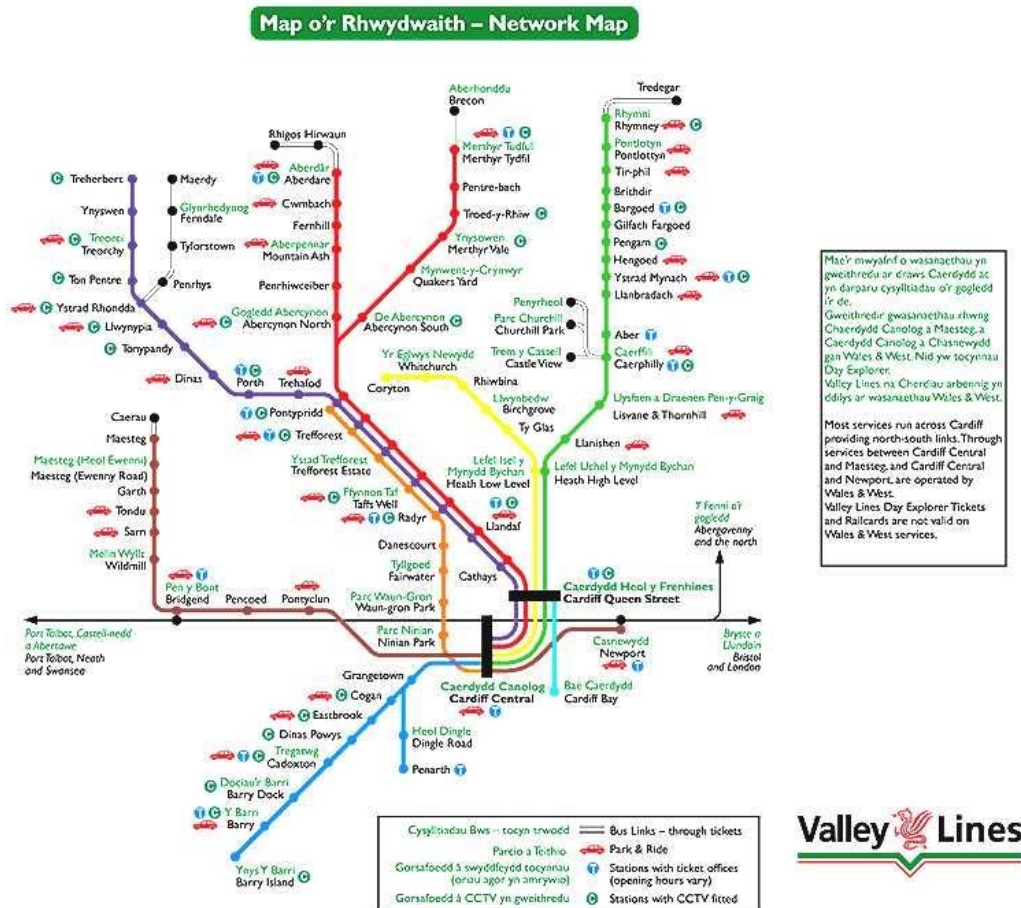
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Annex: Map of the Valley Lines rail network and 'before and after' photographs of a station





Original form of Dingle Road station



Dingle Road station after improvements

INNOVATIVE ASSET MANAGEMENT

Full Paper

DEVELOPMENT OF A USER FRIENDLY GUIDE FOR REHABILITATION OR STRENGTHENING OF BRIDGE STRUCTURES USING FIBER REINFORCED POLYMER COMPOSITES

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ABSTRACT

A worldwide interest is being generated in the use of fibre reinforced polymer composites (FRP) in rehabilitation of reinforced concrete structures. As a replacement for the traditional steel plates or external post-tensioning in strengthening applications, various types of FRP plates, with their high strength to weight ratio and good resistance to corrosion, represent a class of ideal material in external retrofitting. Within the last ten years, many design guidelines have been published to provide guidance for the selection, design and installation of FRP systems for external strengthening of concrete structures. Use of these guidelines requires understanding of a number of issues pertaining to different properties and structural failure modes specific to these materials. A research initiative funded by the CRC for Construction Innovation is currently underway (primarily at RMIT) to develop a decision support tool and a user friendly guide for use of fibre reinforced polymer composites in rehabilitation of concrete structures. This paper presents the development of the user friendly guide and recommended procedures for the design and construction of externally bonded FRP systems for strengthening of aging reinforced concrete bridge based on the design guidelines reported by ACI committee 440, the European design guideline (FIB 14), AS 3600 (2002) and Austroads Bridge design code (1992).

Keywords: Bridges, rehabilitation, strengthening, user friendly guide line, design and construction.

1 INTRODUCTION

Rehabilitation and upgrading of existing civil engineering infrastructure has been of great importance during the last decades. There are number of situations where the structural capacity of a structure in service needs to be increased. Fibre reinforced composite (FRP) systems can be used for the strengthening or retrofitting of existing concrete structures to resist higher design loads, correct deterioration-related damage, or increase ductility. These advanced composites used in bridge rehabilitation are being developed from fibres, polymers, metals and composites of these materials. While the concept of composites have been used in building industry for several millennia, the application of fibre reinforced polymer (FRP) for rehabilitation and strengthening of reinforced concrete structures is relatively new. Externally bonded FRP systems have been used to strengthen and retrofit existing concrete structures overseas and in Australia, eg, Westgate Bridge and Little Bridge Victoria (Kalra and Neubauer, 2003 and Shepherd and Sarkady 2002). The number of projects utilizing FRP systems has dramatically increased worldwide, from a few ten years ago to several thousand today (Bakis et al. 2002). The FRP composites combine the strength of the fibres with the stability of the polymer resins. They are defined as polymer matrix, that are reinforced with fibres or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a desirable reinforcing function in one or more directions. The FRP composite materials are different from traditional construction materials such as steel, aluminium and concrete because they are anisotropic; i.e., the properties differ depending on the direction of the fibres.

FRP composites gain their strength largely from the fibres, which are usually glass, carbon, or Aramid fibre. FRP materials are lightweight, non-corrosive, non-magnetic and exhibit high tensile strength. Additionally, these materials are readily available in several forms ranging from factory made laminates to dry fibre sheets that can be wrapped to conform to the geometry of a structure before adding the polymer resin. Although the fibres and resins used in an FRP system are relatively expensive compared with traditional strengthening materials like concrete and steel, labour and equipment costs to install FRP systems are often lower. FRP systems can also be used in areas with limited access where traditional techniques would be difficult to implement.

Due to the characteristics of FRP materials, behaviour of FRP strengthened members, and various issues regarding the use of externally bonded reinforcement, the development of design guidelines for FRP system is ongoing in Europe, Japan, Canada and the United States. Within the last ten years, many design guidelines have been published to provide guidance for the selection, design and installation of FRP systems for external strengthening of concrete structures. However there is still little independent user friendly guidance on the design and construction of the FRP strengthening systems. Some FRP suppliers provide limited advice but this tends to be system specific and may not be compatible with Australian design codes. Because of this lack of design and construction guidance, a user friendly guide in rehabilitation and strengthening of reinforced concrete bridge structures is being developed as part of the CRC-Construction Innovation funded project of "Decision Support Tool in Rehabilitation of Concrete Infrastructures", which would be applicable to all types of FRP and all strengthening systems, and set in the context of the Australian codes and standards. The aim of this paper is to briefly describe the background, nature and mechanics of producing the user guide. Set in the context of limit state philosophy, the guide provides design guidance on flexural and shear strengthening of the beam and columns, and flexural, axial compressive and ductility

enhancement of columns. The construction procedures are also briefly explained including material types and properties, field applications, workmanship and installation.

2 SCOPE OF THE USER GUIDE

The user guide generally aims to provide design and construction guidance on strengthening of concrete structures with fibre composite materials in accordance with Australian design codes and standards. The design procedures are the key feature of the guide, which may be applicable to all FRP materials and strengthening techniques. The procedures are based on generally accepted principles, and in line with the approaches developed elsewhere based on extensive research, particularly such as in USA and Europe. The material and physical properties of FRP materials and manufacturing methods are reviewed in so far as they have a direct impact on the design and construction of the FRP strengthening system. Information on the properties of commercially available materials is also presented and a list of the suppliers and their contact details are included. Surface preparation of the substrate concrete and installation of FRP are vital aspects and have therefore been covered in the guide. Some guidance in quality control and inspection and monitoring are included.

It is required to assess suitability of an FRP system for a particular application. A condition assessment of the existing structure should be performed and the best treatment option should be then determined based on the assessment (ACI, 440, 2002). The condition assessment can be performed based on AS 3600(2002), Austroads Bridge design code (1992) and other related Australian codes and standards. The recommended assessment procedures are outlined in the user guide.

3 MATERIAL PROPERTIES

FRP composite materials for strengthening of civil engineering structures are available today mainly in the form of:

- thin unidirectional strips (with thickness in the order of 1 mm) made by pultrusion
- flexible sheets or fabrics, made of fibres in one or at least two different directions, respectively (and sometimes pre-impregnated with resin)

FRP systems come in a variety of forms, including wet lay-up systems and pre-cured systems. FRP system forms can be categorized based on how they are delivered to the site and installed. The FRP system and its form should be selected based on acceptable transfer of structural loads and ease and simplicity of application. The manufacture of FRP materials is outlined and some general guidance on selection of FRP system and materials for particular strengthening applications are also provided. Indicative physical and mechanical material properties of some FRP prefabricated strips and fibres are included in the guide. The other related aspects of FRP materials such as durability, fire and electricity resistance, safety and environmental impact on material properties for different types of fibres are also discussed.

4 STRENGTHENING TECHNIQUES

To help the users in selection of an appropriate strengthening system, a brief summary of the available strengthening techniques and projects where externally bonded FRP has been applied for rehabilitation of existing concrete structures have been given. The references to published articles and guidelines are provided wherever possible. These will provide the users with a source of further information and help to identify and select the most suitable technique for a particular case of strengthening.

5 DESIGN GUIDELINES

Since the use of FRP composites for strengthening of reinforced concrete structures is a relatively new technique, the development of design guidelines for externally bonded FRP system is ongoing in Europe, Japan, Canada and the United States. Within the last ten years, many design guidelines have been published to provide guidance for the selection, design and installation of FRP systems for external strengthening of concrete structures. Applications of provisions of the two major guidelines of Task Group 9.3 of the international Federation for Structural Concrete published bulletin 14 (FIB 14) and ACI Committee 440 in rehabilitation of the headstock were discussed and compared by Nezamian and Setunge (2004). It was then concluded that the use of ACI 440 design guideline may be more appropriate for FRP strengthening applications in Australia. The design concepts and philosophy used by ACI is similar to those adopted by AS3600 (2002). However, in considering the failure of FRP composites in de-bonding and anchorage zones, use of FIB appears to be more appropriate since it systematically covers all possible scenarios. The design guidance in the user friendly guideline is developed mainly based on the ACI 440 (2002) recommendations. The FIB recommendations in preventing the delamination of the FRP were included to check debonding.

6 DESIGN GUIDANCE

In accordance with the Australian codes of practice for structural design, the design methods are based on limit-state design philosophy. This ensures that a strengthened member will not become unfit for its intended use. It will not also fail at an accidental overload during its design life with 95% confidence. All necessary design situations and load combinations need to be considered according to Austroads Bridge design code (1992). This approach sets acceptable levels of safety against the occurrence of all possible failure modes. The nominal strength of a member is then assessed based on the possible failure modes and subsequent strains and stresses in each material (see Figure 1).

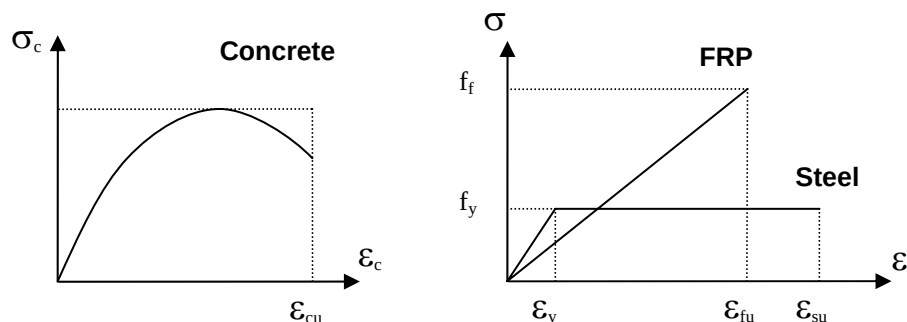


Figure 1: Idealised stress-strain curves for constitutive materials at ULS

The design of the FRP composites involves assessing the effects of the additional FRP reinforcement provided to the section (designed assuming full composite action) and the ability of transferring forces by means of the bond interface. All possible failure modes should be investigated for a FRP strengthened section (Ganga Rao and Vijay 1998). In general, the failure modes can be subdivided to those assuming full composite action between the reinforced concrete / pre-stressed concrete member and the FRP and those verifying the different de-bonding mechanisms that may occur. The state of the structure prior to strengthening is taken as a reference for the design of the externally bonded FRP reinforcement. The strength of strengthened member depends on the controlling failure mode. However, the user guide identifies and discusses limit states relevant to the use of FRP for strengthening and rehabilitation of concrete structures. It also includes checks for FRP separation and other requirements, which are peculiar to this method of construction. The user guide contains procedures for the Flexural, shear and torsional strengthening of the beams and slabs and axial compressive and ductility enhancement of columns. The recommended design procedures are briefly reviewed in the following subsections. Worked examples will be provided illustrating each design scenario.

6.1 FLEXURAL STRENGTHENING

Bonding FRP to the tensile soffit of the beam increases the flexural strength of the concrete elements. In the section analysis for the ultimate state in flexure, the user guide follows well established procedures using the idealised stress-strain curves for concrete, FRP and longitudinal reinforcement (Figure 1). These curves, along with the following assumptions, form the basis for the capacity analysis of a concrete element strengthened in flexure. Design calculations are based on the actual dimensions, internal reinforcing steel arrangement, and material properties of the existing member being strengthened.

- The strain in reinforcement and concrete are directly proportional to the distance from the neutral axis, that is, a plane section before loading remains plane after loading.
- There is no relative slip between external FRP reinforcement and the concrete
- The shear deformation within the adhesive layer can be neglected since the adhesive layer is very thin with slight variations in its thick

The cross section analysis identifies all possible failure modes. Failure of the strengthened element may then occur as a result of various mechanisms as follows:

- Crushing of the concrete in compression before yielding of the reinforcing steel
- Yielding of the steel in tension followed by rupture of the FRP laminates
- Yielding of the steel in tension followed by concrete crushing
- Shear/tension de-lamination of the concrete cover
- De-bonding of the FRP from the concrete substrate

The design principles are shown in Figure 2

6.1.1 Anchorage

Experimental investigations show that the FRP rupture is a rare event and de-lamination of FRP strips is more likely to occur before stress in the FRP reach the

ultimate level. De-bonding implies the complete loss of composite action between the concrete and FRP laminates. Bond failure will be a brittle failure and should be prevented. The guide place a limitation on the strain level in the laminate to prevent de-lamination of FRP from the concrete substrate.

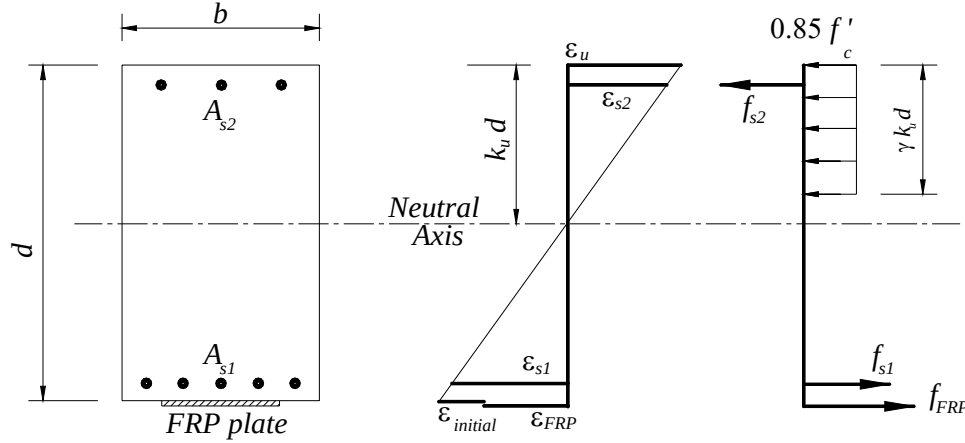


Figure 2: Internal strain and stress distributions for the beam cross section

With due consideration to the conclusions of the comparison between the ACI and the FIB guidelines conducted by Nezamian & Setunge (2004), the following failure modes were also considered in the user guide to prevent de-lamination of FRP.

- De-bonding in an un-cracked anchorage zone
- De-bonding caused at flexural cracks
- De-bonding caused at shear cracks

6.2 SHEAR AND TORSIONAL STRENGTHENING

Externally bonded FRP laminates and fabrics can be used to increase the shear strength of reinforced concrete beams or columns. It can be seen that the shear capacity of columns can be easily increased by complete wrapping of FRP around the element. Shear strengthening of beams is likely to be more problematic due to the difficult access to all faces of a beam element. This increases the risk of debonding at the beam / slab junction. The design for shear strengthening of a reinforced concrete member is generally based on truss model and superposition principle with some considerations for the orthotropic behaviour of the CFRP material. The shear strength of a strengthened member is determined by adding the contribution of the CFRP reinforcing to the contributions from the concrete and shear reinforcement.

$$\phi V_n = \phi (V_{uc} + V_{us} + \psi_f V_f) \quad \text{Eq. 1}$$

To calculate the shear resistance of the FRP wrapping, the design strain in the FRP need to be evaluated. Its value depends on the failure mode of the strengthening member. The following failure modes are also considered to cover the possible failures.

- Loss of aggregate interlock
- FRP rupture

- Delamination of the FRP from the concrete surface

Design involves calculating the design strain and determining the shear capacity of the FRP wrapping system.

Strengthening for increased torsional capacity may be required in conventional beams and columns, as well as in bridge box girders. The principles applied to strengthening in shear are also valid in the case of torsion. There are a few minor differences, which are highlighted in the user guide.

6.3 STRENGTHENING OF THE COLUMNS

Bonding hoop FRP to the column surface enhances axial load capacity, shear capacity and ductility of columns. FRP wrapping exerts a continuously increasing confining action. The amount of this action depends on the lateral dilation of concrete, which in turn is affected by the confining pressure. Thus, FRP-confined concrete models should account for the interaction between the laterally expanding concrete and the confining device. Predictive equations of the ultimate strength and strain of FRP-confined concrete should also consider this peculiar behaviour. The confinement delays rupture of the concrete, thereby enhancing both the ultimate compressive strength and ultimate compressive strain of the concrete. The compressive strain to failure of the concrete due to the hoop wrapping should be known to calculate the effect of hoop wrapping in axial compressive enhancement of columns. The axial compressive strength of a strengthened concrete member confined with FRP wrapping may be calculated using the confined concrete strength. The formulations of the confinement model and axial capacity of the strengthened member are presented in the user guide.

The method of selecting the jacket thickness for a target displacement ductility factor μ_Δ is a relatively straightforward procedure: First the equivalent plastic hinge length L_p for a given column is calculated based on the yield stress and diameter of longitudinal rebars. From L_p and μ_Δ the curvature ductility factor $\mu_\phi = \Phi_u / \Phi_y$ is established. The yield curvature Φ_y may be found from moment-curvature analysis of the cross section, whereas the maximum required curvature Φ_u may be obtained (again from section analysis) in terms of the ultimate concrete strain. Hence the required value for ϵ_{cu} can be established and an appropriate confinement model can be used to solve for the required FRP thickness.

6.4 OTHER CONSIDERATIONS

The user guide suggested imposing reasonable strengthening limits to guard the strengthened member against failure of the FRP strengthening system and collapse of the structure due to fire, vandalism, or other causes. It is recommended that the existing strength of the structure be sufficient to a level of load as described by below Equation.

$$(\phi R_n)_{existing} \geq (1.2S_{DL} + 0.85S_{LL})_{new} \quad \text{Eq. 2}$$

where S_{DL} is dead load and S_{LL} is live load.

Environmental conditions affect the performances of the FRP system. The mechanical properties of FRP systems degrade under exposure to certain

environments, such as alkalinity, salt water, chemicals, ultraviolet light, high temperatures, high humidity and freezing and thawing cycles. The user guide accounts for this degradation using the environmental reduction factor for the design material properties of FRP.

7 SURFACE PREPARATION AND FRP INSTALLATION

Clearly, the design guidance is only valid if the installation of the fibre composite materials is carried out correctly. Condition of FRP application should be examined carefully during the winter season or in cold zones. Temperature, relative humidity, and surface moisture at the time of installation can affect the performance of the FRP system. Conditions need to be observed before and during installation include surface temperature of the concrete, air temperature, relative humidity, and corresponding dew point. An auxiliary heat source can be used to raise the ambient and surface temperature during installation

If the FRP installation is to remain effective, focusing on the condition of the existing substrate is an essential requirement. The behaviour of concrete members strengthened or retrofitted with FRP systems is highly dependent on a sound concrete substrate and proper preparation and profiling of the concrete surface. An improperly prepared surface can result in debonding or delamination of the FRP system before achieving the design load transfer. All problems associated with the condition of the original concrete and the concrete substrate that can compromise the integrity of the FRP system should be addressed before surface preparation begins.

Externally bonded FRP systems should not be applied to concrete substrates suspected of containing corroded reinforcing steel. The expansive forces associated with the corrosion process are difficult to determine and could compromise the structural integrity of the externally applied FRP system. The cause(s) of the corrosion should be addressed and the corrosion-related deterioration should be repaired before the application of any externally bonded FRP system.

Some FRP manufacturers have reported that movement of cracks 0.3 mm and wider can affect the performance of the externally bonded FRP system through delamination or fibre crushing. Consequently, cracks wider than 0.3 mm should be pressure injected with epoxy. Smaller cracks exposed to aggressive environments may require resin injection or sealing to prevent corrosion of existing steel reinforcement. Prior to FRP installation, the surface of the concrete must be cleaned so that is free of laitance, dust, grease and other bonding inhibiting materials that are likely to effect bond strength between FRP and the concrete. Uneven concrete surface irregularities (off sets) must be ground and smoothed to less than 1 mm. Where fibres wrap around the corners of rectangular cross sections, the corners should be rounded to a minimum 13 mm radius to prevent stress concentrations in the FRP system and voids between the FRP system and the concrete. Roughened corners should be smoothed with putty. Obstructions, re-entrant corners, concave surfaces, and embedded objects can affect the performance of the FRP system and should be addressed. Obstructions and embedded objects may need to be removed before installing the FRP system. In applications involving confinement of structural concrete members, surface preparation should promote continuous intimate contact between the concrete surface and the FRP system (ACI 440, 2002).

8 QUALITY CONTROL AND INSPECTION

There will be a need to check the FRP strengthening system as part of the regular inspections and monitoring. Quality assurance and quality control programs and criteria are to be maintained by the FRP system manufacturers, the installation contractor and others associated with the project. The quality-control program should be comprehensive and all aspect of the strengthening procedures needs to be covered. Quality assurance is achieved through a set of inspections and tests such as adhesion testing, load testing and tensile pull-off test to evaluate acceptability of the FRP installation. A qualified inspector or licensed engineer shall observe all aspect of on site material preparation and application, including surface preparation, resin component mixing, application of primer, resin and FRP, curing of composite, and the application of protective coating. The surface of the fibre composite should also be inspected visually for signs of crazing, cracking or delamination. De-bonding of the FRP material from the concrete may be determined by acoustic tapping or thermography tests.

FRP strengthening system needs to be evaluated and accepted/rejected at the end of construction based on conformance with the design drawing and specifications. This includes FRP material properties, installation within specified placement tolerances, presence of the delaminations, cure of resins, and adhesion of the FRP material to substrate.

9 CONCLUSIONS

The paper described the development of the content of a user guide for design and construction of strengthening schemes using FRP composites for bridge structures complying with the Australian standards. After wide industry consultation, following areas were identified as essential elements to be included in the user guide. The paper describes reasoning behind the content of each segment and a brief description.

- Scope of the user guide
- Material properties
- Strengthening techniques
- Design guidelines
 - Flexural strengthening*
 - Shear and torsional strengthening*
 - Strengthening of the columns*
 - Safety considerations*
- Worked Examples
- Surface preparation and FRP installation
- Quality control and inspection

The user-guide being developed is the first of its kind published to the best of the authors' knowledge.

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VISUALISATION AND INFORMATION

Full Paper

CURRENT STATE OF KNOWLEDGE MANAGEMENT, POTENTIAL AND TRENDS: IMPLICATIONS FOR THE CONSTRUCTION INDUSTRY

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ABSTRACT

During the past decade a paradigm shift in the domain of knowledge management (KM) has emerged out of learning occurred from unfulfilled KM initiatives. This emerging KM perspective considers it to be more of a human activity rather than a technological endeavour. The notion that knowledge can readily be captured and embedded in machines to be easily shared has lost its potency. Rather, knowledge creation and sharing is being advocated through socialisation processes like building communities of practice, either real or virtual. The esoteric, contextual and problematic nature of knowledge is becoming evident as KM research is advancing into the realms of social constructivism. These constraints in KM are being recognised, and KM strategies are being devised that consider these limitations. Issues like leadership, vision and culture have become central to the successful KM initiatives. This paper presents the changing face of KM through a literature review. It argues that KM is not just another management fad or recycled concept. Rather, various trends and potentials of KM research are identified within the context of expanding boundaries of this domain to the potential benefit of the construction industry.

Keywords: Knowledge Management, Knowledge, Innovation, and Learning

1. INTRODUCTION

Knowledge is being recognised as a vital resource and source of competitive advantage in today's dynamic and changing business environment and knowledge economy (Burton-Jones, 1999). For this reason, research in KM has gained tremendous pace since its inception in the last decade. This is evident in enormous amount of literature existing and further growing in the area of KM. A thorough review of the literature, however, reveals the transformation that KM has been through and is still undergoing. The struggle of KM researchers and advocates is evident in their fight to keep it as a separate domain, saving it from a impression of being regarded as a management fad like TQM (Total Quality Management), BPR (Business Process Re-engineering), downsizing etc or recycling of concepts like MIS (Management Information System), DSS (Decision Support System), EIS (Executive Information system) etc (Wiig, 1997; Spiegler, 2000).

This paper compliments the notion that KM is far from being a management fad (Malhotra, 2004; Kidd, 2001). It is a paradigm in its own right and occupies a separate domain of investigation, especially in the construction industry. What is required is a more comprehensive framework of theory and identification and discovery of various components of this domain. This paper discusses the current state of KM research and identifies further trends and potential in it for the benefit of the construction industry.

2. CURRENT STATE OF KM: FROM PAST TO PRESENT

The quest for obtaining knowledge and effectively utilising it is not new. This struggle is as old as the history of human thought (Spiegler, 2000). Plato, Descartes and Kant have all made attempts to define and understand the nature of knowledge and to unearth the forces underpinning various phenomena in life. The methodologies used by these philosophers in their pursuit to obtain and construct knowledge still serve today as the fundamental guidelines for basic and applied research.

The discovery, creation and construction of knowledge encapsulated in a form of various management theories in the twentieth century supported the industrial revolution, which turned later into the information revolution. In turn, this has made it possible to attain business goals in a more profound and realistic way. But it was not until mid 1980's that individuals and organisations began to appreciate the increasingly important role of knowledge in the emerging competitive environment. At this time there was the realisation that information systems and technology were continually growing, and technology was regarded as a panacea for all the complex business problems. This acted as an impetus for experts in the field of information system and technology to undertake various initiatives in the domain of artificial intelligence, and to develop different kinds of expert systems replicating the expert knowledge of human experts. The basic assumption was that knowledge could be readily obtained from an expert, easily codified and promptly put into use by others. To the researchers dismay, such initiatives did not meet with a lot of perceived success in actual practice. They met with failures and non-use primarily because of the complexity and user-non-friendliness of such technologies rendered them ineffective (O'Brien, 1997).

The technological advances in the information distributing mediums and the development of Information Communication Technologies (ICT), internet and intranet, provided IT experts with new technological tools to make it possible to capture, codify, transfer and share knowledge. Unfortunately these initiatives have also significantly failed to realise expected benefits (Aouad et al., 1999; Davenport and Porsak, 2000; Fernie et al., 2002). Various causes behind the failures may include (Davenport and Porsak, 2000; Fernie et al., 2002, Walker, 2003; Liebowitz and Megbolugbe, 2003; Kamara et al., 2002; Malhotra, 2000):

- The high technological dependence of these initiatives,
- An inability to properly understand the complexity of knowledge and its esoteric nature,
- The neglect of human related factors associated with change,
- A lack of recognition of the need for appropriate leadership, vision, strategy and culture,
- Ignoring individual value systems and the notion of trust, and
- An insufficient reward system and a lack of motivation.

Storey and Barnett (2000) conducted a study of what can be learnt from the failure of KM initiatives and confirmed above mentioned factors. Egbu (2000) observes that the lesson learnt from these failures is that KM is 90% human activity and 10% technology. Similarly, Tiwana (2003) notes that KM is not about building smart intranets, digital networks, one time investment and enterprise wide 'Infobahn'.

Under this emerging paradigm of KM, the notion that knowledge can be readily made available from humans and made part of the machines is being questioned. Fernie et al. (2003) have argued against the assumption, on which orthodox KM is based; that knowledge freely exists and can be easily captured and shared through machines. They believe knowledge is a problematic esoteric concept that doesn't lend itself easily to codification. This applies especially to tacit knowledge capture that has become a contemporary theme of KM research. Tacit knowledge is highly individualistic and concomitant with various surrounding contexts within which it is shaped and enacted. For this reason KM supports and requires the building of communities of practice (Wenger, 1998) and the development of social networks through which tacit knowledge transfers and sharing may be made possible (Bresne et al., 2003; Augier and Vendelø, 1999; Swan et al., 1999; Hearn et al., 2002). These communities of practice may be real and exist in form of informal gatherings or formal conference/seminars/workshops. Alternatively, they can be virtual in the form of online forums or web-discussion boards, where experts can interchange ideas and leave their expertise and knowledge in the forum for others to utilise and share (Liebowitz and Megbolugbe, 2003).

It can be argued that the current KM research and theory has generally restricted itself to organisational knowledge contained within the boundaries of the organisation. The emphasis is to capture, codify, transfer and share such knowledge that is embedded in the organisation's routines and processes. Knowledge resides in employees' heads in a tacit form, and KM seeks it to make it explicit through the balanced use of technology and soft human related factors like leadership, vision, strategy, reward systems and culture. This offers an efficient yet rather restricted and narrow scope of KM, and compares poorly with what KM is actually perceived to offer. There is a need to further expand its boundaries and provide benefits to organisations that meet realistic expectations.

3. DIRECTIONS IN KM RESEARCH: TRENDS AND POTENTIALS

This section outlines the various potentials and trends that form part of the current direction of undertaking KM research. The following illustrates more recent foci of KM research including revisiting the underlying concept of KM. For this reason Tiwana (2003) observes that KM is progressively developing since the 1950s. Collins (2002) who felt a sense of “Déjà vu” expressed the same sentiment while analysing knowledge work. KM may act as an umbrella term encompassing all similar concepts that are apparently having a flow of their own into one single stream. The resulting synergy would help strengthen KM concepts and would make it easy for researchers to concentrate on their research endeavours.

3.1 KM AS AN INNOVATION ENABLER

Research into the management of innovation is more than 50 years old. Organisations have always looked for improved ways of business to keep themselves highly competitive and sustainable in the market. As a result they continually create knowledge with a view to differentiate and gain advantage over their competitors. KM may well provide a means of producing advantages through innovation. Stewart (1997) explained that tacit knowledge of individuals is of immense value to the organisation as a whole, and is the ‘wellspring of innovation’. The ability of KM to convert people’s tacit knowledge into explicit knowledge is an essential part of innovation (Nonaka and Taguchi, 1995; von Krogh et al., 2000). A number of research initiatives are investigating the role of KM in producing and supporting innovation in the construction industry (Miozzo and Dewick, 2002; Salter and Gann, 2003; Husin and Rafi, 2003). The lessons learnt from such initiatives provide direction for future research into innovation and KM.

3.2 KM AS A LEARNING PROCESSOR

Learning is always associated with better outcomes. Having learnt lessons avoids ‘reinventing the wheel’ and ‘making the same mistakes again’. Argyris (1978) and Senge (1990) introduced the idea of single loop learning and double loop learning, organisational learning and the learning organisation. In a project environment, and industries like the construction industry, it is highly desirable that lessons learnt are captured from one project and put into use on next projects, achieving reduction in project times and subsequent efficiencies (Kamara et al., 2002). Construction organisations usually develop project histories and databases as repositories to keep such knowledge of the lessons learnt. KM provides a structured way for developing such repositories and ensures that knowledge is disseminated in a timely fashion to the users. Maqsood et al., (2003) identify the role of KM in generating organisational learning and transforming organisation into a learning organisation. Bringing organisational learning and the learning organisation under the umbrella of KM helps various similar concepts to merge together and remove the confusions and contention influencing the research community.

3.3 KM ENCOMPASSING INNOVATION ADOPTION AND DIFFUSION ISSUES

All organisations at some point are confronted with the decision to adopt a certain innovation in a form of improved technology or process, and are faced with the challenge of how to diffuse it throughout the organisation. This is a

crucial decision as it involves significant investment and commitment on behalf of the organisation, and it may determine the success of the organisation. Researchers like Roger (1995) have discussed this issue of adoption and diffusion of innovation at great length, however the relationship with KM is an emerging theme for research. A new innovation that is adopted and diffused becomes transferred knowledge, percolating the organisation that accommodates and then manages the knowledge. This process of transfer, accommodation and management is a continuing field of research.

3.4 KM AS A KNOWLEDGE SHARING FACILITATOR IN SUPPLY CHAINS

The emerging concept of supply chains and supply chain management is revolutionising the business world. This revolution is evident in changing the unit of competition from organisation vs. organisation to chain vs. chain. At the forefront of this philosophy lie long term and strong commitment and trust among the trading partners. This sort of commitment and trust emanates from sharing the knowledge with other trading partners in the supply chain as well as joint problem solving within the concept of a 'super-team'. Conventionally information flow from one end of the supply chain to other but setting up KM elements in supply chain management, knowledge not information alone would flow from one extreme end of supply chain to other. As a result, workmanship improves, quality gets enhanced and the number of defective items reduces, producing significant amount of time and related costs savings. KM principals are for everyone in the supply chain. Only, the way through which they may want to reap benefits may vary and depend on the organisation's position in the supply chain. The type of knowledge required by organisations significantly varies depending upon its role in the supply chain. Assertions that KM is principally an issue for large organisations is misleading, all organisations regardless of their size may benefit from KM. There is a need to customize KM strategies based on the organisation's, which in turn is dependent on its position in the supply chain.

3.5 KM AS AN INTERFACE WITH ACADEMIA AND EXTERNAL INNOVATION SOURCES

Most valuable academic research with significant potential for providing benefits goes unnoticed. Similarly, other innovative organisations involved in cutting edge research find it extremely difficult to penetrate user organisations. As a result, they adopt lavish marketing strategy for their products, which often significantly raises the product price. In today's complex and highly competitive business environment, no organisation wants to give up their competitive advantage. They are often ready to adopt any sort of innovation provided they can foresee, through cost benefit analysis, benefits arising out of it. Construction organisations, especially, are so busy coping with the swift pace of construction that hardly any time is left for them to look for the ways to improve their work practices. Their main objective is always to get the work done as soon as possible and save themselves from the sword of liquidated damages that always looms over their heads. A strong need is felt by construction organisations, therefore, for having an interface with the external world and to be able to browse through available innovations and cutting edge research, choose and sample those based on the needs of the organisation and

disseminate them to concerned personnel and departments. KM can well take up this role (Maqsood, et al., 2003).

3.6 KM AS AN R&D FACILITATOR AND INNOVATION DIFFUSER

Business organisations in various sectors operate their own R&D departments fairly well but construction organisations find it very hard to justify investment in R&D. As described earlier, most of the time, they are happy with the tools and techniques they already have and consider those enough to finish the on-going project. Settling R&D under the theme of KM would give a new vigour and vitality to the concept of R&D, where the objective would not only be the creation of knowledge but also codify and disseminate it in timely fashion through sharing and socializing.

Recent research results on ICT diffusion and its link with KM has reinforced KM's role (Peansupap et al 2003). Further acknowledgment of the 'stickiness' of knowledge, its difficulty in being effectively transferred (Szulanski 2003) together with improved understanding of how innovation and knowledge is transferred (Dixon 2000), has led to a greater appreciation of the role of KM as a diffusion mechanism of bringing R&D and innovation together as joint mechanisms in building competitive advantage. Further, the link between R&D and building what Cohen and Levinthal (1990) describe as absorptive capacity, the ability to build learning through experience of experimentation and reflection, is being more widely appreciated now that wider principles of KM are linked to the R&D process.

3.7 KM COMPLIMENTING THE HUMAN RESOURCE FUNCTION

As we learn, under the new and emerging paradigm, it's people not machines that matters most to the organisation. Human resource management (HRM) for a long time is associated with handling of people's intelligence. Here lies a great opportunity for KM to assist and compliment existing human resource management practices and provide with some framework where it may be possible to quantify people's intellect so their knowledge is best exploited to the benefit of the organisation. Potential research in this realm also includes the re-evaluation of HRM as a more active and strategic enabler of building organisational competencies, of developing reward systems to more effectively facilitate knowledge exchange and embedding knowledge and competence within organisations provides fertile ground for KM research.

4.0 CONCLUSIONS AND FURTHER WORK

The paper has discussed the current state of KM research and has identified various research directions that may be possible under the theme of KM. The list of initiatives examined is not exhaustive and may enlarge as the research area progresses.

KM research has seen a paradigm shift in focus from more technology dependent to less technology dependent and is being considered more human oriented activity. This has made often ignored issues like leadership, vision, culture, motivations and rewards even more crucial to the success of KM initiatives. KM is emerging as a business philosophy promising enhanced benefits to the organisations. Some may argue that KM is not new *per se* or a recycled concept. However, this is not true, KM is a paradigm in its own right and occupies its own intellectual domain. At present researchers are focussing

their effort on a very restricted view of KM. KM is actually associated with the handling of any type of knowledge which makes it possible to merge various streams of research (knowledge) with KM. Research in innovation, organisational learning and learning organisations, adoption of innovation and its diffusion can suitably be merged with KM theory. This would simplify the research process and would reduce complexities and confusion in a research process. At the same time it would make easy for practitioners to understand it and hence employ it.

The identification of various potential and trend makes ground fertile for our future work, where we are researching to show the legitimate existence of KM function or department in a certain organisation and roles and responsibilities that can specifically be undertaken by it.

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PROCUREMENT AND RISK SHARING

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OCCUPATIONAL HEALTH AND SAFETY : BUILDING AND CONSTRUCTION INDUSTRY PERSPECTIVES.

1. INTRODUCTION

1.1. OVERVIEW OF OCCUPATIONAL HEALTH AND SAFETY IN THE CONTEXT OF THE AUSTRALIAN BUILDING AND CONSTRUCTION INDUSTRY

- 1.1.1.** Historically, Australia's building and construction industry has had a reputation of having one of the highest incidences of workplace injuries and fatalities when compared with other Australian workplaces. This grave assessment still holds true today, with the Australian construction industry's incidence rates for injuries and fatalities, 25.1 injuries per 100,000 employees, being significantly greater than the Australian average of 14.1 injuries per 100,000 employees.¹ Moreover, workplace fatalities, injuries, illnesses and fatalities impose significant costs on individuals, businesses, the community and the economy as a whole. The total economic cost of workplace injuries and fatalities has been estimated in excess of \$31 billion annually.²
- 1.1.2.** Australia's 10 Occupational Health and Safety (OHS) regulatory regimes aim to address the risks involved in the workplace to prevent workplace illnesses, injuries and fatalities and impose a requirement on employers to adhere to minimum levels of OHS standards in their workplaces.
- 1.1.3.** The implementation of effective OHS policies, procedures and systems by an employer not only reduces their exposure to the economic and social costs of workplace accidents, but also has positive implications for their business and their commercial success.
- 1.1.4.** As the benefits of an injury-free workplace are often intangible, it is increasingly popular to assign a benefit to OHS standard adherence to ensure compliance is maintained at the highest standard possible. To this end, it is becoming apparent that reward-based incentives incorporated into a

¹ National Occupational Health and Safety Commission, *Preliminary Regulation Impact Statement: Draft National Standard for Construction*. June 2004.

² Productivity Commission Inquiry Report, *National Workers' Compensation and Occupational Health and Safety Frameworks*. No. 27, 16 March 2004.

construction contract will ensure OHS standards are met and exceeded for the duration of a project.

- 1.1.5. In Australia, OHS is being embraced by employers and employee alike. It is a growth area, particularly in the building and construction industry. Recent developments in OHS include Government recognition of the need for tougher penalties for non-compliance, reform of the OHS regimes and implementation of national standards and codes of practice for particular workplaces and workplace hazards.

2. BUILDING OCCUPATIONAL HEALTH AND SAFETY STANDARDS INTO CONSTRUCTION PROJECTS

2.1. LEGAL REQUIREMENTS VERSUS PRACTICAL REQUIREMENTS

- 2.1.1. Implementing OHS standards in a workplace and ensuring OHS standards are maintained in a practical environment can prove challenging. Employers are advised to undertake a number of steps to ensure appropriate implementation of OHS standards.
- 2.1.2. Employers should affirm their commitment to a safe workplace, through communication with employees, drafting of policies and procedures and employee training.
- 2.1.3. Employers should ensure employee involvement in the creation of procedures and policies and ensure employees have opportunities to voice concerns. Most importantly, employers should address the OHS concerns of employee promptly and ensure follow-up on the progress of implemented solutions.
- 2.1.4. Hazard management is vital to ensuring overall OHS standards are met. Where a specific hazard exists, a procedure should be drafted to manage that hazard. Audits of the workplace should be undertaken regularly to ensure identification of new hazards. Employers should maintain good communication with employees such that new hazards identified by employees are reported to the employer promptly.
- 2.1.5. Maintaining safety records and information is also vital to ensuring OHS compliance. Safety records and information provide an objective assessment of the state of a company's OHS compliance, which may be used to boost employee morale about OHS, or act as a measure for improvement in OHS compliance.

2.2. THE IMPLEMENTATION OF REWARD-BASED INCENTIVES

2.2.1. Contract-based Incentives

- 2.2.1.1. Fulfilment of OHS requirements does not produce a tangible, accountable benefit for a corporation. Compliance with OHS requirements usually results in "non-events", which are not self-reinforcing.³ Therefore, the significant

³ Angela O'Dea and Rhona Flin, *The Role of Managerial Leadership In Determining Workplace Safety Outcomes*. University of Aberdeen Research Report 44. 2003.

consequences of non-compliance means that, for OHS standards to be maintained, tangible benefits must be incorporated into projects.

2.2.1.2. Reward-based incentives may be incorporated into a construction contract to ensure high OHS performance. In some instances, an appropriate incentive may be a contractual provision which establishes that part or all of an otherwise earned fee, fixed fee, profit or share of cost saving is subject to reduction by the principal or superintendent where OHS performance is below pre-set, expected levels. The use of this type of incentive integrates OHS into the overall construction contract and is particularly effective where there is a critical risk which must be properly managed.

2.2.1.3. In all circumstances, incentives should be structured to promote the integration of OHS into all aspects of contractors' work. To this end, OHS performance should be assessed at the end of each performance period, alongside other usual payment assessments. Not only does this system formally integrate OHS into usual work practices, but it also allows assessment of OHS performance on a step-by-step basis throughout the duration of the contract and acts as a constant check on performance.

2.2.1.4. It is imperative that the parties to the contract agree to objective standards for OHS to which they must comply. Such standards may include maximum hours of lost time for injuries, rates of injuries and illnesses. This is particularly relevant where there are specific risks to be addressed. The standards applicable to assessment of OHS performance should be able to be amended by the parties by agreement to adapt to the changing conditions of the work site. For example, a contract may stipulate different standards for different stages of the project; the parties may agree to amend applicable standards during the course of a project in light of variations to the contract work.

2.2.2. Other Incentives

2.2.2.1. There are numerous incentives outside the contractual relationship for good OHS performance. Primarily, decreased workers' compensation premiums for good OHS management and low injury rates is an incentive for good OHS and is also a major commercial incentive which serves as an ongoing reminder to firms of the value of making the workplace safe.

2.2.2.2. The social and economic benefits of OHS performance provide further incentives for good OHS practice. These benefits are discussed in detail below.

2.3. APPROPRIATE MANAGEMENT OF RISK

2.3.1. Risk Allocation

2.3.1.1. During the late 1980s and early 1990s, commentators suggested that there was a low base of expertise available within Australia for the management of major construction projects, so much so that many major projects were managed by expatriates.⁴ However, in 2004, not only has the depth of

⁴ See, eg., the Maddock Committee (1989, p2-8).

Australian construction management improved, but so has the industry's knowledge of, and adherence to, OHS requirements.

2.3.1.2. Corporations today must ensure OHS risks and responsibilities are properly allocated given the significant consequences of OHS regulation breaches. To this end, corporations should ensure sufficient resources are directed towards OHS initiatives and personnel, the instruction, training and supervision of employees and third parties, the creation of clear policies, systems and procedures with respect to OHS which are applicable to all employees and third parties and encourage a workplace culture which is supportive of OHS initiatives.

2.3.1.3. Management of risk also entails sharing the responsibilities of OHS compliance, accountability and responsibility. Each person in management should be aware of their OHS responsibilities and the responsibilities of those working under their management and maintain lines of communication between management and employees as regards OHS.

2.3.1.4. Depending on the scale of any particular project, it is often cost-effective to have a designated OHS manager to ensure OHS compliance on site.

2.3.2. Balancing Risk and Cost

2.3.2.1. The OHS incentives put in place by corporations should properly balance the benefits and costs of avoiding workplace injuries and fatalities. The high cost of workplace injuries is discussed below.

2.3.2.2. Given the high cost to business and the community caused by workplace injuries, it is imperative that corporations address their OHS responsibilities responsibly and mindful of the cost benefits that a good OHS record can have.

3. THE SOCIAL AND ECONOMIC BENEFITS OF GOOD OHS PRACTICE

3.1. Social Benefits

3.1.1. Positive working environment and worker morale

3.1.1.1. Occupational health and safety not only pays financially but it pays in terms of other non-tangible benefits such as customer satisfaction, corporate reputation, worker morale and worker motivation.

3.1.1.2. Accidents in the workplace often lead to poor worker morale, affecting productivity, motivation and behaviour in relation to safety. A positive approach to OHS in the workplace ensures greater workforce compliance and motivation to ensure reduced risk of injury and illness of workers. Increased understanding of the risks involved on site and how the employer addresses those risks will increase staff morale through decreased absence of workers due to illness and injury.

3.1.2. Goodwill and Company Image

3.1.2.1. An employer's positive and successful approach to OHS will also reap benefits for it in the marketplace.

3.1.2.2. Companies with highly effective OHS systems and procedures in place will attract highly-skilled workers who require above-average OHS standards of their employers.

3.1.2.3. Companies are often rewarded by governments for their achievements in good OHS records.

3.1.2.4. Furthermore, a positive OHS record will place a company in good stead in the marketplace, particularly with respect to tendering for projects and new clients. A company's OHS record is often recorded in its annual reports. The threat of negative publicity arising from a workplace incident is a strong motivator for OHS compliance. Having effective OHS policies and procedures, coupled with a strong OHS record, presents an image of a competent, successful and well-managed corporation to the marketplace and is a commercial advantage.

3.1.3. Economic Factors

The impact of work-related illness and injury reaches further than the significant emotional and physical impact on workers and their families. It imposes a significant economic cost on workers, employers and the community. There is a commercial advantage for corporations in improving occupational health and safety performance, that is, the 'safety pays' argument, that accidents which generate costs could be avoided by expenditure on safety precautions, which would generally be lower than the overall cost of the accident.

By way of overview, it is estimated that 40% of the cost of a workplace injury is borne by employers, in the form of workers' compensation, loss of productivity and overtime costs; 30% is borne by the injured worker, by way of medical costs, loss of future earnings and pain and suffering and 30% is borne by the community, in the form of loss of human capital, social welfare, health and medical costs.⁵ Furthermore, figures drawn from the National Workers' Compensation Statistics Database indicate that the average workers' compensation claim cost for the construction industry was \$11,900 for the year 2001 – 2002, which is 23% higher than the all industry average of \$9,700.⁶

As will be seen by examining the costs of work-related illness and injury in Australia, adherence to good OHS practice is a necessary precondition for high productivity and commercial success.

3.1.4. Improved Productivity

⁵ Industry Commission, 1995.

⁶ Preliminary Regulation Impact Statement, June 2004.

3.1.4.1. It has been estimated that the number of working days lost through injury is nearly 50 times greater than those lost through industrial action.⁷

3.1.4.2. Lost Time Injuries (LTIs) pose significant costs for employer construction companies. LTIs on site will impact the productivity of one or more trades affected by the injury or by the absence of the injured worker.

3.1.4.3. Depending on the severity and frequency of LTIs on site, the project delays may result in financial penalty to the head contractor or sub-contractors. Furthermore, the head contractors and sub-contractors may incur additional cost by way of overtime payments of other employees to complete the work of the injured worker, as well as the costs of high employee turnover and recruitment of new workers.

3.1.4.4. A reduction in LTIs through effective OHS management will equate to improved productivity in the workplace.

3.1.5. Reduced costs

3.1.5.1. A reduction in costs is a clear motivator to employers to improve OHS systems. Insurance costs may be reduced in recognition of good OHS performance, just as workers' compensation refunds may be received for a good OHS record.

3.1.5.2. The employer will also incur intangible benefits, such as the reduction in costs of rehabilitation of ill or injured workers, as well as the absence of workers' compensation claims.

3.1.5.3. Good OHS practice also reduces the risk and potential cost of OHS prosecutions and penalties as well as the associated costs of investigation and reporting of the workplace incident.

3.1.6. Reduced Industrial Disputes

3.1.6.1. It is likely that a high proportion of industrial disputes in the construction industry would encompass, to some degree, OHS concerns at the workplace.

3.1.6.2. The Australian Bureau of Statistics reports that in 2002-03, industrial disputes in the Queensland construction industry reached the highest level in five years, at 57 disputes.⁸ Moreover, these industrial disputes involved 11,200 employees and resulted in 34,000 working days lost.⁹

3.1.6.3. The above figures illustrate the significant cost to employers of industrial action. Employers who adequately address OHS concerns of employees are likely to minimise the cost of workplace disputes in relation to OHS.

⁷ National Occupational Health & Safety Commission, *Key Management Motivators in Occupational Health and Safety, Volume 1: Main Report*. February 2001, at 29.

⁸ Australian Bureau of Statistics, ABS Year Book Australia 8931.0, *Focus on the Queensland Construction Industry*. May 2004.

⁹ Australian Bureau of Statistics, ABS Year Book Australia 8931.0, *Focus on the Queensland Construction Industry*. May 2004.

4. NEW DEVELOPMENTS IN OCCUPATIONAL HEALTH AND SAFETY IN AUSTRALIA

4.1. TOUGHER PENALTIES FOR BREACHES OF OCCUPATIONAL HEALTH AND SAFETY REQUIREMENTS

INDUSTRIAL / CORPORATE MANSLAUGHTER

- 4.1.1. Several Australian jurisdictions have mooted the introduction a new offence of industrial manslaughter, aimed at holding directors and corporations criminally liable for workplace fatalities where the directors' policies and decisions have directly caused the workplace fatality, or where the directors have allowed development of a culture which disregards OHS. Industrial manslaughter would be created as a separate crime to overcome difficulties in the common law requirements of proof of manslaughter, particularly the issue of vicarious liability for criminal acts. The legislation aims to ensure that directors and employers can be held responsible for workplace deaths.
- 4.1.2. The Australian Capital Territory (ACT)'s *Crimes (Industrial Manslaughter) Amendment Act 2003* (ACT) was the first Australian legislation which provided for industrial manslaughter. The legislation, which commenced on 1 March 2004, ensures that an employer who is "reckless about causing serious harm to the worker... or is negligent about causing the death of the worker, by its conduct" can be held responsible for a workplace fatality. Omissions are included as "conduct".
- 4.1.3. The Victorian government introduced a bill prior to the most recent state election, which sought to amend the *Crimes Act 1958* (Vic) to introduce a new offence of 'corporate manslaughter' and 'negligently causing serious injury by a body corporate'. Notably, the bill provided for imposition of fines on a body corporate which were proportional to the size of the body, including its workforce, gross operating revenue and gross assets. The bill has not been re-introduced as yet.
- 4.1.4. Queensland's *Workplace Health and Safety Act 1995* (Qld), in its current form, contains a penalty structure based on the seriousness of OHS breaches and includes as a sanction imprisonment at the discretion of the sentencing judge. This legislation maintains OHS issues within the specialist jurisdiction of the Industrial Magistrates Court.
- 4.1.5. New South Wales continues to debate the introduction of the offence of industrial manslaughter. Its introduction has been criticised by employer groups and the government and opposition alike. This opposition is supported by the principle that the best way of achieving high standards in OH&S is by focussing on the implementation of systems to provide safe methods of production and work, rather than focussing on sanctions. Moreover, prevention of workplace accidents and fatalities, rather than sanctions, are the driving force behind OH&S. Furthermore, criminal sanctions for breaches of OH&S requirements transports part of the specialist jurisdiction of workplace health and safety into the mainstream criminal law jurisdiction.

- 4.1.6.** The passing of the *Occupational Health and Safety (Commonwealth Employment) Amendment (Employee Involvement and Compliance) Bill 2002* (Cth) on 12 August 2004 increases the maximum criminal penalty from \$100,000 to \$495,000 for instances where an employer's negligence or recklessness causes a workplace death or serious bodily harm. The federal government's approach seeks to address OHS through the imposition of stronger penalties, without the introduction of an offence of industrial manslaughter.
- 4.1.7.** The introduction of industrial manslaughter offences is also currently under debate in the United Kingdom and Canada, amongst other jurisdictions.
- 4.1.8.** The legitimacy of an offence of corporate manslaughter is questionable in view of public policy. Whilst employers are required to be accountable for their safety systems, the introduction of the concept of corporate manslaughter regime would, in this author's view, be completely at odds with public policy in the presence of an Act, such as the Queensland *Workplace Health & Safety Act*, where the onus of proof has effectively been reversed. The offence of corporate manslaughter should not be introduced without allowing Criminal Code-type defences currently available to be used in connection with OHS prosecutions. Nor would it be possible to introduce such a concept in circumstances where the owners or directors of a company are the sole subject of charges.
- 4.1.9.** Should an offence of corporate manslaughter be introduced, it must extend to all persons in the safety chain, including the injured worker's co-workers, the OHS officers of the company and direct line managers. Regardless of whether or not an offence of corporate manslaughter allows the types of checks and balances referred to above, any such provision is an utter breach of civil liabilities.

'ENFORCEABLE UNDERTAKINGS' AS A PENALTY FOR BREACH OF OCCUPATIONAL HEALTH AND SAFETY REQUIREMENTS

- 4.1.10.** In keeping with the notion of promoting OHS 'best practice', enforceable undertakings have been introduced, and widely used, as a penalty for breach of OHS requirements, whilst also providing a mechanism for improving compliance. Queensland is one such jurisdiction in which enforceable undertakings are commonly used as an alternative to fines or other penalties for breaches of OHS requirements.
- 4.1.11.** Enforceable undertakings focus on the nature of the breach and require an employer to undertake certain activities and meet set standards for a prescribed period. For example, an employer may be required to train employees on a particular hazard, create new work plans for the hazard and undergo an independent OHS audit at regular intervals for the hazard.
- 4.1.12.** Underlining the *Building and Construction Industry (Workplace Health & Safety) Taskforce – Final Report* published in 2000,¹⁰ was the premise that the public / commercial education of employees on safety was not working

¹⁰ Building and Construction Industry (Workplace Health & Safety) Taskforce – Final Report, 2002, *Department of Employment, Training and Industrial Relations, Queensland*.

sufficiently and that harsher penalties were required. The Report was driven by labour relation issues examining OHS practice. It essentially identified that a policy change was needed in enforcement of OHS and that a shift from a consultative education role to an aggressive prosecution role was needed.

- 4.1.13.** This resulted in the introduction of on-the-spot fines, an audit system, more stringent enforcement of the provisions of the workplace health and safety legislation and legislative amendment to include a better codification of the Act in order to facilitate easier prosecution and the imposition of higher penalties.
- 4.1.14.** The amendments, which came into force in 2003, did not actually expand the powers of the Act, but did provide inspectors with the ability to more easily establish a case against an employer, resulting in easier prosecutions for breaches.
- 4.1.15.** Commerce Queensland supported the amendments, at least in part, largely on the basis of the enforceable undertaking provisions of the Act. It was anticipated by Commerce Queensland that those provisions would actually provide a useful incentive for employers to embrace OHS and to channel money into education, further training of their personnel and investment in better workplace systems, as opposed to expending those funds on a fine.
- 4.1.16.** In practice, however, it is a different story. The regulatory guidelines and framework developed by the OHS authorities has meant that the utility of enforceable undertakings has been reduced. In most cases, the grounds for achieving an undertaking are far more oppressive than any fine would be. The costs associated with compliance with an undertaking, including independent audits, increased training and education of employees and amendment of work practices and procedures, often for prolonged periods, impose a great burden on employers. In addition to the financial costs associated with an enforceable undertaking, there is the intangible cost of having the details of the breach and the resulting enforceable undertaking being published. Consequently, the enforceable undertaking regime has the effect of operating as a disincentive for employers to improve their work systems, as the option of bearing a once-off fine becomes more attractive.
- 4.1.17.** The enforceable undertaking regime also fails to allow an employer credit where the employer actually has very good OHS systems in place. This may often be the case where it is in fact the act, deliberate or otherwise, of an employee contrary to the employer's prescribed OHS systems, which results in the breach. In these circumstances, where the employer is vicariously liable for the breach, the enforceable undertaking fails to acknowledge the existence of the employer's systems and OHS record and past behaviour. This is in contrast to the situation where a fine is imposed, as these factors must be taken into account in the imposition of a fine.
- 4.1.18.** Improvement of OHS standards in the industry is dependent upon improved incentives for compliance. In circumstances where compliance with OHS does not produce any direct, tangible benefit, there are few tangible incentives for compliance. To this end, financial incentives would provide a real benefit to employers for compliance and must be identified. These may include workers' compensation insurance premiums / rebates or a 'credit

points' system for work completed without lost time injury, so that employers can actually see an added benefit for their efforts. Where additional incentives exist, employers would more actively seek to take their systems beyond what is reasonable, to 'best practice'. It is not appropriate to expect that the shadow of industrial action and increased workers' compensation premiums, which loom in the absence of an adequate system of OHS compliance, are sufficient incentives for employers to positively embrace the system and endeavour to achieve best practice.

4.1.19. Moreover, in circumstances where the private sector has identified the use of bonus and other financial incentives in order to achieve certain Key Performance Indicators on a project by project basis, there is no reason why government ought not to be able to adopt a similar model in terms of its workers' compensation or other administration. This would require a paradigm shift for government, particularly with respect to the administration of workers' compensation. The use of workers' compensation funds' consolidated revenue would need to be re-evaluated so that consolidated savings beyond the necessary actual funds required for fund operation, could be refunded to employers who achieve consistently high safety performance levels.

4.2. NEW NATIONAL CODE AND STANDARD FOR THE CONSTRUCTION INDUSTRY: THE PREVENTION OF FALLS FROM HEIGHTS

4.2.1. The National Standard and Code

4.2.1.1. The National Occupational Health and Safety Commission (NOHSC) is currently preparing a National Standard for Construction Work and National Code of Practice for the Prevention of Falls From Height in Construction Work.

4.2.1.2. Central to the Australian building and construction industry's higher than the average Australian rate of workplace injuries and fatalities is the OHS issue of prevention of falls from heights.

4.2.1.3. The National Standard generally seeks to:

"provide a framework to assist in the protection of persons from the hazards arising from construction work by requiring specified classes of persons to eliminate the hazards or, where this is not practicable, to minimise as far as practicable the risks arising from the hazards:

- (a) by ensuring that the hazards are identified and the risks assessed and controlled; and*
- (b) by requiring the provision of information and training."¹¹*

¹¹ National Occupational Health and Safety Commission, *National Standard for Construction Work: Draft for Public Comment*. June 2004.

3.3.3.1 The National Standard will create a construction industry-specific framework for consistent national regulation of OHS, by considering stakeholders' responsibilities for safety management and the general and specific OHS responsibilities of managers in the construction industry, particularly with respect to control of specific hazards common to the construction industry.

3.3.3.2 NOHSC will be receiving public comment on its Draft National Standard until 8 September 2004 and is likely to publish the final National Standard and Code in late 2004.

3.3.4 Other Work in the Field

3.3.4.1 The Australian and New Zealand Joint Compliance Project on Falls Prevention in Construction was initiated by the Heads of Workplace Safety Authorities.

3.3.4.2 The Project aimed to conduct site inspections at over 920 sites during May 2004.

3.3.4.3 The primary focus of the inspections was housing construction sites and small-scale commercial construction sites up to \$2 million in value, particularly services installation work and finish and fit-out work.

3.3.4.4 The Project is yet to publish its results.¹²

4.3. CREATION OF THE AUSTRALIAN SAFETY AND COMPENSATION COUNCIL (ASCC)

4.3.1. In response to the Productivity Commission's report on National Workers' Compensation and Occupational Health and Safety Frameworks, the Australian Government announced on 24 June 2004 its proposal to establish a new tripartite body, the Australian Safety and Compensation Council (ASCC).¹³

4.3.2. The ASCC will develop policy advice on workers' compensation and OHS programs for the Workplace Relations Ministers' Council, provide leadership and co-ordination of national efforts to prevent workplace death, injury and disease and improve workers' compensation arrangements. It will also provide a national forum for consultation and participation in development of OHS policies.

4.3.3. The ASCC will also promote national consistency in OHS and worker's compensation regulatory frameworks, oversee collation of OHS data and promote best practice in OHS.

¹² WorkSafe Victoria.

<http://www.workcover.vic.gov.au/vwa/home.nsf/pages/joint_falls_project> Site Accessed 30 August 2004.

¹³ The Hon Kevin Andrews MP, *Joint Media Release: Response to Productivity Commission Report On Workers' Compensation and Occupational Health and Safety*. 26 June 2004.

- 4.3.4.** The ASCC will be comprised on an independent chair, one Australian Government member, one representative from each State and Territory, 3 employer representatives and 3 employee representatives, all appointed by the Minister for Employment and Workplace Relations. It will be supported by the Department of Employment and Workplace Relations.
- 4.3.5.** The National Occupational Health and Safety Commission (NOHSC) will continue its work under the new framework.

5. CONCLUSION

- 5.1.** Occupational Health and Safety is an issue relevant to all employers, however it is particularly pertinent to employers in the Australian building and construction industry, given that industry's record of high worker injuries and fatalities.
- 5.2.** Contract-based incentives along with economic and social benefits make compliance with OHS standards more attractive for business. The economic and social benefits of OHS compliance significantly outweigh the costs to employers of OHS compliance.
- 5.3.** Management of risk is also a key issue to be considered by employers when assessing their OHS responsibilities in the workplace.
- 5.4.** Government initiatives indicate that national consistency of OHS standards and regulation is on the agenda, which will ease the burden of compliance, particularly for inter-state employers and mobile workers.

INNOVATIVE ASSET MANAGEMENT

Full Paper

PHOTONIC TECHNOLOGIES IN SMART STRUCTURES

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ABSTRACT

The relatively new field of Photonics has resulted from many years of investment in electro-optic technology development across a wide range of applications. These technologies have revolutionised the world of telecommunications by providing orders of magnitude increase in bandwidth, driven by a substantial growth in the use of the Internet.

Photonic technologies have wide ranging implications to the building and construction industry apart from simply 'wiring' a building or structure for communications through the use of optical fibre. This paper presents an overview of new and existing building and construction applications of technologies that have resulted from a substantial worldwide investment in this emerging technology area.

Asset management, OH&S, security, and client comfort are the key drivers for Photonics in complex structures, and this paper will demonstrate the potential to provide high spatial resolution, wide coverage monitoring of a number of important parameters including temperature, strain, environmental factors, and indicators relevant to security. For example, the ability to monitor temperature fluctuations at very high spatial resolution across the walls, ceiling, and floor of a building with fast response (effectively several thousand independent sensors) has implications for fire detection and control, security monitoring, and environmental control of the building as a whole.

Technical details will be presented of fundamentally new photonic devices that have the potential to monitor strain in civil structures such as bridges, tunnels, and dams as well as in complex mechanical structures such as aircraft. The ability to continually monitor extremely high resolution strain in a bridge, for example, when repetitive loadings are experienced, will enable very early indications of failure to be detected. When networked these devices may occupy the same communications backbone that supplies voice, data, and other sensor information to a central control, further reducing their cost.

Keywords: distributed sensing, strain, temperature, fibre bragg grating, optical fibre sensing.

1. INTRODUCTION

The whole-of-life structural integrity of major fixed infrastructure and smaller but more dynamic transport platforms is critical. Issues resulting from the original design together with normal and abnormal wear and tear mean that continuous, realtime monitoring both during construction and normal operation provide significant opportunities to avoid catastrophic failure. Basic design issues have presented significant challenges as the use of lighter materials and novel design approaches have reduced the margin for error. Recent events such as the 'wobble' in the new Millennium Bridge in London are timely illustrations of the challenge.

Since the mid seventies Photonic technologies have promised to change fundamentally the ability to monitor complex structures in realtime, at high spatial resolution, and at low cost. In this period advances in distributed optical fibre sensing have delivered solutions for measuring temperature and other parameters as a tool for industrial process control in specialist applications, but the cost benefit barrier had not been penetrated.

Early attempts to use the unique properties of light, specifically in a fibre based spectroscopic mode, to measure parameters such as temperature (Dakin, 1985, Paton, 1990, Samson 1990) , vibration (Weir, 1991), gas composition (Scott, 1990), strain (Ohba, 1989) and pH (MacCraith 1991), resulted in systems that were relatively expensive and limited in performance. The commercialization of systems based on these technologies was therefore limited and did not lead to the market penetration that was originally predicted.

Recent advances in distributed, quasi distributed, and discrete optical fibre sensor technology have brought the technology very close to the stage when applications such as monitoring infrastructure ranging from large civil structures, for example bridges and dams, to performance monitoring of complex mechanical structures, such as aircraft frames and skin, for strain, temperature and other parameters is now possible.

One particular sensing device based on the Fibre Bragg Grating (FBG) has generated considerable interest with its potential to network a very large number of sensing elements in a strain gauge configuration to enable embedded broad area strain measurement for realtime monitoring. When integrated with other sensor elements these systems result in a powerful monitoring capability (Li, 2003).

The same technology is being applied to a number of other key sensing processes, including; Geophones and hydrophones for hydrocarbon exploration and defence sonar, and multi-element phase sensitive microphones for defence and other applications.

This paper presents an overview of a number of sensing techniques, including this new approach, and considers their application in areas relevant to structural health monitoring .

2. THE OPPORTUNITY

From a structural integrity perspective the high level requirements of a practical sensor system has been identified as:

- Strain and/or temperature measurement
- Physically small – non intrusive
- Environmentally rugged
- Does not introduce electromagnetic interference
- Is not interfered with by other sources of noise
- High spatial resolution
- Low cost per sensor
- Easily networked
- Scaled to a large number of sensors

These performance parameters have been the target for the development of optical fibre based sensor network for measuring strain and temperature. Some of these parameters are more important in certain applications, for example, to build a sensor into a composite structure such as an aerofoil surface or aircraft frame having the sensor extremely small and non intrusive is imperative. In addition, if the structure is experiencing complex forces under transient conditions then high spatial and temporal resolution measurements will be required.

In contrast, instrumenting railway bridges to provide an early indication of failure would require a large number of sensor elements possibly a long distance from the monitor, with high temporal resolution being required in short bursts.

In addition, sensors meeting the above targets provide an opportunity to contribute significantly to the longstanding promise of the 'smart' building. Because the path of a sensor array is defined by the optical fibre itself, the fibre when built into the walls, ceilings, and floor of a building encapsulates the area in sensors. If these are, for example, temperature sensors the system will produce detailed knowledge of the distribution of temperature around periphery of the area – and this can be used to:

control airconditioning at individual exit ducts so an area can be maintained at a uniform temperature irrespective of the heat loading at different parts of the area (eg west facing windows),

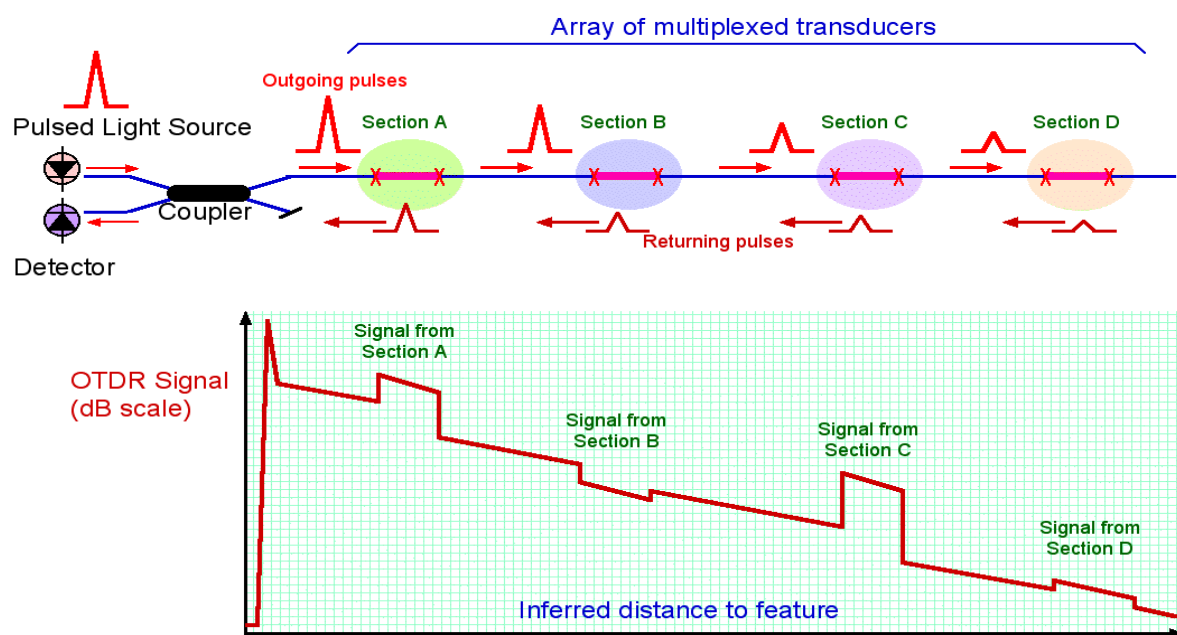
control alarms and sprinkler systems for fire prevention, having the benefit that detecting more localized small sources of heat will provide an earlier indication of a source of fire,

enhance security through the detection of radiant heat changes both temporal and spatial, which might be associated the passage of an intruder.

The ability to build the fibre into the skin of the interior of a space and reduce its thermal response time will be a determining factor in the uptake of this technology for this application.

3. THE TECHNOLOGY

Conventional optical fibre sensors for temperature and strain use a specific scattering feature of an optical fibre where this feature changes with a change in the measured parameter. The feature might be a scattering property of the silica core of the fibre, for example Raman or Brillouin scattering which are directly effected by temperature and stress respectively. Figure 1 shows the distributed nature of this natural scattering and a configuration based on Optical Time Domain Reflectometry (OTDR) for interrogating the scattering magnitude – operating on the same principal as radar but at optical frequencies and confined to the fibre.



Optical Time Domain Reflectometry (OTDR) – Distributed Measurement.

A pulse of light is injected into a fibre where it travels along the fibre and is scattered back to a detector, via a coupler, from the entire length of the fibre. The scattering from each section is separated in time at the detector so the scattering at each section (A, B, ...X) acts as a discrete measurement. This is the basis of current commercial distributed temperature measurement devices.

The effectiveness of the sensor section of the fibre can be increased by modifying the core of the fibre to make it more sensitive to the parameter being measured. A relatively simple fibre based temperature measurement technique based on the introduction of a dopant to the core of the fibre has been commercially exploited. It is based on fluorescence lifetime decay in fibre that has been doped with a fluorescent material, such as neodymium.

Figure 2 illustrates the approach. A short pulse of light is injected into a fibre where it is absorbed by the fluorescent dopant which in turn fluoresces with a decay time directly dependent on the temperature of the fibre. The technique provides a single

point measurement and cannot be easily converted to a linear array using the OTDR approach because of interference with the fluorescence decay in the time domain.

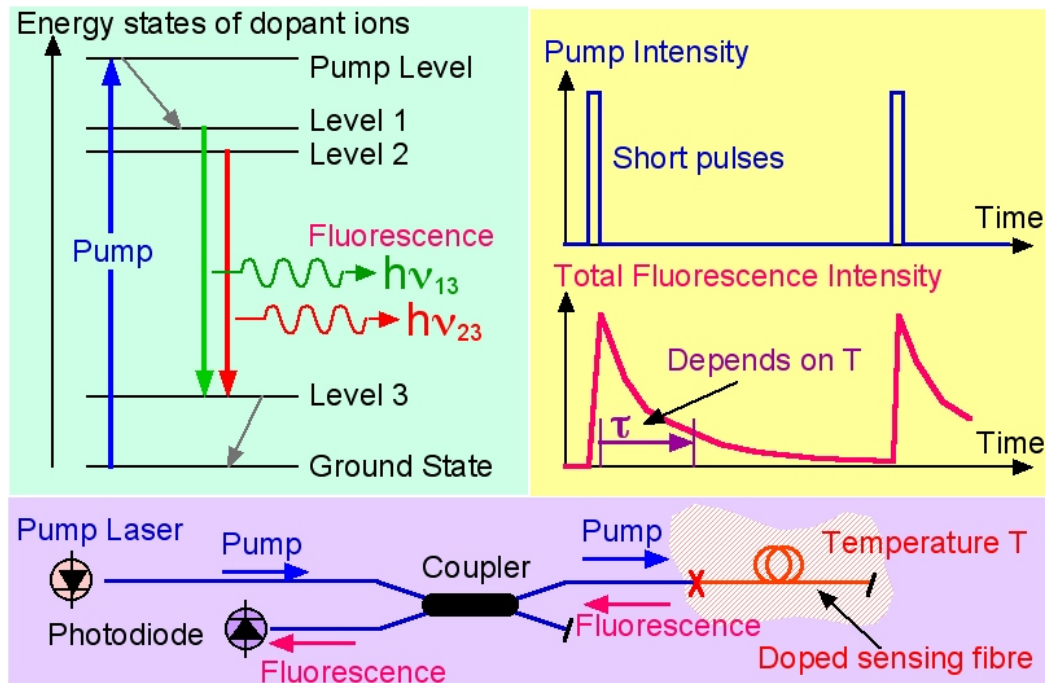


Figure 2.
Fluorescence Decay Temperature Measurement.

3.1 FIBRE BRAGG GRATINGS

A different type of sensor scattering section that can be introduced to the core of an optical fibre to enhance its detection properties is a Fibre Bragg Grating. These are analogous to a conventional optical diffraction grating where a series of physical discontinuities (lines) spectrally modify light by diffraction and have the effect of an optical filter.

The diffraction grating is formed in the core of a relatively standard optical fibre using a 'printing' process where the fibre is exposed to UV light in a way that leads to regions of high and low refractive index within the core. This periodic high and low refractive index forms a diffraction grating, or filter, that operates only on the light within the fibre. The printing process is extremely flexible and gratings with very complex spectral characteristics can be manufactured in a reproducible manner in large quantities.

These are the devices used in telecommunications systems to multiplex multiple channels of information in a fibre through a process known as Dense Wavelength Division Multiplexing (DWDM). Figure 3 is a schematic diagram of an FBG within a fibre and a simple example of the filter characteristics that can be obtained. The filter operates on the incident broadband light entering from the left producing a

backscattered signal exiting to the left and a residual transmitted signal exiting to the right.

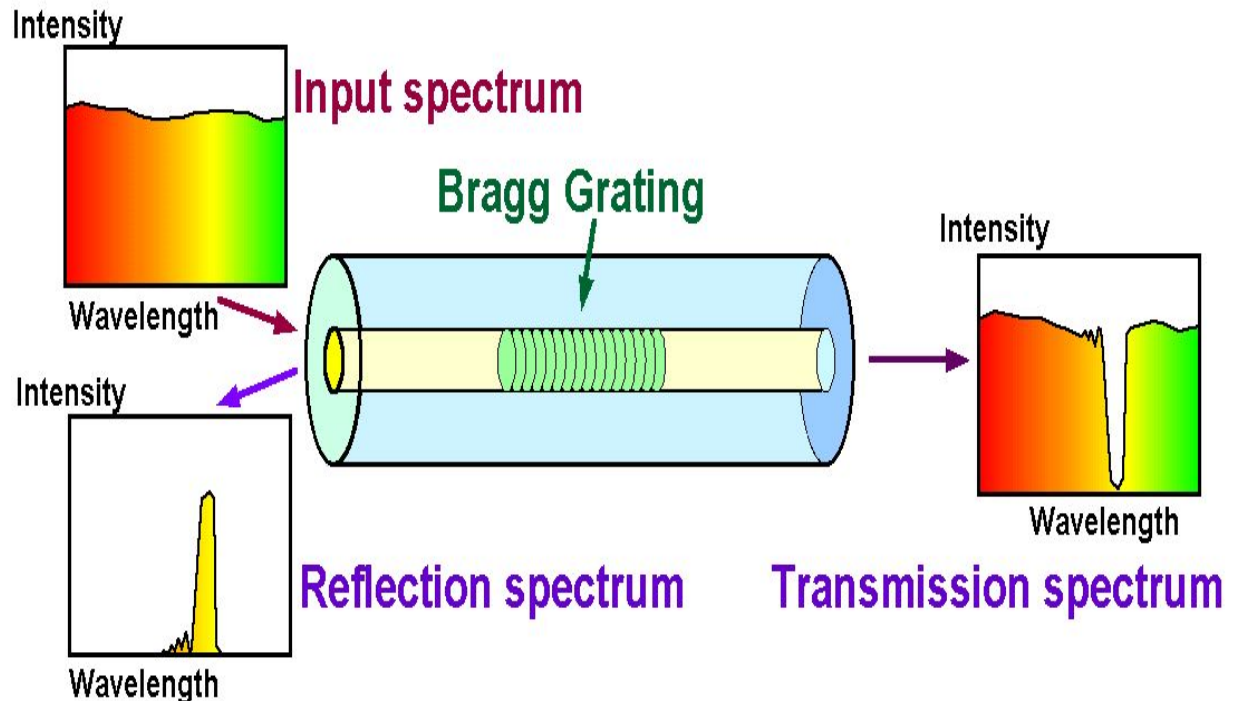


Figure 3. Fibre Bragg Grating

The FBG can be 'printed' into the fibre anywhere along its length and in large numbers. In a simple form each FBG becomes a point of measurement. For strain measurement it is easy to see that if the fibre is stretched the period of the grating changes and the spectral characteristics of the backscattered or transmitted light occurs. A simple spectrometer is used to interrogate the strain signal from the spectrum and if each FBG is slightly different many sensors can be placed in the same fibre interrogated simultaneously.

Figure 4. shows a networked array of point sensors which may be configured for strain and/or temperature measurement. Several hundred sensors may be placed in a single fibre and the sensing elements can be placed in any spatial configuration required. Many of these single fibre arrays can then be multiplexed to provide thousands of points of measurement with a single interrogation system mounted many 10's of kilometers away

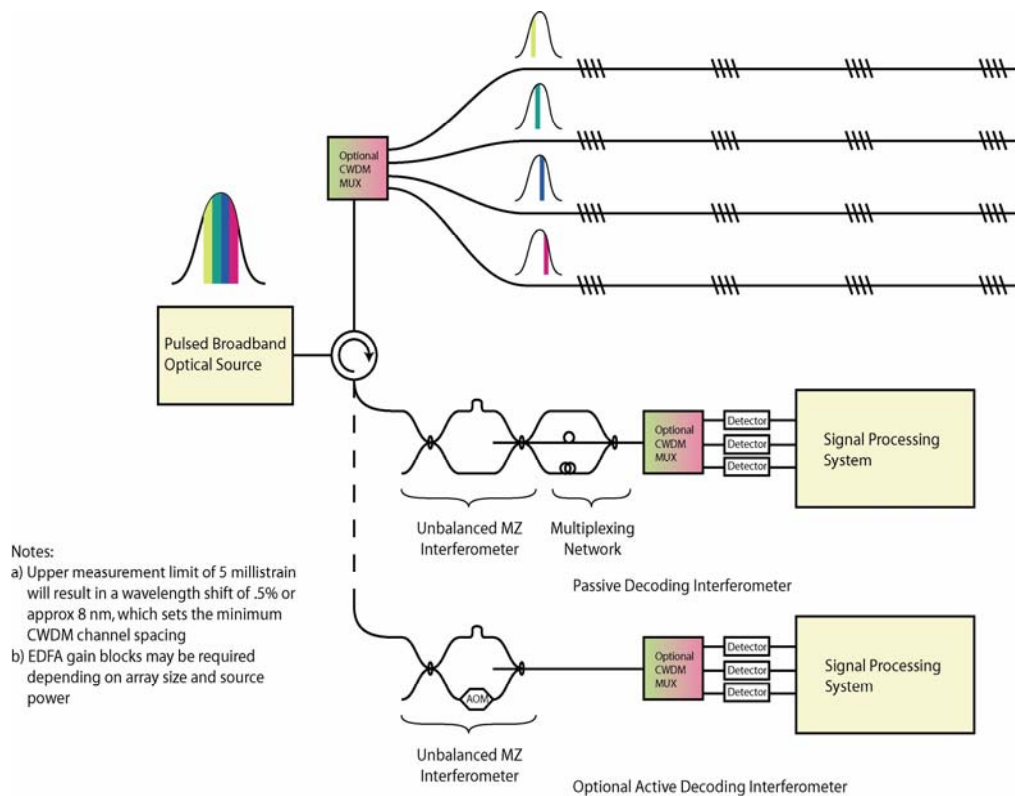


Figure 4. Point Array of Sensors

This configuration is suitable for discrete multiple point strain sensing covering large areas, a long distance from the observer. Applications include multiple (up to several hundred) point strain measurement in concrete and steel bridges, dams, tunnels, complex structures such as powers stations and processing plant, and anywhere a large number of discrete points are required to be monitored. The basic version measures one axis of strain at each point, a more advanced configuration measures multiple axes at each point.

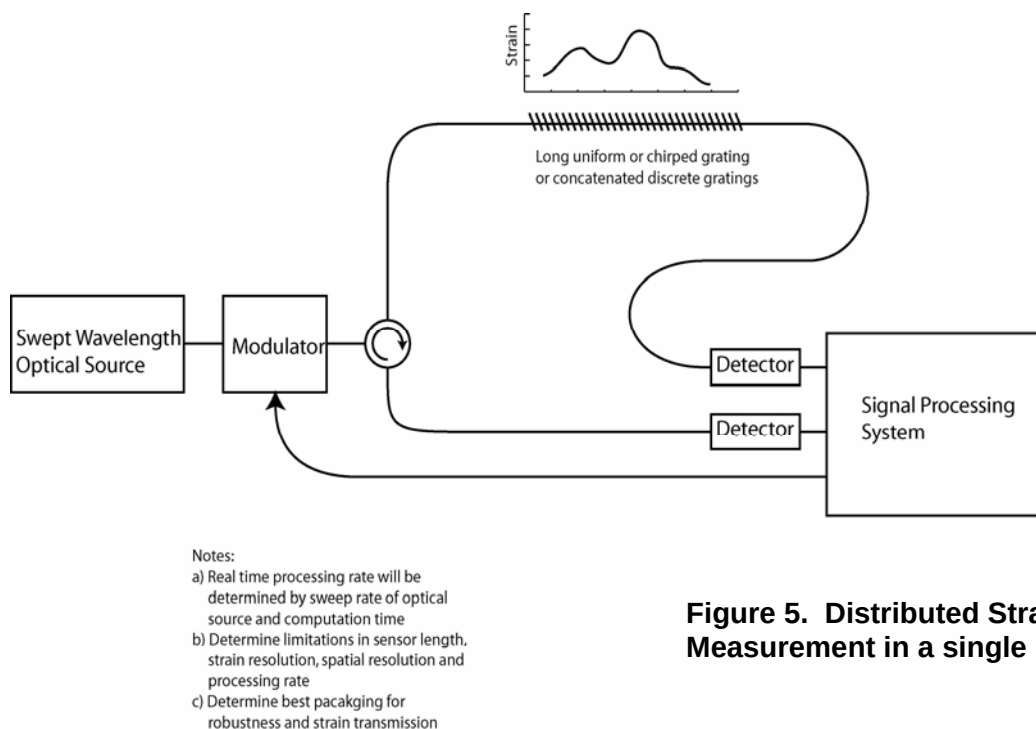


Figure 5. Distributed Strain Measurement in a single FBG

4. DISTRIBITED STRAIN MEASUREMENT

If a long FBG (up to 10 centimeters) is printed into a fibre and the FBG is designed to have certain spectral characteristics then it is possible to measure strain (or temperature) distributed along the length of the FBG. Due to the flexible process for printing the FBG into the fibre a grating with a gradual change in 'line' spacing (chirp) can be generated, this in effect becomes an array of slightly different gratings.

In Figure 5. an FBG is shown in an interrogation configuration that enables strain as a function of position along the FBG to be measured by spectrally separating different regions within the grating. The spatial resolution might be just a few millimeters so the measurement is effectively hundreds of discrete points spaced at millimeter intervals over a 10 centimeter length. The fibre may be wound or laid out in a way that produces an area of very precise high spatial resolution strain/temperature measurement.

The above discussion focuses on single fibres. If multiple fibres or a single fibre with multiple cores is used to carry a sensitive scattering region it is possible to measure the parameter (such as stress) in directions other than longitudinally within the fibre. If the multi core sensor is a temperature sensor and the cores are not highly thermally coupled it is possible to measure thermal fluxes by the temperature differences across the fibre. The application of these multi core fibres are numerous.

5. BEYOND THE FIBRE BRAGG GRATING

A family of fibres called 'Holey' fibres is beginning to be developed for a range of applications including telecommunications and sensing. These fibres do not rely on a different material to change the refractive index of the fibre to define the core, but use an array of holes running along the length of the fibre to change the effective refractive index the light will 'see', and hence guide the light.

Figure 6 are micrograph of such a fibre which can be made from silica or polymer.

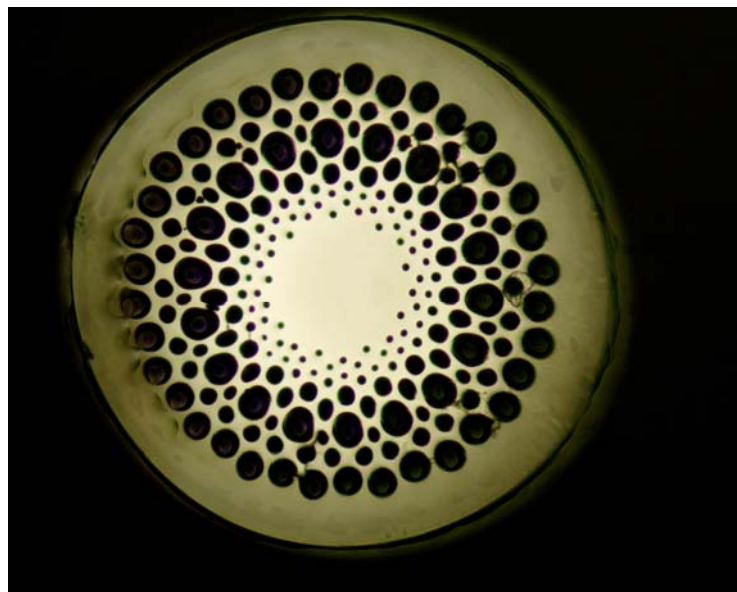


Figure 6. Holey Fibre

The high index core is the section in the center with no holes and the low index cladding has the holes. Apart from the possibility of printing FBG's into the core of this fibre and achieving the benefits outlined above for conventional fibres, its intrinsic physical characteristics (particularly in polymer) make it suitable for distributed monitoring of force, so applications in security and inertial systems are possible. Other applications being considered include the introduction of gases into the holes where the light will interact with the gas in a well defined region enabling spectral characterization of the gas.

6. CONCLUSION

Recent advances in optical fibre technology are creating opportunities for sensor arrays in novel high performance low cost configurations. These sensors are making possible the monitoring of a wide range of complex structures, both during construction and under normal operation, in a way not considered possible before now.

The Australian Photonics Cooperative Research Centre is a leader in the field of novel fibre component and systems R&D and is pursuing collaborations with industry and other groups which will help bring the results of this research to commercial reality. A consortium is being developed which will, initially, focus on construction and aerospace applications.

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CAPTURING AND MAINTAINING THE CLIENTS REQUIREMENTS

Full Paper

FRONT-LOADING THE BUILDING DESIGN PROCESS FOR ENVIRONMENTAL BENEFIT

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ABSTRACT

Front-loading is the notion of placing increased emphasis on making decisions at the earliest possible stages of the design process. In this case the emphasis is on those decisions regarding the building's relationship to the environment (Watson 2004).

Investigations into the nature of the design process reveal that design moves forward through a process of problem solving. Popper's model of conjecture and refutation as the means by which scientific knowledge advances, has been applied to the process of design (Hillier et al, 1972). Hillier et al found that the role of problem *setting*, is as important as that of problem *solving*, when it comes to achieving environmentally responsible outcomes. If an environmental issue is not contained within a design problem, then it is unlikely that it will form part of the solution. A key task then, in the designers problem solving process, is that of *pre-structuring* of the design problem. It is at this stage of pre-structuring that environmental issues must enter the problem solving process to influence the design outcomes.

One explicit influence on pre-structuring is the brief for a building design. It is the brief that lays out the specific requirements of the client, and it is in this document that environmental issues may be explicitly stated. Research in practice has involved a series of case studies that were conducted to examine the process of front-loading the design process. The front-loaded process was based around the development of an 'Environmental Brief' (Watson et al, 2000). The conclusions are that a key path of events lead, not directly to improved implementation of environmental strategies in the final designs, but to improved achievement of goals set at the beginning of the design process, no matter what the level of sustainability of those goals. Hence, the key process becomes that of attempting to set environmental goals as high as possible.

Keywords: Front-loading, Briefing; Pre-structuring; Environmental Brief, Design Process.

1. INTRODUCTION

When a client approaches a designer with environmental responsibility as part of their agenda for the design of a building, it becomes the responsibility of the designer to try to achieve this goal, just as it is their duty to try to achieve the other design goals set by the client. How does a designer take on issues such as environmental responsibility, and incorporate them into a design? To understand this it is important to understand how design actually occurs, that is how the design process proceeds forward from a set of requirements to a solution that fulfils those requirements.

The first part of this paper will examine the theoretical mechanisms by which designers can take on environmental goals. It looks at how the influence of those goals is enforced as the design progresses, so that the final design reflects the goals set, and then how the designer can assess design decisions as they are being made as a means of ensuring goals are met. Popper's model of *conjecture and refutation* (Popper, 1999a), which was developed as means of describing how scientific knowledge advances, is used in this context as the basis upon which to investigate the process of design. Design is shown to proceed through the solving of design *problems*. The role of the designer in *setting* design problems is shown to be as important in achieving environmental outcomes, as the process of *solving* the problems.

The second part of the paper moves to the practice of architecture, and in particular the role of briefing in design. The argument is made that the briefing process, and the design brief as a document, must play a critical role if environmental goals are to be translated into strategies for design and then design outcomes. The brief can play a key role in informing the setting of design problems throughout the design process. A series of case study projects have been undertaken to test the notion of *front-loading* of the design process with environmental considerations. The medium through which this front-loading occurred was defined as an *Environmental Briefing* process, and the development of an *Environmental Brief* as a document. Some of the more interesting and informative outcomes from these case studies are presented here as a means of illustrating the key roles of the design briefing process, and the brief as a document, in terms of facilitating the implementation of environmentally responsible design.

2. THE NATURE OF DESIGN

There have been numerous attempts to define the process by which design moves forward from a need to a solution that satisfies the need. A review of these is contained elsewhere (Watson 2004). The theory presented here is based around the idea that design moves forward by a process of problem solving.

2.1. DESIGN PROBLEMS

In response to shortcomings of earlier attempts to describe the process of design, Hillier Musgrove and O'Sullivan in their seminal paper on design methods 'Knowledge and Design' (Hillier et al, 1972) proposed the model of *conjecture/analysis*. The conjecture/analysis (C/A) model is based on Karl Popper's work investigating the development of knowledge in science. Popper proposed the model of *conjecture and refutation*, as the means by which scientific investigation moves forward (Popper, 1999a) (the distinction between refutation and analysis will be made below). Simply put, the conjecture/refutation (C/R) model proposes that it is problems and not observations that are the starting point for scientific investigation (Bamford, 2002). Once a problem is identified a solution for that problem is conjectured and then begins the process of refutation or *error elimination*, in which

the conjectured solution is subjected to tests in an attempt to prove it false. If the conjecture is refuted then the process begins again. If the conjecture is not refuted then scientific investigation may move on to other problems and the piece of theory stands as accepted until such time as it is refuted (Popper 1999a). The model can be represented by the following equation, which is useful shorthand with which to discuss the model (Brawne, 1995).

$$P_1 \text{ } ^{\text{TM}} \text{ } TS \text{ } ^{\text{TM}} \text{ } EE \text{ } ^{\text{TM}} \text{ } P_2$$

Here P_1 is an existing problem, TS is a tentative solution proposed for that problem (a conjecture), EE is the process of error elimination (attempted refutation) and P_2 is the new problem or set of problems that arise from the error elimination process.

Popper's model is centred on the process of error elimination. That is, refuting erroneous theories and discarding them. The process of error elimination is one that can be seen to be the way in which nature advances – Darwin's theory of evolution by natural selection – hence it makes sense that it would explain the way knowledge would progress (Popper, 1999b). Popper makes this point by the title of one of his presentations 'All Life is Problem Solving', inferring that essentially life moves forward through error elimination and that all problem solving can be seen to be conducted in the same manner (Popper, 1999b).

The distinction between refutation and analysis, that is between C/R as a model for science and C/A as a model for Design is made because of the nature of design conjectures. Design conjectures are predominantly of a nature that they are not refutable or falsifiable (Brawne, 1995). Design moves forward by analysis of a conjecture and then discarding of it as unacceptable rather than by refuting it as in proving it to be false (Bamford, 1990). However, some design problems could be seen to be false, for example a design for a building that included ceiling heights of 1.5m. Such obviously problematic conjectures, though, are rarely put forward in the first place, at least by experienced designers.

The C/A process, $P_1 \text{ } ^{\text{TM}} \text{ } P_2$, can be applied as a description of problem solving in design, in three ways. Firstly the whole building may be conceptualised as a problem to be solved where P_1 = the design problem and P_2 = the final design. It must be remembered however that this is not a description of the design process, as in a period of putting forward tentative solutions followed by a period of error elimination and then a solution P_2 is reached. C/A describes a cognitive process that may be occurring over a very short or very long period of time either during or outside the actual time being spent designing a building. For example, a designer may have designed a number of libraries over her career. The design of libraries as a type of building becomes a design problem in itself. Even though the designer is not currently engaged in the design of a library, the problem still exists and she may spend time analysing conjectures regarding the problem.

The second way the $P_1 \text{ } ^{\text{TM}} \text{ } P_2$ process may be applied is in the progression of design throughout the design process of one particular project. For example, in relation to the problem of obtaining natural daylight in a building there will be a series of problems to be resolved starting at the very broad level and moving to more detailed ones, such as from building orientation, to window size and position and on to shading elements.

The third application is in the development of ideas or techniques across a series of design projects. Brawne provides an example of this in the work of engineer Peter Rice and his development of structural detailing for the Centre Pompidou. The solutions were arrived at through the development of ideas that had been observed in previous projects by Rice and others in the design team (Brawne, 1995).

The conjecture/analysis model defines design essentially as an act of problem solving. It delivers the notion that design moves forward within a single design and across subsequent designs, by a process of error elimination. In delivering this understanding the C/A model forms a solid framework for more detailed investigation of the design problem-solving process. In particular the following section will look into what occurs pre- P_1 , or in other words pre-design problem.

2.2. PRE-STRUCTURING AND SETTING OF DESIGN PROBLEMS

In the conjecture/analysis model conjectures are presented by the designer as tentative solutions to problems, but the question remains 'how does the designer arrive at a conjecture?' Except for complete novices, designers tend to conjecture with a reasonable expectation that what they are proposing will satisfactorily solve the problem, or at least give an approximation that can be used for further refinement (Bamford, 2002). But what do they base their expectations on? Hillier et al argue that the designer *pre-structures* the design problem, P_1 , and that they do this by applying constraints (Hillier et al, 1972). Constraints are either externally produced, such as by clients, site or regulation, or they are internally produced cognitive constraints, such as aesthetic sensibilities, social or environmental ethics, or any combination of these. Further, Hillier et al suggest that design solutions are only understandable in relation to the design problem as set by the pre-structuring (PS) process. Hence, they suggest that the critical point at which to influence the design outcome is at the stage of the pre-structuring of the design problem. In other words, if a consideration is not part of the definition of P_1 then there is no way that it will be part of the solution P_2 (Hillier et al 1972). Adding PS to the simplified representation of the C/A process gives the following:

$$PS^{\text{TM}} P_1^{\text{TM}} TS^{\text{TM}} EE^{\text{TM}} P_2$$

The concept of PS added to the conjecture/analysis model gives a description of the realistic notion that the designer in addressing P_1 , brings all of the conceptual baggage of previous experience both, in design and from their life in general. Further the concept of PS means that this experience, along with the characteristics of the project at hand informs the definition of P_1 , that is, the design problem itself (Hillier et al, 1972). Hence a critical part of the designer's role is the *setting* of the design problem, not just the *solving* of it. This becomes a critical concept when introducing new parameters into the design process, such as environmental considerations.

At the beginning of the process of solving a design problem, whether it be the design of a whole building or a detail within it, there are theoretically an infinite number of potential solutions that could be reached in solving the problem. In design there is no single 'correct' answer as there apparently is in science, but numerous designs that could solve a problem satisfactorily.

Building on Hillier et al's, work, Darke introduces the concept of the *primary generator* (PG) as the means by which architects quickly reduce the number of potential solutions to a design problem (Darke, 1984). A PG is in essence a constraint to the possible set of solutions (Darke, 1984). PGs are a part of the act of the setting of the design problem, that is, the pre-structuring process, as defined by Hillier et al. This is the case whether or not the PGs are made explicit and form part of the design brief or remain implicit to the architect's cognition.

An example revealing the effect of primary generators comes from Darke. She interviews Kate Macintosh (KM), designer of a housing project by the name of 'Dawson's Heights'. When asked to discuss how the concept for the project was arrived at Macintosh replied:

KM: 'Well, obviously the site is a very unusual one, in London, and I always have been one of the romantic school that think you should try to express the unique quality of the site... ..so that was the main starting off point. And of course the other peculiar fact... ..was the fact that the hill is unstable, and only the top third... ..was buildable economically...(Darke, 1984)

This shows two constraints being applied to the setting of the problem for the design of the housing estate. The first, expressing the nature of the site, is an internally applied constraint imposed by the designer. It is something that she brings to the design problem. This inclination to express the quality of the site is something she would have brought to any project. It just happens that this project came to be under her control. As a primary generator this notion of expressing the qualities of the site has the effect of immediately reducing the number of potential solutions. The design is now predestined to move in a certain direction, different from what it would have had other primary generators been put in place, such as, for example, the notion that all of the houses on the estate should face the equator for the best passive design. The second primary generator, the condition of the soil, is an externally applied constraint. This also immediately reduces the potential field of solutions, but this is not something that the architect brought to the project, it is specific to this project. Taking these two primary generators into consideration the architect now has a more refined design problem, upon which to conjecture. The representation of the design problem solving process may now be refined with the following, where IF = the infinite field of potential solutions and PG = the primary generators:

IFTM PSTM P1TM TSTM EETM P2TM
(PG)

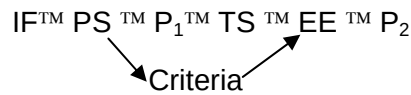
From this discussion then it can be seen that, the notion of the PG is very useful in terms of the pre-structuring of the design problem. It does provide the designer a more refined design problem upon which to conjecture. This returns to the point of the designer as problem setter and it can easily be seen how environmental issues could become primary generators if designers are aware, or have the inclination and or the requisite knowledge upon which to conduct such a problem setting exercise.

In essence then, there must be a broadening of the scope of issues dealt with when defining the design problem, such that it includes environmental considerations. The point to be made is that it is not enough to take a standard design problem as the starting point for the design process and then to attempt to adopt environmental strategies at a later point. If environmental considerations are not part of P_1 , then there will be no reason to eliminate non-environmental conjectures through the error elimination process and hence P_2 will not reflect environmental considerations. Inherently therefore, the first point at which environmental considerations must be dealt with in the problem solving process is at the stage of formulating P_1 , the design problem, both for the building as a whole and for individual design problems throughout the design process.

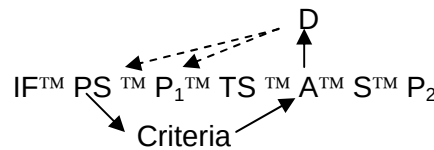
2.3. CRITERIA FOR ASSESSING DESIGN SOLUTIONS

Another useful aspect of the concept of pre-structuring is the way in which it establishes criteria for the designer against which the success of TS (conjectures), proposed in response to P_1 , may be assessed. Using Darke's example of Kate Mackintosh given above, there would be explicit requirements placed on that design due to the conditions of the soil. These requirements become design constraints, such as a two-storey height limit or conglomeration of buildings in that area of the site that is most suitable. They then form criteria, albeit very basic in this example,

against which conceptual design conjectures could be assessed. Criteria based on the romantic notions that Mackintosh speaks of would be more subjective, but would none-the-less be critical in guiding the assessment of conjectures by the designer. These criteria produced as part of pre-structuring the design problem may also be shown on the $P_1^{TM} P_2$ representation:



To explain, the criteria produced through the pre-structuring process are used in the process of error elimination to assess tentative solutions. This assessment process leads to the TS being either supported or discarded and hence the $P_1^{TM} P_2$ model may be refined again as shown below:



Here A = the assessment based on criteria from the pre-structuring, D = discarded conjecture and S = supported conjecture. In the case of S, P_2 is achieved and the process moves on to the next problem to be solved. In the case of D the process may return either to the original problem and the proposal of an alternative, but better informed, tentative solution based on the original problem, or the process may return to the pre-structuring of P_1 . The latter would occur when the process of design problem solving has revealed more about the nature of the problem and hence a re-framing of it is warranted. This is very often the case and a quote from another of Darke's respondents, Richard MacCormac illustrates this point.

A brief comes about through essentially, an ongoing relationship between what is possible in architecture and what you want to do. And everything you do modifies your idea of what is possible... you can't start with a brief and (then) design, you have to start designing and briefing simultaneously...(Darke, 1984)

The essence of this comment is that the process of design always has the potential to inform the setting of the design problem itself.

As the building design process progresses, the problem solving process and in particular the process of EE, reduces the number of potential solutions from an infinite field at the outset to the final, single design that is constructed. Though logically this statement is incorrect, as there will always be an infinite number of potential solutions at any point during the design process, the notion of a gradually reducing set of possible solutions is a good representation of the reality of the design process and therefore is a good model to work with (Bamford, 2002). Once design decisions are made they place constraints on future decisions. A good analogy for this situation is that of the sculptor with a block of stone. Initially it could be sculpted in to anything. However, there is a certain point at which enough maneuvers have been made such that it can no longer be, for example, a horse and it is obviously going to become a person, though it may still yet be a man or a woman. Further along the process it is obvious that it is not to be a man, and that it is to be a woman, but it could still be any number of individual women, and so it goes on.

Where a definite goal is put in place at the outset of a design process, for example to design a building that requires an absolute minimum of artificial lighting, it can be seen how it is critical that decisions relating to the achieving of that goal are made in

a certain sequence. For example, there are decisions about siting and orientation, openings, shading, internal layouts and zoning and the internal surfaces, that will all have an effect on achieving the lighting goal stated above. Though there may not be quite so fine levels of tolerance as the sculptor works with, these individual design problems must be addressed in roughly the order given here, in order that major design revisions, such as a re-siting of the building late in the design, may be avoided. Design goals set at the outset of the design process are essential to informing design problem setting and solving all the way through the design process

The important point to note is that, just as pre-structuring is critical in all design problems throughout the design process, not just during the early stages, so too, error elimination is critical from the very first decisions to the last. It is worth repeating that there is no pre-structuring phase, or tentative solutions phase or error elimination phase in the design process. They each occur in relation to every design problem encountered.

In relation to environmental information then, it seems that it would be beneficial to have information about certain problems available at certain times throughout the design process to facilitate both the PS and EE processes, or in fact the PS TM Criteria TM EE process. In addition, in relation to EE there is the opportunity to provide help to create criteria, or even to provide assessment criteria in themselves, with the aim of guiding the assessment of conjectures. Finally there is also scope for providing assistance in actually conducting assessment of criteria, in other words the process of design decision-making.

For building design then, the critical activity in the design process is the briefing process. By the process of developing the brief clients can have input into the design process by defining requirements, and in particular defining environmental issues to be considered and levels of performance that are desired. It is through the brief as a document that the design problems for the building are made explicit. However, the brief is not something that is formed at the beginning of the design process and then remains unchanged. Framing MacCormac's quote from above, in terms of the conjecture/analysis model, it is through proposing tentative solutions, and error elimination that the designer is able to redefine and refine the design problem. This again, is the notion of the designer as problem setter, not just problem solver.

3. A FOCUS ON THE DESIGN BRIEF

Having gained an understanding of the internal mechanisms of the designer's processes we can move on to the interaction between the client and the designer through the practice of design. It is through the briefing process that the client is able to have formal input into the design process.

The process of briefing, as stated by the Royal Australian Institute of Architects (RAIA), involves the coming to an agreement by the client and the designer as to among other things, the design objectives, spatial requirements, functional requirements and budgetary requirements (RAIA, 1993). In reality, negotiation on these aspects continues throughout the design process, as was suggested by the quote from MacCormac presented above. To this end the RAIA also state 'The Brief is a dynamic document which is refined throughout the design process. (RAIA, 2003). However, for the purposes of getting under way with designing of the building, a point must be reached at which the brief is agreed to by the client and designer. The RAIA state 'It is important, however, that before extensive design work commences, the design brief is compiled and signed off by the client.'(RAIA, 2003). At this point the

brief as a document comes into existence and it becomes a key reference for the remainder of the design process.

3.1. FRONT-LOADING THE DESIGN BRIEF

Research into environmentally responsible design process has been undertaken through a series of six case studies (Watson, 2004). These included five single, domestic residences and one commercial office fitout. The clients for all of the projects expressed a desire, to a varying degree, to be environmentally responsible through their buildings. One of the primary aims of the research was to investigate whether or not placing increased emphasis on environmental issues at the earliest stages of the design process improved the implementation of environmental strategies in the design outcomes. The term used to describe this increased emphasis is *front-loading*.

From the theoretical investigation of the design process it was noted that, for environmental issues to be part of design solutions they have to be part of the design problem and hence they need to be in the designers pre-structuring. Therefore front-loading the design process with environmental issues was seen as being the way to make these issues explicit, such that they would be able to inform problem setting throughout the design process.

The case study projects occurred in series over a span of three years. The research took a reflective practice approach. The front-loading approach was initiated out of discoveries from the first of the projects. The approach was then refined through the series of case studies as the results what had been implemented were analysed.

3.2. THE ENVIRONMENTAL BRIEF

For application in practice in the case study projects, the form taken to create a front-loaded design process was termed an *Environmental Briefing Process*. Discussion between the designers and clients were based around the development of a document which came to be termed the *Environmental Brief*. One of the key research findings was that it is important to distinguish between the document produced and the process undertaken, because of the different roles they played in producing benefits for the design outcome.

As might be expected, the environmental brief contains more than a typical design brief. By bringing environmental design decisions to the start of the design process the information contained within the brief is broader in scope and typically more detailed than a standard brief. This was so much so that late in the series of case studies it was determined that the term 'Brief' was misleading and undervaluing the amount of information contained within the document and the term Environmental Strategies Report was used.

The case studies revealed some critical roles of the briefing process and the brief as a document. The following is a brief summary of these leading to a critical path of events that were seen to ensure that environmental goals were met, whether they be strenuous or weak. The results also points towards the way to achieving improved implementation of environmental issues.

4. KEY ROLES OF AN ENVIRONMENTAL BRIEF

4.1. THE BRIEFING PROCESS AS EDUCATIONAL TOOL

Clients enter the design process as the party with control over the resources that are going into the project. They also enter with a level of environmental knowledge that varies between clients. There is a role therefore, in the process of environmental

design to attempt to educate the client with the goal of raising their level of understanding and therefore their desire to allocate resources to the environmental aspects of the project.

The clients of the five residential case studies were characterised by being well educated, at least one member of each household held a university degree, and by all having the desire to be environmentally responsible. These factors may be seen to have made them a more receptive audience than would be typical. However, the clients differed in four key ways crucial to the eventual level of implementation of environmental strategies. Firstly, they all came with a different perception of what was environmentally sustainable. Secondly, they had unique set of desires and priorities for the project. Thirdly, they were open to being educated in the environmental issues to a different degree, and fourthly they all had different budgets and hence access to resources to work with. Of these factors, education cannot change the budgetary constraints, though it could change priorities within those constraints. The other three factors however, may be influenced by the education of clients, hence the aim of education was to raise the understanding of the concept of sustainability and to change desires and priorities to be more in favour of environmental considerations.

Evidence from the case studies did not suggest that education of the client directly informed the pre-structuring for the designer, but certainly it had an effect on problem setting, because the clients must come to agreement with the designer as to what many of the design problems will involve.

The education of clients is critical as an intermediate step towards implementation. The role of education is to alter priorities in order to alter implementation. To this end, clarity of the presented information is of critical importance.

4.2. THE DISCUSSION OF ENVIRONMENTAL ISSUES

Apart from education regarding environmental issues, it is also important that these issues are simply raised at the outset of the design process, even if all parties are fully aware of the issues. If they are not raised then there is not much chance that they will be considered for inclusion in the brief and hence form a part of the design problems. The wider the range of environmental issues raised at this early stage the wider range that may be included in design solutions.

In the case studies it was possible to discern a link between the raising of issues, the setting of goals and then the achieving of goals set, whatever the performance level of those goals in terms of implementation. An aim for the environmental briefing process therefore is to attempt to cover the broadest possible range of environmental issues. Having said this, there is a balance to be struck between being too detailed and hence bogging down the design process, and confusing or scaring the client, and being too simplistic and hence missing opportunities that may have otherwise emerged if issues had been discussed.

4.3. THE BRIEF AS BRIDGE BETWEEN GENERIC AND SPECIFIC

Having said that the broadest possible range of issues should be raised in the briefing process, it is also important to note that not all issues can be considered or taken on board. The brief acts as a bridge between the consideration of generic environmental issues and the specific issues that will be included in the project.

The briefing process must facilitate unique project requirements to be taken into consideration and thereby shape the rest of the design process. Environmental issues range from global in nature such as greenhouse gas emissions to very particular, project specific issues, such as specific health requirements of a client

that may have asthma. Figure 1 illustrates the environmental briefing process taken from one of the case study projects. In this particular case a Building Environmental Assessment tool, the GBTool, was used as a comprehensive and widely accepted source of environmental issues and assessment criteria. Through the briefing process these were tailored to the nature of an office fitout, and then tailored to the specific client requirements for the project.

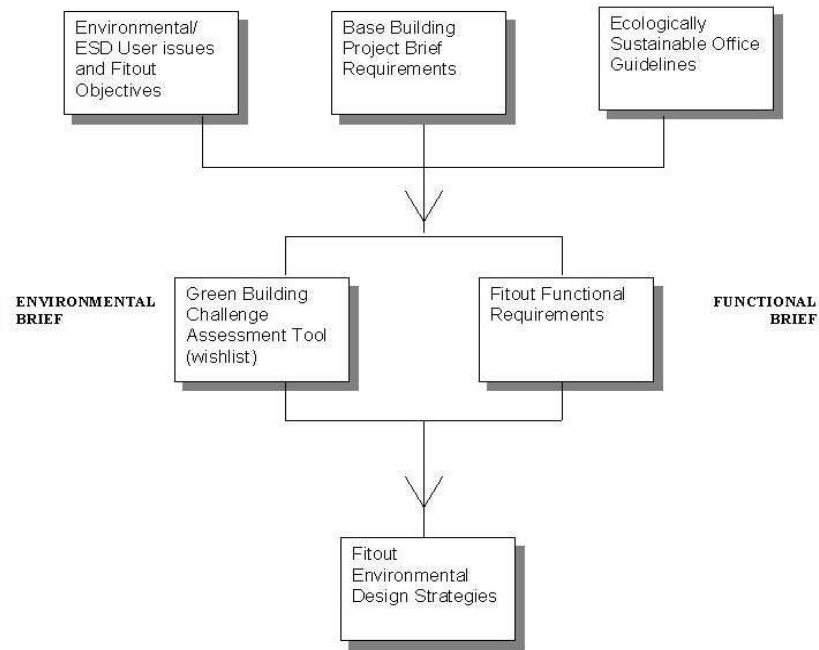


Figure 1: Flow diagram representing the environmental briefing process of the EPA Fitout project (Thomson et al, 2001)

4.4. FACILITATING THE SETTING OF PRIORITIES

The raising of issues, and the education of clients, through the process of creating a specific brief, out of a set of generic issues, is in essence assisting the client to determine priorities for the allocation of their resources. The aim is that environmental issues will be raised in the list of priorities on the assumption that the top priorities will get the greatest attention and have the highest chance of being achieved. As noted above, all of the clients in the case study projects had the intention of being environmentally responsible, though to varying degrees. This was reflected in the priorities that they set.

Through the case studies it was found that the setting of priorities, is the primary means of dealing with value conflict between environmental issues and between environmental and non-environmental issues. The aim of the environmental briefing process is to facilitate the setting of priorities at the earliest possible stage of the design process. Where priorities were not firmly established conflict tended to occur right through the design process, causing delay and angst between client within a project. Once a set of priorities are established then specific environmental goals can be set for the project.

4.5. FACILITATING GOAL SETTING

Typically a client brings a series of functional goals to a project. As part of the environmental briefing process they were asked to include their environmental goals. The designers brought to the process what was termed an 'environmental wishlist' as seen for example in figure 1, which included an extensive set of environmental

design issues for potential inclusion into the design. The briefing process then involved the ‘marrying’ of functional and environmental goals to form a set of overall goals.

The setting of goals regarding the environmental performance of the project is a key activity that must take place at this early stage of the design process, even if those goals change throughout that process. The goals, once set are able to inform the pre-structuring of design problems. Goals may be prescriptive, such as the inclusion of specific environmental technologies or strategies, or they may be performance based, setting the desired levels of environmental impact, such as energy, water or material usage over the life of the building. Evidence from the case studies that goals were set, either formally or informally, with regard to environmental performance would indicate that consideration has been given to environmental issue. These goals then become the source of criteria which will facilitate the environmental decision-making throughout the rest of the design process.

An simple example of goal setting informing design decision-making comes from one of the domestic residences, in which there was a goal on behalf of the clients to be self sufficient in terms of electricity usage. Part of the design problem for the roof of the house, therefore, was for it to be north facing at around 30° for the optimal installation of photovoltaic cells and a solar hot water system. In general the results from the case studies showed that there was a reasonable correlation between the level of environmental performance set at the outset of a project and that which was achieved in the final design.

In order to improve implementation however, this will only be achieved through education of the client and discussion of issues. An issue can only be included in a goal and therefore influence problem setting is if it is raised as an issue. Logically the same would apply to the increased environmental performance of goals set. Only through education and discussion regarding more stringent environmental performance may such things possibly be incorporated into goals. It must be noted that education and discussion will not necessarily lead to inclusion of issues into goals, but that without these inclusion will definitely not occur. Figure 2 characterises the critical sequence of events leading to the improved implementation of environmental strategies as derived from the evidence from the case studies regarding the front-loading process.

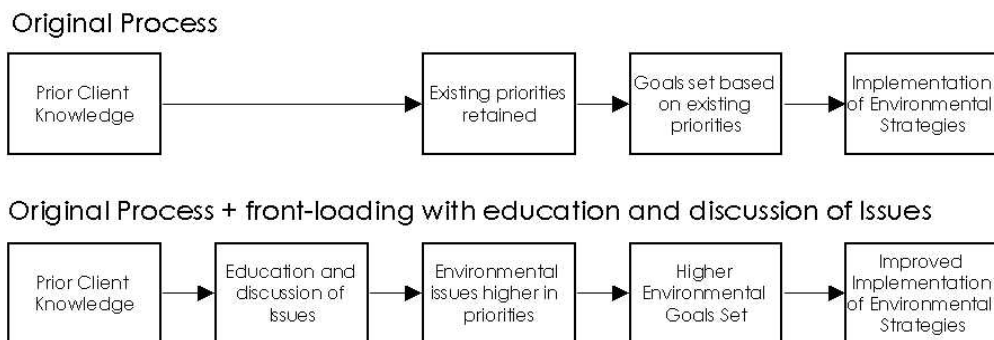


Figure 2: The sequence of events leading to improved implementation of environmental strategies, with and without front-loading of environmental issues (Watson, 2004).

4.6. THE BRIEF AS STARTING POINT FOR DESIGN ASSESSMENT

If implementation of environmental strategies is to be achieved in the final design, then there must be some way of assessing the design as it evolves. As part of the

$P_1 \Leftarrow P_2$ process criteria are developed either implicitly or explicitly from the pre-structuring of the design problem. It is these criteria that are used as a means for making assessments of design conjectures as part of error elimination during the problem solving process. Hence, evidence that environmental criteria were being produced out of the front-loaded design process would indicate that the process at least had the potential to aid in the decision-making process. In some cases, as for example in figure 1, explicit assessment criteria were taken from existing sources, in that case the GBTool.

There was evidence from the case studies that criteria from problem setting were being used as a means of assisting design decision-making and that this in turn lead to implementation of environmental design strategies. The strongest evidence came from those case studies in which the environmental goals were the highest. This makes sense, because if there are more environmental issues locked into goals, then there should be more criteria based on those environmental issues with which to assess design decisions. The best example is perhaps the criteria of roof slope for solar technologies that was suggested in the front-loading process of all of the residential projects, but which was only achieved in the end for the one of the houses. It was those clients that had placed the highest priority on the strategy, hence when the issue of roof slope came up as a criteria against which to measure conjectures, and only those conjectures which satisfied that criteria were accepted.

Figure 3 illustrates the sequence of events connecting goal setting to the design problem solving process and the criteria for assessing conjectures. The importance of goal setting as a task in the front loading process becomes apparent. If there is no environmental goal setting in place, as seen in the top half of figure 3, then this can not form part of the design problem, which in turn will produce no criteria against which to measure conjectures, there would be no influence on the error elimination process and hence no influence on implementation of environmental strategies.

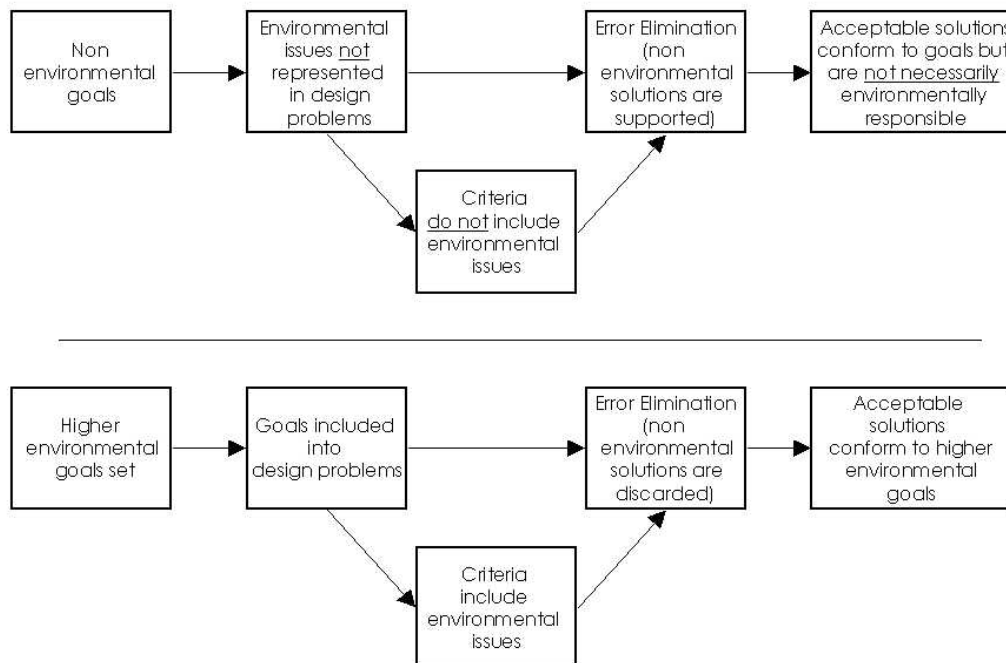


Figure 3: Comparison of design problem solving process leading to potentially non-environmentally responsible solutions (above) and to environmentally responsible solutions (below). (Watson, 2004)

An important task for the environmental brief is to facilitate the linking of environmental assessment criteria to the particular goals set for a project. To this end there needs to be a certain degree of flexibility in the content of environmental assessment criteria in order to cater for unique project goals.

4.7. THE BRIEF AS A RECORD

The final role of the environmental briefing process to be examined, is that of providing a record. Recording the issues considered, goals set and decisions made, benefits not only the project for which the brief is being developed, but future projects. Dealing with the complexity of environmental issues, though these issues vary from project to project, will be assisted by reference to such a record of previous decisions made and the outcomes that resulted from them.

The notion of bringing forward of information, knowledge, experience or solution sets from previous projects for use on the project under consideration is termed *feed forward* (Prieser, 1999). Feed forward is a critical process as part of the iterative improvement of building design in general and, in particular here, in terms of improving environmental performance. It is particularly useful if knowledge gained from past projects can be used to inform the design process from the earliest stages, to prevent progressing in directions that may have already been found not to be useful and to prevent the need for repeating research groundwork. The feeding forward of knowledge and ideas had a large influence on the pre-structuring of design problems for the designer. As the Hillier et al state, a large part of pre-structuring relies on the designers past experience (Hillier et al, 1972).

For the individual project, in order that the front-loaded process, and the products coming out of it, namely the briefing document and the goals contained within it, may have some bearing on the design decision-making process, there must be evidence that this document is being referred to throughout the design process. There was certainly evidence of this in the process of design decision-making in the case studies. However, importance was placed on the environmental briefing process and continued adjustment of the brief as a part of the design process, as opposed to the importance of the brief as a document itself.

The process of recording goals in the brief cements issues in place for the designer and perhaps more importantly for the client. When design decision-making then occurs there can be a greater degree of confidence that the correct decision is being made relative to the project goals. An architectural brief should continue to evolve throughout the design process and recording this evolution will assist in keeping a harmonious relationship with the client as the designer attempts to fulfil the clients wishes. In those case studies where goals were not formally recorded problems were encountered when it came to making design decisions.

5. CONCLUSIONS

For design solutions to achieve the environmental performance level desired by clients, goals must be put in place as early as possible in the design process. These goals, encapsulated in the briefing process, go on to inform the pre-structuring of design problems by the designer, throughout entire design process. Design problems addressed early in the design process have the greatest impact on the design because they limit the potential solutions to later design problems. It is most critical that these early design problems are set with environmental considerations in place.

The indication from the research is that in order to increase the implementation of environmental strategies the key tasks are to educate the clients and raise

environmental issues with them as early as possible in the design process with the aim of encouraging the clients to raise environmental issues up their list of priorities. Only then will these issues be more likely to be enshrined in to project goals and then be able to inform design problem setting and hence design solutions.

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THEME 4: PROCUREMENT AND RISK SHARING

Full Paper

THE DEVELOPMENT AND USE OF SECONDARY PERFORMANCE INDICATORS FOR MEASURING PROJECT HEALTH

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ABSTRACT

Maintaining the health of a construction project can help to achieve the desired outcomes of the project. As part of an ongoing research project of the Cooperative Research Centre for Construction Innovation (CRC-CI), a multi-stage toolkit is being developed to monitor and correct the condition of construction projects. The first stage of the toolkit is designed to assess the state of the construction project through the use of critical success factors (CSFs). CSFs that are found to be underperforming are identified and used as the basis of a more detailed investigation in the second stage of the toolkit to identify factors contributing to the problems. Secondary performance indicators (SPIs) are used to assess the condition of the contributing factors so that root causes can be identified and remedial actions suggested. The final stage of the toolkit monitors the project for changes to ensure continuous improvement. This paper will discuss the way that SPIs were obtained for this toolkit and how they are used to guide the identification of root causes.

Keywords: Construction project condition, critical success factors, key performance indicators, secondary performance indicators.

1. INTRODUCTION

There is a constant stream of public reports and commentary about projects that fail to meet pre-determined objectives. Adverse impacts include cost and time overruns, inadequate build quality, poor project relationships, loss of reputation, public clamour and legal disputation. In some instances poorly performing projects can attract unwanted publicity, particularly those which are publicly funded and enjoy a high profile.

In order to improve the potential for a project to achieve the outcomes expected, a construction project health check model is being developed to allow assessment of current project health, identification of root causes as to why the project is not performing as expected and suggest a means of returning the project to better health (Humphreys et al, 2004). The model evolved from a human health care model and uses symptoms to evaluate project health. The model undertakes a detailed investigation of key symptoms to diagnose cause of problem and proposition of a remedy to return the project to good health

2. BACKGROUND

Rubin and Seeling (1967) were the first to introduce success and failure measures. The findings from their study concluded that the wrong choice of project manager, unplanned project termination and unsupportive senior management were the main reasons for project failure. Russell & Jaselskis (1992) and Abidali & Harris (1995) measured project success by using financial ratios derived by statistical search through a number of plausible financial indicators. Their research was based on investigating the impact of a project manager's experience on project's success or failure. Technical performance was used as a measure of success. It was concluded that project manager's previous experience had minimal impact on the project's success or failure. Concurrent research carried out by (Belassi et al, 1996) proposed that Time, Cost and Quality were the basic criteria of project success. They are also discussed in articles on project success such as that of Skitmore (1997) and Shenhar & Levy (1997). Atkinson (1999) called these measures as the 'iron triangle'.

Pinto and Pinto (1991) based their findings on soft measures such as satisfaction levels and suggested that success measures should also include psychosocial outcomes such as safety, litigation and others that relate to interpersonal relationship within the project team. Pinto and Slevin (1987) and Morris and Hough (1987) found out that communication, environment events, community involvement, team member conflict, lack of negotiation and arbitration, legal disputes, management inability to understand site people, and stakeholders value were likely candidates for measuring project success or failures and warranted the need of including them along Cost, Time, Quality and Safety.

Mian et al (2004) found that the most common cost overrun measures found in the literature over the last decade were poor estimating, inclement weather and insufficient and untimely cash flow. Less common issues included lack of contractor project type experience and contractor's lack of familiarity with local regulations. Issues such as complexity of project and inflation were found occasionally. Similarly time overrun measures most commonly encountered included communication gap

between project parties, inaccurate prediction of production output, inclement weather, design changes, safety issues, industrial action and skill shortages. Issues reviewed less frequently included lack of supply of plant, equipment & materials and site storage problems. Issues that were occasionally covered included locational project restrictions (site access) and production of design drawings.

They also found out that over this period the most commonly found quality measures were reluctance to adopt quality systems, inadequate quality assurance and control systems, lack of product identification and traceability, lack of internal and external audits, infrequent inspections and insufficient training. Less commonly found factors included lack of control of inspection/measuring/testing equipment, lack of control of non-conforming product and poor data control. Quality measures least commonly found in the literature included lack of employee conscientiousness and lack of encouraging specialization in construction work. This indicated that the majority of clients and stakeholders now took the issue of quality conformance more seriously and believed that the issue of resuscitating failing projects due to poor quality of documentation or workmanship is vitally important to a vibrant, healthy industry. The old adversarial attitudes which were ingrained as part of poor project outcomes for at least some of the key participants were seen as being passé.

Like CSFs, the contributing factors will need to be assessed to pinpoint the areas most likely to be causing poor project health. This will be accomplished with a series of Secondary Performance Indicators (SPIs) for each contributing factor. The Construction Best Practice Program (Cbpp, 2003) defines an SPI as ‘...an indicator showing the level of performance achieved against an operation that is of secondary importance to the successful completion of the services being provided. An SPI often provides a diagnosis the SPIs of the result of KPI. To ensure the usefulness of the model to carry out detailed diagnose, the SPIs need to possess the same characteristics as the KPIs. However, the SPIs will also be used as the basis for prescription of remedies and will therefore need to be easily benchmarked.

3. THE USE OF PROJECT HEALTH MODEL TO DIAGNOSE CONSTRUCTION HEALTH PROBLEMS

Humphreys et al (2004) proposed that human physical health can broadly be thought of as the condition of the body. When physical health is poor, performance or quality of life can be compromised. Poor physical health often has associated symptoms that can be used to help pinpoint the cause of ill health quickly and accurately. Once the cause has been identified, a remedy can be implemented to return the body to good health. If symptoms are left unchecked, they can develop into critical situations and become much worse.

In many ways the “health” of a construction project is analogous to human physical health. Some of the parallels between construction project health and human physical health identified in the work of Humphreys et al (2004) include:

- State of health influences performance
- Health often has associated symptoms
- Symptoms can be used as a starting point to quickly assess health
- Symptoms of poor health are not always present or obvious
- State of health can be assessed by measuring key areas and comparing these values to established norms

- Health changes temporally
- Remedies can often be prescribed to return good health
- Correct, accurate and timely diagnosis of poor health can avoid small problems becoming large

In this approach project health infers the degree to which the project is meeting expected outcomes. It is synonymous with project performance in that a project or any particular aspect of a project which is not performing as expected by the stakeholders would be perceived as unhealthy or failing. Conversely, a healthy project would be one which is fulfilling the expectation of the stakeholders.

The requirement for rapid, accurate diagnosis lead to the concept of an initial broad health checking mechanism which could guide a further more detailed investigation designed to identify the factors contributing to poor health. The use of performance indicators to assess the state of the contributing factors allows remedies to be prescribed, based on the condition of the contributing factors investigated. Figure 1 shows the basic form of the model. The SPIs discussed in this paper are used in stage 2 of the model "Identification of root cause". The root causes are then used in the third stage of the model to help develop a set of remedies. Note that the model has been designed to include a Deeming (1986) type feedback loop for continuous improvement. This provides a means to assess the effectiveness of the proposed remedies to return the project to good health and is also analogous to the human health model.

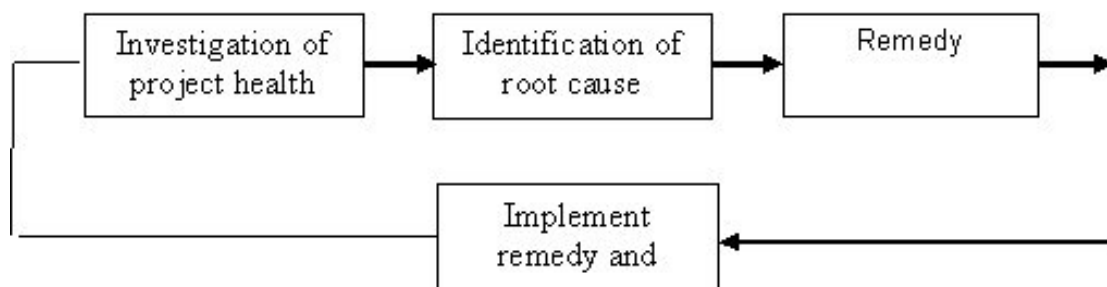


Figure 1 – Project Diagnostics Model

The use of KPIs to assess the performance of CSFs in stage 1 this model has been described in work by Mian et al (2004). In summary, the proposed model uses CSFs as the basis for a broadly inclusive fundamental health check to gauge project health in terms of specific success factors agreed to by interested parties. In order to use these CSF's as an indication of health, they need to be assessed. This was achieved by developing an associated list of Key Performance Indicators (KPIs) for each CSF.

The areas which form the focus of stage 2 are determined by the outcome of the stage 1 investigation. CSFs that are found in poor health in stage 1 are studied in more detail in stage 2. This is an important feature of the model as it allows rapid initial identification of problem areas followed by efficient and accurate identification of the root causes. In order to facilitate a more detailed investigation of underperforming CSFs the main factors contributing to each underperforming CSF needs to be identified. Once a broadly inclusive set of CFs is identified, they are used to pinpoint the areas most likely to be causing poor project health. One of the main features of the CF approach is that it allows the uncoupling of single issues which may span several CSFs.

Like CSFs, the CFs will need to be assessed to pinpoint the areas most likely to be causing poor project health. The method used to assess the CFs was designed with the requirements of stage 3 in mind. Stage three of the model requires specific problem areas to be identified and described so that appropriate remedies could be prescribed. This led to the development of a series of secondary performance indicators (SPIs) associated with each CF. These could then be used to assess the performance of each CF and, if found underperforming, would become the basis of a suggested remedial strategy.

The Construction Best Practice Program (Cbpp, 2003) defines an SPI as ‘...an indicator showing the level of performance achieved against an operation that is of secondary importance to the successful completion of the services being provided. An SPI often provides a diagnosis the SPIs of the result of KPI’. To ensure the usefulness of the model to carry out detailed diagnosis, the SPIs need to possess the same characteristics as the KPIs as presented by Humphreys et al (2004). However, as the SPIs will be used as the basis for prescription of remedies they will also need to be easily benchmarked.

4. IDENTIFICATION OF CONTRIBUTING FACTORS AND SECONDARY PERFORMANCE INDICATORS

Pilot interviews were conducted on seven projects identified by the industry partners. These interviews were conducted using a structured questionnaire. The respondents included clients, consultants, contractors and sub contractors. A total of 28 interviews were conducted. The questionnaire was designed to allow identification of contributing factors and to allow them to be ranked in terms of relative importance using a numeric scale. The projects were varied and included a variety of contracts types such as Design and Build, Lump Sum and Schedule of Rates. Most of the projects were more than A\$10M in value. The questionnaire was undertaken by personal interview with each respondent to ensure each question was understood and addressed adequately. This was particularly important in this case as terminology used to describe CFs was derived from an initial literature and did not necessarily reflect the terminology of the respondent. For this reason also, the raw data from all interviews needed to be collated as the name for a single CF can vary from person to person.

The data analysis started with examination of questionnaire to identify of CFs for each of the seven unhealthy CSF themes. The collation of CFs based on common terminology reduced the total number of CFs by identifying common CFs between the seven CSF themes. The respondents were required to limit the number of contributing factors that they proposed to four. In most cases respondents provided four different contributing factors of varying relative importance, however occasionally the answers consisted of one contributing factor for each CSF. The respondents were required to rank the CFs using a scale of 1-4.

To determine the overall ranking of the identified CFs for each unhealthy CSF using the importance scale nominated by the respondents (clients, consultants, contractors & sub contractors) the importance index was computed using the following modified equation by Mezher (1998):

$$II = \left(\sum_{i=1}^4 \frac{x_i y_i}{3} \right) \quad (\text{Eq. 1})$$

Where II denotes importance index and x_i is a constant that represents the weight of the i th response where $x_i = 1, 2, 3, 4$ and y_i represents the frequency of the i th response where $i = 1, 2, 3, 4$. Hence;

y_1 = frequency of the least important contributing factor.

y_2 = frequency of the less important contributing factor.

y_3 = frequency of the important contributing factor.

y_4 = frequency of the most important contributing factor.

Table 1 provides an example of the CFs identified in the study for the CSF “Cost Overrun” as well as the rank and importance index of the CF.

Table 1: Rank and index of contributing factors

CSFs	Contributing Factors (CFs)	Index	Rank
Cost Overrun			
	Variations	14.7	1
	Inaccurate cost estimate	6.0	2
	Rework	3.3	3
	Lack of client decision making	2.7	4
	Competitive nature of market	2.3	5
	Poor quality of design & documentation	2.3	5
	Approvals	2.0	7
	Contractor / Sub contractor work efficiency	2.0	7
	To manage project simultaneously a large component of work was done in another city branch office	2.0	7
	Poor workmanship	1.3	10
	Work sequencing with other trades	1.3	10
	Audit testing	1.0	12
	Change of management	1.0	12
	Emissions and under measures in documentation	1.0	12
	Lack of completeness of contract documents	1.0	12
	Limited resources	1.0	12
	Lack of architect higher management interest	0.7	17
	Productivity of workforce due to traveling involved due to remote location of project	0.7	17
	Relationship workshop	0.7	17
	High quality product required	0.3	20
	Higher management direct involvement	0.3	20
	Programming issues causing pressure on contractors	0.3	20

A similar listing was generated for each of the seven CSFs. A total of 127 contributing factors were identified. Table 2 ranks the seven CSF themes based on the findings of the investigation (note3 that quality has been divided into two groups for Table 2 – quality of construction and quality of documentation).

Table 2: Rank and index of CSFs

CSFs	Index	Rank
Cost	6.68	1
Quality of construction- increase in rework	4.65	2
Relationships	4.15	3
Time	3.86	4
Safety	3.60	5
Stakeholders value	3.43	6
Environment	3.40	7
Quality of documentation -Increase in RFI's	3.20	8

In addition to the CF identified in the study, other important findings included:

- ❑ All projects were considered successful by the respondents; however, some projects possessed unhealthy CSFs.
- ❑ Contributing factors for the healthy CSFs may be useful for identifying remedies in Stage 3.
- ❑ A variety of perspectives were obtained from the broad range of respondents interviewed in each project.
- ❑ Verbal clarification was required for some questions, particularly those requiring percentage estimates and relationships.
- ❑ All respondents were extremely co-operative although reluctant to focus on negative issues.
- ❑ The investigation of only projects which were considered successful may have implications on the completeness of the set of CFs.

Due to the investigation of only successful projects in this pilot study the list of CFs was not considered comprehensive and was augmented with CFs identified from a literature survey.

The CFs were further validated using a Delphi type approach using industry partner as specialists and asking them to add CFs to the list obtained from pilot study so as to have a comprehensive list. This was repeated by have a second round of feedback on CF and finally they were discussed in a workshop attended by the same specialists to get a final list bases on the consensus of these specialists.

5. SPI'S

Although a large number of SPIs were identified in the literature review, these often lacked certain characteristics that would make them applicable, useful, independent and practical. To increase the robustness and usefulness of the model certain characteristics were chosen which need to be possessed by SPIs used in this model. The SPI characteristics along with description are shown in Table 3.

Table 3: Required SPI Characteristics

Characteristic	Description
Easily measurable	Must able to be measured quickly, directly and accurately with as little effort as possible.
Sensitive	The indicator must be tuned to project health to allow accurate health assessment.
Assessable	Once measured, the indicator must be able to be compared to a known value to allow judgement of health to be made.
Reflect reality	The measured variable must encourage a description of reality rather than 'ideal' or perceived situations.

The focussed assessment of SPIs should allow underperforming CFs to be rapidly identified. A number of SPIs fulfilling the above criteria were identified from the literature survey for each of the CFs. However due to the nature of some of the characteristics described above it was necessary to validate the robustness of these SPIs by testing them on actual projects. The validation stage was also important as the outcome of this stage was to be a robust set of SPIs that would facilitate in pinpointing root causes of poor construction health. The validity was assessed with three projects within Australia and a fourth international project overseas that was especially helpful in validating measures associated with international joint ventures.

To enhance the chances of checking the robustness of SPIs, the case studies were chosen to be *unsuccessful*: An unsuccessful project was preferred to maximise repetitive evaluation of the SPIs, *live*: This was useful for SPIs meant to give a snap shot at a point in time. This would facilitate the implementation and monitoring of remedial measure, which was the final objective of the health check model and of *different sizes*: helped to evaluate the size dependent SPIs. The projects were carefully chosen to ensure that they encompass different project stages and different procurement methods.

SPIs consisted of objective metrics and subjective questions. In order to increase the objectivity the questions consisted of a series of conditional statements that facilitated assessment whilst minimising subjectivity.

The data was collected through face to face interviews and the interview questions were structured around the information required to measure SPIs. At the beginning of the case study a list of project documentation required for measuring the SPIs was circulated among the case study participants. It is envisaged that this would help in cross checking the subjective answers of the respondents with the hard data from the project documentation e.g. RFI register, Claims register, EOTs and many other. The third important factor as shown in Table 3 that contributes to a cost overrun is rework and the associated SPI to investigated rework is shown in Table 4.

Table 4 – Example of CF / SPI

CF	Contributing Factor	SPI
Cost Overrun		
	Rework	Definition

		$RR = RC / TACV$ Where: RC = rework cost TACV = total adjusted contract value contract

The aim of the validation process was to assess how 'well' an indicator measures what it is intended to measure. For the purpose of immediate assessment of contributing factors to pin point the root causes 'well' for a SPI refers to its ability; to be measured easily, to be comprehensively applicable i.e. applicable to all project stages and many procurement methods, to be assessed and make the correct assessment, to be sensitively tuned to health of a project. The validation process for the health check model helped to identify the most efficient, robust and effective SPIs.

The main findings of the validation process for RR (Rework Ratio) are summarized as follows:

- Easily measurable: As shown in Figure 2, the data required to measure RR was readily available on three out of four all (75%) the case studies. On projects where rework cost was not being measures this cost was based on an approximation formula = 30 % of (total value claimed - total value approved) i.e. rework cost is approximately 30 % of the contractor claims that are not approved. The claims data was collected using contractor progress claim showing the claimed and approved. The availability of any of the above facilitated in measuring RR quickly, directly and accurately with little effort.
- Broadly applicable: Although the measure was only designed to measure contractor's rework cost, it was easily measurable for all the case studies using different procurement methods such as construction management, traditional and design & construct.
- Assessable: Based on literature review and past experiences of industry specialists a benchmark of 0.02 was chosen to assess this SPI. It was also decided that any project having a RR ratio greater than this benchmark was unhealthy. Although RR was easily measurable and thus easily assessable on all the case studies but it was more important to check if the results obtained from the assessment was the correct indication of actual cost performance of the project. The use of other psychosocial and subjective indicators that were based on the public, media and stakeholders comments reinforced the RR results on all three out of four (75%) case studies.
- Reflect reality –This characteristic is linked to the availability of data for a SPI. SPI data was realistically available on all (100%) case studies mainly due to the presence of appropriate documentation.

- Sensitivity. Cost is directly tuned to project health as a cost overrun clearly indicates poor health. Rework is one of the factors that contributed to cost overrun and poor project health. It was noted in the validation process that RC kept on changing throughout the life cycle of the project and due to their influence on RR and in turn on project health; the project health was sensitive to even minor changes in RC. The sensitivity characteristic was only validated on one case study (50%) because of the time associated with sourcing, collecting and analyzing data at different stages of the project.

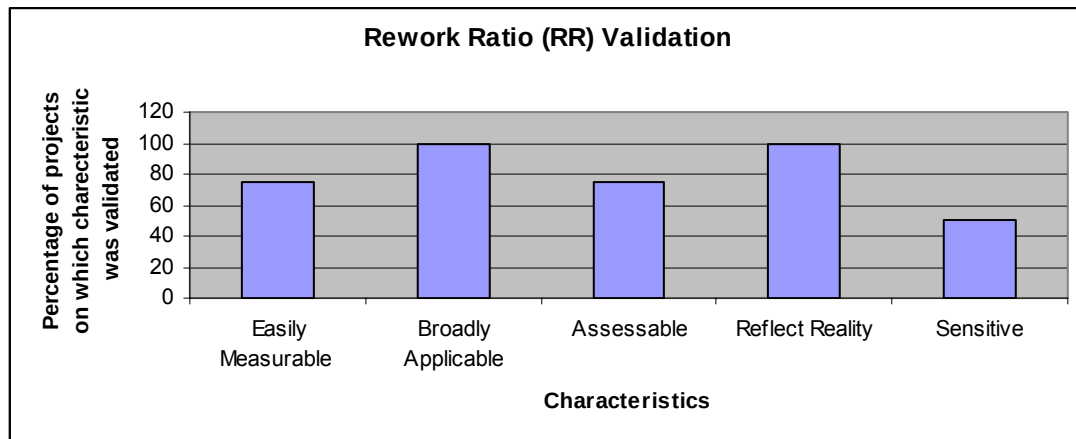


Figure 2: Rework Ratio (RR) Validation

The main overall conclusions drawn from the validation process are:

- The seven CSFs identified through the literature were the most significant for project success or failure as they receive the most attention from the on-site activities and the involved stakeholders.
- The robustness criteria defined above acted as a decision tool for retaining, discarding or changing SPIs. However it was necessary to retain only the most robust set of indicators that fully addressed the set criteria. This helped in minimizing the chances of producing a tool that might end up being time and resource consuming and impractical to use.
- As the majority of SPIs were objective and use mathematical formulas the evaluation process was rather straight, inexpensive and quick to implement. However the set also included some subjective SPIs that used opinions of clients, community and media. These were read together with the results obtained by using objective SPIs e.g. the safety incidents was measured using a direct question but the result was read together with Lost Time Injury Frequency (LTIF) and negative media coverage

6. SUMMARY

Project Diagnostics is developing a three stage toolkit to rapidly pinpoint underperforming areas of the project, identify factors which contribute to the underperformance and propose remedial measures to return the project to good health.

The second stage of Project Diagnostics identifies root causes of problem areas that have been identified by an initial investigation in stage 1 of the process. Factors which contribute to the root causes of the problems are evaluated using a system of secondary performance indicators.

A series of industry consultations and literature survey were used to identify a large number of contributing factors (CFs). Similar CFs were grouped to reduce the total number of CFs and workshops with industry partners were undertaken to refine the list. Each CF required a series of SPIs to measure its performance. The SPIs associated with each CF were determined as before through a consultative process with industry partners and detailed literature survey. The large primary list of SPIs was reduced by grouping like SPIs and a final list of SPIs was achieved through an industry partner workshop.

The CF / SPI system was tested on a series of case studies and found to possess the characteristics necessary for it to be an effective and efficient solution to stage 2 of the Project Diagnostics model.

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CLIENTS DRIVING INNOVATION

Keynote Address

OCCUPATIONAL HEALTH & SAFETY – THE CARING CLIENT

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1 INTRODUCTION

1.1 DOES ANYONE CARE?

When you look at occupational health and safety (OH&S) statistics in the construction industry – fatality rates three times the national workplace average; injury rates 50% higher than in other sectors; long term compensation claims double the national workplace average; and a plethora of long term health issues such as hearing loss – one has to ask whether anyone in the industry cares about occupational health & safety ... and unfortunately, I think that it is fair to say that many in the industry don't.

Certainly there are sectors of the industry that have very poor statistics, even against the low achievement of the construction industry itself. If these statistics are a measure of "Caring" in any significant way, then these sectors certainly don't care.

However, some parts of the industry do care.

In particular, we see clients who stand apart in the requirements they impose on themselves and their contractors and the effort they go to in order to improve safety in their operations.

1.2 THE IMPORTANCE OF "CARING CLIENTS"

One of the things that is abundantly clear in occupational health & safety management, is that success is driven from the top – in the client/contractor equation, by the client, and within the individual organisations, by senior management.

Therefore, when you see a very good OH&S performance on a venture or a project, you can be pretty sure that at the top of the structure is a "Caring Client".

You can also be pretty sure that as you go down the "food chain" you will find "Caring Contractors" – caring clients simply do not accept contractors who aren't, irrespective of commercial and other considerations. Of course in turn the caring contractors are "Caring Clients" to their subcontractors.

You will also find that in these "Caring" organisations, the responsibility for good OH&S behaviour is not just accepted by senior management, but it is

driven by those people personally. In such organisations it is usually the CEO or even the Chairman who is the champion of the “Caring” culture.

I will be therefore be talking today about “Caring Clients” and describing some of the things that caring clients, and caring contractors such as John Holland, do. A lot of what I say is really about “attitude”, because good OH&S behaviour is a culture without which good outcomes are simply not possible.

1.3 THE PRESENTATION

Before I look at particular “Caring Clients” and some of the things they do, I will talk a bit about the industry and some of the issues that now confront it.

I will mention my company John Holland, not just for the opportunity to get a plug in, but because I believe that we have established a position in the industry that entitles us to speak about some of the industry's successes and its shortcomings.

I will talk a little about the Cooperative Research Centre for Construction Innovation (CRC-CI) and a project it is undertaking which probably illustrates how far we have to go in the construction industry.

In presenting an overview of the wider industry, I will present a few statistics and touch on some of the behavioural issues that we face. ...and while talking about behaviour, I will touch on a topic that is starting to get some real attention, and assuredly will get a lot more in the future. That is the changing compliance aspect of OH&S management. If the legislative requirements themselves do not impress on industry players the need to become “Caring”, I expect that some of the penalties applicable under new legislation may.

I hope that case studies on “Caring Clients” that I will present, will not only give credit to their achievements, but will show the way forward for others.

2 JOHN HOLLAND

2.1 JOHN HOLLAND'S HISTORY

Firstly, a bit about my company.

John Holland & Co. was founded in April 1949 and soon after began its first project, a woolshed on the property of former Prime Minister Malcolm Fraser at Nareen in Victoria. John Holland grew strongly in the post War years and through the 50's and 60's, came to be acknowledged as one of Australia's leading engineering contractors.

After a period of difficulties and several ownership changes during the late 80's and the 90's, John Holland's ownership changed again in February 2000. Now it is owned 70% by the listed Leighton Holdings Limited and 30% by Janet Holmes à Court's family company Heytesbury Pty Ltd.

Over the past few years John Holland has undertaken a number of strategic acquisitions, including the rail equipment supplier and operator Loram, the building company Fletcher Projects, and another iconic Australian construction company, Transfield Construction.

John Holland Group once again is one of Australia's largest general contractors with uncompleted work in hand of more than \$2 billion and annual revenues of approximately \$1.7 billion. We directly employ 2,300 people, of which 1,100 are salaried staff.

As well as being one of the largest construction contractors, John Holland is arguably the most diverse.

John Holland is a leader in civil, structural mechanical and process engineering, and it has a large building business.

We are the industry leader in rail, tunnelling, water and power transmission systems.

John Holland prides itself on engineering excellence, professionalism, ethical behaviour and strong client relationships. We are recognised as an industry leader in occupational health and safety.

2.2 COMMITMENT TO SAFETY

At John Holland our commitment to the health and safety of our employees and others involved in our work is central to our business culture. We are determined not just to be, but to be recognized as the industry leader. We strive to achieve our vision of "no harm".

This preoccupation with safety is ingrained in John Holland. However such a company culture is not achieved or maintained unless it is driven personally by the company's leadership.

Without doubt the primary driver in our case over the past decade and a half has been our Chairman, Janet Holmes à Court. Janet has a fervently held belief that "we should send home our employees in the same condition they were when they came to work". She continually talks safety and, more importantly, she walks the talk. Janet visits sites, undertakes formal site safety inspections, and talks to staff and the industry about safety. She gets the message across, as much to the management and workforce of the company as anyone else, that John Holland demands a total commitment to safety.

I believe that over the past four years I have strengthened this commitment even further. It is a strongly held view of mine that we, both as a company and personally, have a moral obligation to ensure that the health and safety of our people is the paramount consideration in all our operations. Our determination to be safe must be driven by a belief that safety is an end in itself, not just "good business".

I think that John Holland is a caring contractor and, to our subcontractors, a "Caring Client".

2.3 OH&S MANAGEMENT IN JOHN HOLLAND

John Holland recently undertook a full, formal review of our occupational health and safety performance, our management systems, and the way we go about planning for and implementing workplace safety.

This review quantified where we want to be on performance; it identified areas where we need to improve; and it established what we need to do to achieve the level of targets we had set ourselves.

Among the principles that drive our “Improvement Strategy” is that we want to be self motivated and self regulated. We want to have and maintain minimum standards for ourselves which apply no matter where we work, what type of project we undertake, or what the client and indeed legal expectations are.

I believe that this is also a key identifier of a “Caring Client”. It is a determination to set standards on the basis of your own belief in what is right, and to lead the way in implementing and enforcing those standards.

3 COOPERATIVE RESEARCH CENTRE FOR CONSTRUCTION INNOVATION

3.1 THE CRC

John Holland is one of the founding participants of the Cooperative Research Centre for Construction Innovation (CRC-CI). While we are engaged in the overall activities of the CRC-CI and directly participate in many of its research projects, of particular relevance to the topic of this paper is our leadership of the project titled *Safety Critical Positions: a Safety Management Competency System for the Construction Industry*.

3.2 THE SAFETY MANAGEMENT COMPETENCY PROJECT

Surprising as it may seem, our industry does not have a competency system in place. The industry does not have a “Standard” which for example sets down those positions considered “safety critical” and what competencies are required of the people in those positions.

Dean Cipolla, the John Holland Group Safety Manager, is the project leader for this research which is being carried out in conjunction with Bovis Lend Lease, the Queensland University of Technology and the University of Western Sydney.

Specifically, the project will identify and then set down implementation requirements dealing with:

- which management and supervisory positions are critical to safety performance;
- the tasks and functions of those positions;
- the skill and behavioural competencies required by persons who occupy each of the positions; and
- the training, exposure and experience required to achieve those competencies.

The ultimate goal is the development of an industry standard, *Construction Industry Safety Critical Positions and Required Competencies*. We hope to work with NOHSC to introduce these standards into the industry.

In this project, we are a “Caring Client” driving innovation in occupational health and safety.

4 THE CONSTRUCTION INDUSTRY – AN OH&S OVERVIEW

4.1 INDUSTRY BEHAVIOUR

The Royal Commission into the Building and Construction Industry in Australia found that:

“...the OHS performance of the building and construction industry is unacceptable”

and

“...the poor performance was found to be as a result of the industry striving to complete projects on time and on budget, and that too often these competitive forces work against OHS standards which are neglected as being too expensive and time consuming.”

Without wishing to disagree with the Royal Commissioner, I must say that I believe that the poor performance of the industry – and it is indisputably poor – is not a “result” of time, budget and competition issues, notwithstanding that they are substantial issues in the industry. The poor performance is a result of a lack of commitment to safety on the part of clients and contractors. If that commitment was there, then irrespective of other pressures, safety would be paramount, and we would be seeing a much better safety outcome.

It is about time that the industry stopped seeing other elements of the business such as profitability and performance as somehow necessitating that safety be disregarded. Safety is not inimical to profit and performance, in fact the contrary. Nor is safety something that can be given a lower priority when times are tough and other pressing issues occupy management time.

4.2 STATISTICS

4.2.1 Data

One thing that becomes very evident whenever one tries to present safety statistics is that there are plenty of them, but rarely are they consistent. Substantially different indices are collected, and very different definitions and data are used for what are, on the face of it, the same indices. Until this is resolved direct comparisons are very seldom useful.

Notwithstanding, we can only run with what we have, and hope that they tell a sufficiently accurate story.

4.2.1 Fatalities

There are more than 50 fatalities in the Australian construction industry each year. This fatality rate is comparable to the USA and Europe, but it is double that in the United Kingdom.

In 2002-2003 the incidence of workplace fatalities in the construction industry in Australia was 9.2 fatalities per 100,000 employees, which is nearly three times higher than the national workplace average of 3.1.

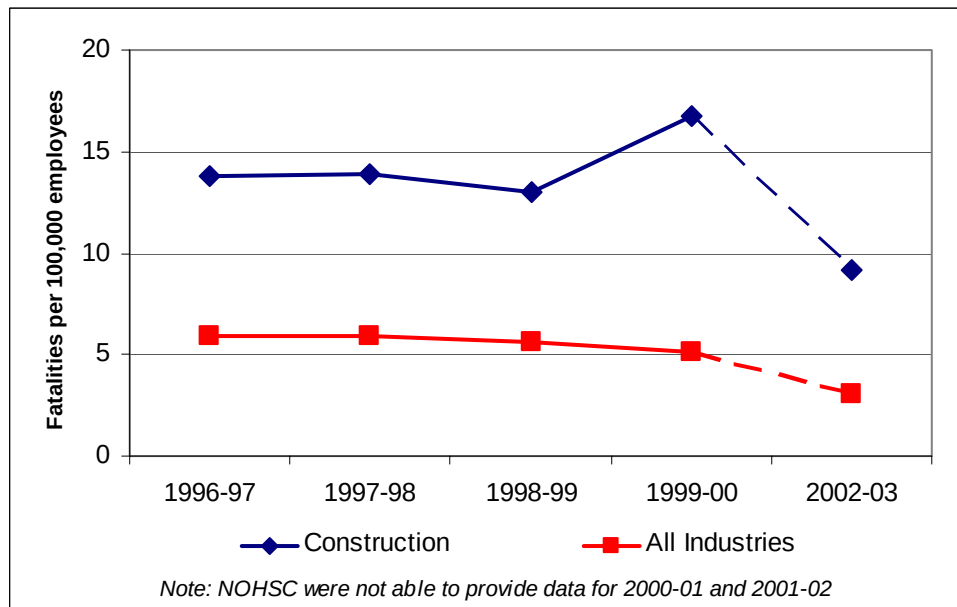


Figure 4.1 – Fatalities

4.2.2 Injuries

The usual industry measure of injury frequency, the Lost Time Injury Frequency Rate (LTIFR), is 50% higher in the construction industry than it is across all industries. (Refer Figure 4.4)

4.2.3 Compensation Claims

In 2002-2003 the construction industry employed approximately 5% of the Australian workforce but accounted for 9% of the accepted workers' compensation claims involving one or more weeks off work.

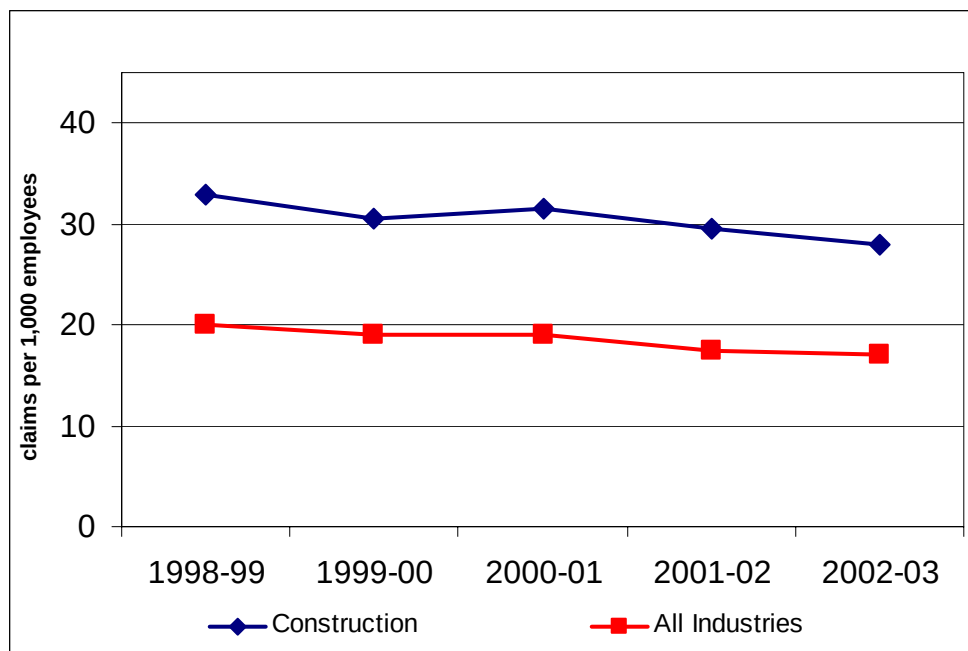


Figure 4.2 – Compensation Claims

Compensation claims in the construction industry for 2002-03 were 27 claims per 1,000 employees. While this was a decrease from a rate of 34 claims per 1,000 employees recorded in 1998-99, it is still much higher than the current national average of 16 claims.

When compared with particular industries, construction lags not only in its performance but in what we are doing about it. The mining industry for example has worked very hard over the past few years to improve its performance, and the results show that they are making progress.

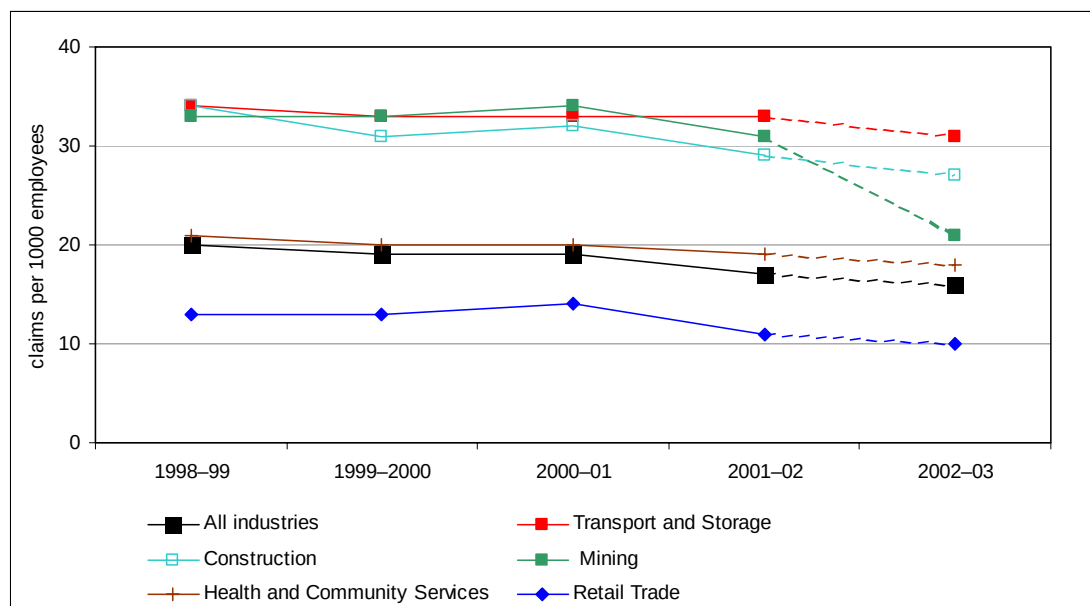


Figure 4.3 – Compensation Claims by Industry

4.3 THE INDUSTRY PLAYERS

4.3.1 Clients

Clients have differing standards and expectations. Many contractors in the construction industry change their level of safety management to suit the projects they are undertaking and the requirements placed on them by clients, contracts and base legislative requirements. This is across the industry, especially with medium and smaller contractors.

4.3.2 Contractors

The 15 or so largest contractors in Australia comprise the Australian Contractors Association (ACA), and they represent the large contractors. However, in total there are some 4,500 identified “construction contractors”, and they range from the members of the ACA, through smaller though nevertheless substantial firms, to a plethora of very small, even Ma & Pa organisations.

The industry is notorious for its low barriers to entry, and not only do we have these small operators, many of whom are undoubtedly efficient and honourable businesses, but we also have a full range of far less honourable operators, including the infamous ‘phoenix’ sub-contractors which were exposed in the recent Royal Commission.

In the absence of genuine client commitment to safety, and unless there are effective pre-qualification schemes in place to eliminate these companies that have no commitment to safety, then we will continue to see safety compromised in the interest of price.

The Australian Constructors Association has been addressing safety performance of the industry and a couple of years ago started to collect and compile the safety statistics of its members. It was not an easy exercise.

Firstly there was the inevitable difficulty with confidentiality – I guess members were either jealous of their own results or embarrassed by them. However, eventually a process was developed to everyone’s satisfaction whereby results would be collected and published in a way that showed the figures for the ACA in total by quartile performance. Each contractor was to be presented with his own figures so that he could compare them against the results of the unidentified others.

Then came the problem of what data was being collected, and what statistics should be compiled. There were as many options and views as there were members of the ACA. It was interesting to find that national standards were of little help.

Eventually it was agreed what statistics should be collected and how they should be defined and compiled, and the process was got underway.

It has been running now for a couple of years and the various problems are getting bedded down. The data is proving to be both enlightening and useful.

Eventually the ACA will be publishing the results, although not in a way that identifies individual performance. But of course that is enough, because each contractor knows that clients will eventually use this information in prequalification assessment and they will ask a contractor where he stands in comparison to the ACA figures.

The ACA is behaving as a “Caring Client” with this initiative. It is a great pity that the rest of the contractors, whose statistics are four or five times worse, do not have the same focus or interest.

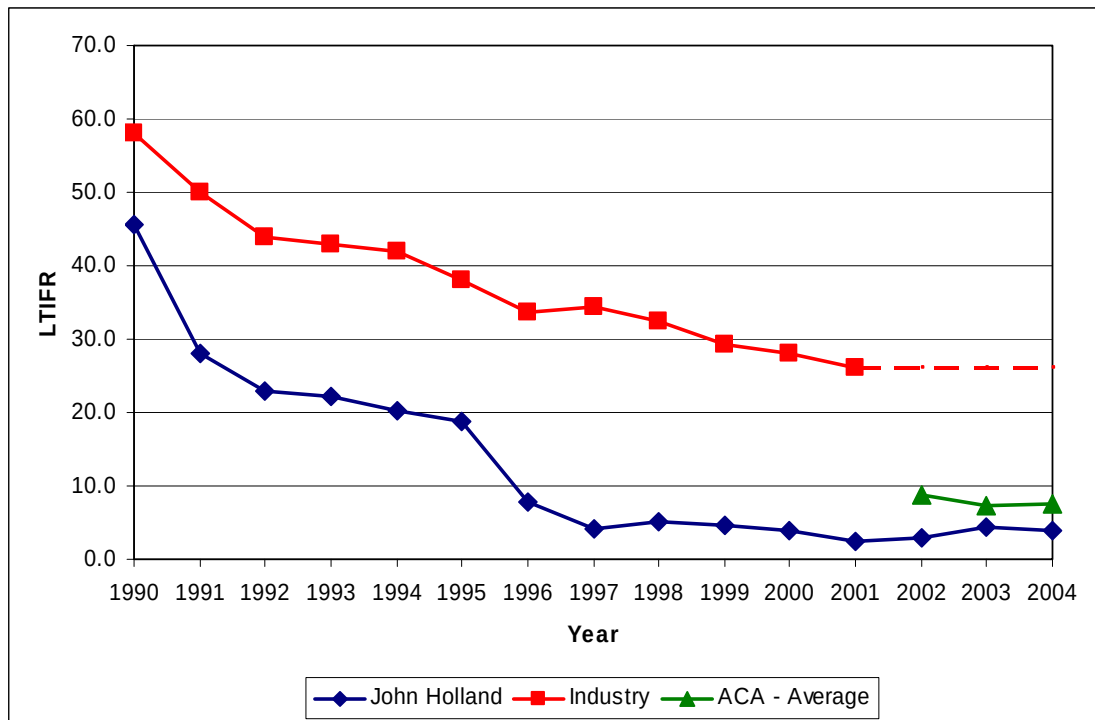


Figure 4.4 – Lost Time Injury Frequency Rate
(John Holland) figures after 1997 are for the financial year)

4.3.3 The Workforce

The workforce itself is probably one of the biggest difficulties. It is itinerant and there is a high degree of staff mobility, and this makes it difficult to instil a robust safety culture or to undertake effective training. Furthermore, much of the workforce is employed by first and second-tier subcontractors and is only indirectly responsible to the principal contractor. Those subcontractors each have their own safety culture, commitment and practices. Many have no interest in safety.

To make matters worse, sections of the union movement see safety as an industrial tool. They impose strikes and bans ostensibly on safety grounds, but really as industrial leverage. Some of the union organizers would not have done a proper safety inspection on a project in decades, but they are vocal and seemingly sincere about safety when they shut a contractor down for alleged safety breaches. More often than not the safety issue seems of secondary importance when negotiations start.

It is also amazing how many unsafe contractors and subcontractors, generally the smaller ones, seem never to have safety issues with the unions even though their safety performance is abysmal. Presumably they satisfy the unions in other ways.

If Governments are serious about safety they will legislate to prevent safety being used in this manner.

4.4 COMPLIANCE ISSUES

4.4.1 Establishment of FSC and a national code of practice

The Royal Commission recognised that *“Governments fund a significant proportion of building and construction activity ... and are therefore important clients of the industry.”* It proposed the introduction of a Federal Safety Commissioner (FSC) as part of a package to ensure that the Australian Government leads by example and fully uses its powers as a client to improve safety outcomes.

It is intended that the FSC will:

- develop a National Code of Practice for Safety on Commonwealth Government funded projects
- raise the level of consideration that is given at the design stage to reducing, if not eliminating, the OH&S risk in construction;
- manage an OH&S accreditation scheme for Australian Government building and construction work;
- build commitment to improved OH&S performance; and
- raise compliance levels with OH&S law.

This initiative has been adopted by the Commonwealth Government, and we hope to be involved in the development of the proposed Code of Practice and the associated audit processes.

If action in this regard does eventuate, then the Commonwealth Government will certainly be acting as a “Caring Client”.

4.4.2 Prosecution and penalties

In recent years there has been considerable pressure on State Governments from the community and from the union movement to introduce more stringent legislation and harsher penalties. Most of the States have either done so or are in the process of doing so.

This legislation is targeting not just the companies themselves, but their officers and directors.

Section 26 of the Occupational Health and Safety Act 2000 (NSW) for example states that:

“If a corporation contravenes, whether by act or omission, any provision of this Act or the regulations, each director of the corporation, and each person concerned in the management of the corporation, is taken to have contravened the same provision unless the director or person satisfies the court that:

- (a) *he or she was not in a position to influence the conduct of the corporation in relation to its contravention of the provision, or*
- (b) *he or she, being in such a position, used all due diligence to prevent the contravention by the corporation.”*

Whilst this Act provides one of the clearest and most direct statements of directors and managers liability, similar provisions exist in the Acts of other states and territories.

The penalties that can be applied for breach now are very substantial, and in a number of jurisdictions can include jail terms even for first offences. While no one can reasonably object to such penalties where management flaunts the requirements of good safety practice, there are elements of the legislation that seem directed more at placating the unions than ensuring that safety management is the real beneficiary.

One must be generous enough to say, however, that the States are behaving as “Caring Clients” in bringing in these changes. But it is a pity that there has not been more recognition given to what I believe are genuine concerns with some aspects of the legislation.

4.5 CONCLUSIONS

The construction industry’s OH&S performance is poor in comparison to that of other industries.

It is clear that the diverse and mobile nature of the construction industry presents it own problems in terms of effective management of health and safety, but this doesn’t excuse the poor performance.

The final report of the Royal Commission into the Building and Construction Industry stated that “*Too often safety is neglected.*” This is unfortunately true.

The whole industry must come to the understanding that legal compliance is necessary but not enough. Legal compliance may prevent prosecution but it will not prevent injuries and incidents. Furthermore, if we as an industry set our sights on legal compliance alone, we will ensure that increasingly onerous legal obligations and legal penalties are imposed.

Firms and the industry collectively must set their own standards that are substantially above those mandated by legislation. They must take it on themselves to be proactive in pushing the boundaries and finding ways to make their own operations safer.

5 “CARING CLIENTS” – SOME CASE STUDIES

5.1 COMALCO ALUMINA REFINERY

5.1.1 The Project

The new Comalco Alumina Refinery in Gladstone, Queensland was constructed under an Alliance comprising the client, his EPCM contractor and

a number of subcontractors. John Holland undertook a major portion of the structural steel fabrication and erection, pipe work installation, and the assembly, installation and alignment of pumps, materials handling and other process equipment.

Under the Cost Reimbursement Performance Incentive there was provision for reimbursement of direct and indirect costs, payment of a fixed fee and payment of an incentive based on performance. The payment based on performance took two forms: a payment based on performance against overall key performance indicators (KPI); and a bonus payment to the workforce teams under a Team Based Performance Incentive Programme.

The contracting arrangements were innovative and the outcome on the project was excellent, with the project completed on time and within budget.

Comalco and its parent company Rio are also extremely focussed on OH&S management and performance. They have a number of internal programs which are leading edge, including a comprehensive Behavioural Based Safety programme. They demand that their contractors and subcontractors are equally focussed, and will not tolerate behaviour that is less than the best. They are willing to pay for good safety performance, but on the other hand they demand it unequivocally.

5.1.2 Client Initiatives

Comalco set “zero incidents” as the target on the site and to support this “zero incidents” focus they established a number of initiatives.

The KPIs for both the company and the workforce teams had safety performance as the top weighted item. The impact of any safety lapse was financial and immediate.

Other initiatives demonstrated their commitment to the “zero incidents” goal:

- Safety was the first item on the agenda for every meeting held on site;
- Each construction group was assigned a Safety Advisor to work directly with their OH&S personnel to promote efficient open communication and speedy resolution of any issues as they arose;
- A process of managing safety (lead indicators) was employed instead of solely looking at the statistics (lag indicators). This was a key element of KPI assessments and the Team Based Performance Incentive Programme;
- Comalco actively promoted the People Based Safety Program (Behavioural Based Safety) which called for the involvement of all staff members. In John Holland’s case over 40 planned “job observations” were performed each week;
- Employees were empowered to participate in the programme and were provided with one-on-one feedback to constantly improve understanding of the process;
- All supervisory personnel actively participated in the Project Leadership programme as well as the training of Core Skills for Supervisors;
- Innovative ideas for improving safety in the workplace were encouraged and received from the workforce, and individuals received Excellence Awards for their contribution.

5.1.3 John Holland on the Comalco Alumina Project

In such an environment, it is not possible or acceptable for a subcontractor not to also be proactive in OH&S management. Accordingly, some of the Initiatives implemented by John Holland included:

- The use of Hazard Based Competency Assessments to ensure that operators were familiar with the occupational health and safety aspect of the machinery and tools that they were given to use;
- Information gathered during the job observation process and incident investigations was collated and fed back to supervisory personnel with daily reports. In turn they fed the information through to the workforce;
- A Hazard Status Board was posted at each work location and the team personnel recorded all hazards identified and the controls put in place to manage them. This information was used to develop a “living” risk profile for the various tasks undertaken;
- “Boot Camp” training for supervisors, designed to ensure that all supervisory personnel had achieved a common standard of understanding of the occupational health and safety requirements of the project and John Holland.

5.1.4 Performance

Table 5.1 – Occupational Health and Safety Performance, CAR Gladstone

Hours Worked (end of May)	821,755
Lost Time Injuries	1
Medical Treatment Incidents	3
Lost Time Injury Frequency Rate	1.22
First Aid Incidents	169
Job Observations	1,849
Competency Assessments	3,949
Minor Workers Compensation Claims	60

5.2 BWEA ALLIANCE

5.2.1 The Project

The BWEA Alliance has been established to upgrade three of Brisbane’s wastewater treatment plants and have those plants operating by October 2006. The principal objectives are to improve the water quality in Moreton Bay and to provide for future capacity with the best whole of life design.

5.2.2 Client Initiatives

This project is also being carried out under an Alliance, which includes the client, Brisbane Water, as an active participant.

Brisbane Water demands outstanding performance in several areas other than capital cost, and safety is one of the highest rated. To reinforce this demand, the alliance partners receive incentives for outstanding safety performance and are penalised for poor safety performance.

5.2.3 Alliance Partner Initiatives

The Alliance, has established a number of focussed safety initiatives:

- The Alliance Zero Harm Target is linked with Brisbane Water’s own Zero Harm Target;
- Systems of Brisbane Water and the BWEA Alliance are linked;
- Joint inductions are undertaken between Brisbane Water and the Alliance;
- The project team has been given a “Vision” for safety performance;
- Safety is treated as part of the total project delivery by incorporating safety in design, procurement, construction planning and operations;
- A reference group (BSAG) mobilizes input from the whole Alliance Team to provide guidance and strategic direction to the programme;
- The operations group is involved in all levels of the project delivery;
- Safety is the first item on all agendas.

5.2.4 Performance

Table 5.2. –OH&S Performance, BWEA Alliance

Staff hours	129,353
Direct Project Labour hours	69,506
Subcontractors hours	55,869
Total Manhours	254,728
Lost Time Injury Frequency Rate (LTIFR)	0
Medical Treatment Injury Frequency Rate (MTIFR)	11.77
Medical Treatment Injuries	3

5.3 WOODSIDE ENERGY LTD PHASE IV EXPANSION (TRAIN 4) FOR THE NORTH WEST SHELF VENTURE ONSHORE LNG PRODUCTION FACILITY

5.3.1 The Project

Train 4 is Woodside’s new LNG Production Facility on the Burrup.

John Holland’s was the contractor for the civil off plot works, which included the concrete foundations for the Power Generation and Acid Gas Removal Unit areas of the plant and all underground electrical and instrument cabling.

Safety in an operating LNG plant is paramount.

5.3.2 Client Initiatives

Woodside has one of the most demanding commitments to safety that I have observed. It demands the highest safety performance, irrespective of cost, and it really does practice the “it starts at the top” culture. It demands that its contractors behave as it does.

During the project, I personally attended site on a quarterly basis for “Sponsor Meetings”. These meetings went on for a fair part of the day and were meant to address all the project issues that involved the particular contractor. I and our senior regional management and our project manager would represent John Holland, and the General Manager Onshore Projects of Woodside and his senior staff and senior representatives of his contract superintendent all attended. A very high level meeting you would say.

There were usually many pressing issues – program, variations, budgets, industrial matters, technical difficulties, weather etc. However, and notwithstanding that by any measure there were no or very minimal occupational health and safety problems, we invariably spent most of the time, addressing OH&S performance and management.

On site, this attention showed. The site “house keeping” was impeccable, with many novel ideas being used to ensure that this was so.



Plate 5.1 –Site Housekeeping – Woodside LNG Train 4

The care taken to protect people working at height – any height - was extreme.



Plate 5.2 –Foundation Construction Access and Barriers Woodside LNG Train 4



Plate 5.3 – Foundation Construction Access and Barriers - Woodside LNG Train 4

All of the workers met in small groups each morning before work commenced for a ten or fifteen minute talk on the safety issues of the day. And these start meetings were attended by management representatives.

Woodside set the most rigorous occupational health and safety targets for the project and staff incentive schemes were designed to ensure that the importance of safety to the company would be reflected in the importance to staff personally.

Woodside initiated tools such as Step Back 5x5, and the Hazob (Hazard Observation/Improvement) Programmes.

Step Back 5x5

Based on the Dupont “Take Five” (minutes) system the Step Back 5x5 system calls for individuals to step back 5 metres and take 5 minutes to assess the risks. Workers carry a small booklet in their pocket which lists a series of questions to answer when doing a Step 5x5.

Hazob

The Hazard Observation / Improvement Programme provides a mechanism by which all individuals participate in identifying potential risks and hazards, and suggesting ways in which processes or practices can be improved. This system:

- promotes a 24-hour, 7-day philosophy to health, safety and the environment;
- empowers all individuals to be advisers on health, safety and the environment;
- raises awareness of others to accident potential, and captures the knowledge and experience of individuals; and
- promotes continuous improvement and accountability.

The number of Hazobs and Step 5x5's that workers did each week were measured.

5.3.3 John Holland Initiatives

Under the Woodside leadership, John Holland also pushed its safety management to the boundaries.

We initiated a system called OAR, an acronym for opportunity, authority and responsibility.

This system was designed to:

- assist the project in achieving goals and targets;
- to enhance the client initiated health and safety tools;
- to reinforce to individuals the newly learnt, project specific health and safety requirements and information;
- to formally pass on to each person working on the project the opportunity, authority and responsibility (OAR) to stop any undesired work practices, or have rectified any potential hazards or risks that the identified; and
- encourage individuals to objectively observe and evaluate their workmates undertaking activities, and to discuss with them the work

practices, methodology and health and safety requirements in relation to the task specific job safety analysis and the health and safety manual.

5.3.4 Performance

Table 5.3 – OH&S Performance, Woodside

Staff	18
Direct Project Labour (Peak)	100
Subcontractors (Peak)	40
Total	158
Total Manhours	193,000
Lost Time Injury Frequency Rate (LTIFR)	0
Medical Treatment Injury Frequency Rate (MTIFR)	10.4
Medical Treatment Injuries	2
Workcover Claims	0

5.4 BHP BILLITON PORT KEMBLA BAG HOUSE

5.4.1 Scope of the Project

The project entailed the erection of building steelwork and installation of mechanical process equipment for the Coal Fines Dryer.

5.4.2 Client Initiatives

The contract was with Dendrobium, a fully owned entity of BHPB. BHPB were directly in all aspects of safety management and performance on their site. They left nothing to chance and demanded very detailed and specific systems, safety deliverables and performance outcomes on John Holland before and during the delivery of this project.

Some of the key initiatives which BHPB initiated on this project were:

- They reviewed their operations and identified tasks and activities which contain hazards which have the potential to kill or maim, and have developed specific “Fatal Risk Protocols” which mandate detailed specific performance standards and requirements for each particular activity on their sites. The requirements within the “Fatal Risk Protocols” were mandatory across all operations.
- Their project construction manager was directly involved in all aspects of safety on site, was involved in all project planning meetings and ensured that safety was the first point on the agenda and considered in all planning activities.
- Safety was the first consideration for any activity to be undertaken. If a full risk assessment and control plan was not in place and approved then no activity was allowed to commence.
- All site managers, John Holland and BHPB were required to undertake formal safety inspections and observations on a daily basis and stay directly involved in workplace safety
- All incidents were investigated jointly by JH and BHPB.
- Employee input in all aspects of task and workplace planning and safety was mandatory.

5.4.3 John Holland Initiatives

A full project risk assessment was undertaken before mobilisation to site. The risk assessment included identifying the risks involved with all project scope activities and hazards which are not normally covered by the John Holland Safety Management System and included them in the development of the Project Safety Management Plan and Procedures.

As a part of this process we also reviewed the BHPB Fatal Risk Protocols and ensured that we had integrated their specific requirements as well.

5.4.4 Performance

Table 5.4 – OH&S Performance, Port Kembla Bag House

Total Manhours	49,481
Lost Time Injury Frequency Rate (LTIFR)	0
Medical Treatment Injury Frequency Rate (MTIFR)	40.4
Medical Treatment Injuries	2
WorkCover Claims	0

5.5 JOHN HOLLAND GROUP BOARD SAFETY SUB-COMMITTEE

5.5.1 Background

With the increasing personal liability that company directors and officers are facing in respect of their roles in companies, we are starting to see in business generally a reluctance on the part of such people to undertake particular roles which increase their personal exposure. In the area of safety management, we can expect more of this “risk aversion” as legislation progressively increases the risks and penalties to which individuals are exposed.

Against this trend, the John Holland Board has actually moved into a more direct role in safety management by establishing a Board Safety Sub-committee. John Holland is a leader in doing this and unique within the construction industry.

The Board decided to take this innovative step, not only because members of the Board feel very strongly about the health and safety of John Holland’s workforce, but because some of them in particular felt that people needed to show leadership in this area and be prepared personally to do something about the poor safety performance of our industry.

5.5.2 Sub-committee Composition and Meetings

The Sub-committee comprises three non executive directors, one of whom is the Sub-committee Chairman, the John Holland Group Managing Director, the Managing Director of John Holland Construction, the Corporate General Manager HR/IR/Safety and the Group Manager Safety.

The Sub-committee meets at least quarterly, at the time of Group Board Meetings.

The meetings are of a day's duration and include site inspections, generally of one or two projects, and a formal Sub-committee meeting. Other company officers and sometimes a specialist advisor are invited to meetings.

The report of the Sub-committee is an agenda item at the main Board meeting.

5.5.3 Committee Charter

At the inaugural meeting the Sub-committee established a charter which specifically sets and communicates the committee's purpose and intent across the Group.

The key elements of the charter are:

- oversight of the company's occupational health and safety strategy and performance; and
- ensuring that the company's commitment to safety is visible and effective.

The Sub-committee members:

- undertake specific training in occupational health and safety at a level appropriate to Sub-committee membership;
- must become and remain aware of relevant regulatory changes which may affect the Company in relation to occupational health and safety;
- review and authorise the Group Occupational Health and Safety Strategy and monitor its implementation;
- review the Company's safety statistics and performance;
- review all Class 1 and Class 2 actual and near miss incidents, and assess corrective actions arising from the investigations;
- participate in activities designed to demonstrate management's commitment to safety including recognition activities, safety inspections and face to face discussions with Company employees;
- must become and remain aware of world class safety organisations and initiatives across all industries.

As can be seen, these are onerous obligations and require a serious commitment on the part of the Sub-committee members.

It is a source of great pride to me that our Board has members who are prepared to enter into such commitment.

5.6 JOHN HOLLAND & NATIONAL OCCUPATIONAL HEALTH & SAFETY COMMISSION (NOHSC)

In June 2004, a landmark conference brought together governments, industry and unions to push for improved occupational health and safety performance in the building and construction industry. Since the industry has a reputation as among the worst OH&S performers, this was a great opportunity for all parties to do something about it.

For its part, the NOHSC is working to conduct forums to engage the building and construction industry on safety issues, particularly at CEO level. John Holland Group will be working in partnership with NOHSC on this and other

initiatives to promote health and safety in the building and construction industry.

6 CONCLUSION

If the safety performance of the Australian construction industry is to improve, we need more “Caring Clients” and “Caring Contractors”. We need to get rid of those who don’t care.

Governments fund a significant share of construction activity and are the most influential clients of the industry. All the individual governments do to some extent use their buying power to drive improved industry performance in health and safety. However, much needs to be done nationally to further this approach. The creation of the position of Federal Safety Commissioner and the development of a National Code of Practice may be a step in this direction.

Whilst I have significant issues with some aspects of the “industrial manslaughter” type legislation that is currently being promulgated, I certainly believe that the time has come for a substantial tightening of legislation to increase the obligations of all the industry players, from clients and designers, to contractors, and to employees and unions.

For many, occupational health & safety has become a plaything. The industrial relations games that are played by some unions must cease; the lip services that is given to safety by too many clients and contractors must cease; the political point scoring that is engaged in by Governments (at all levels and of all persuasions) must cease.

More “Caring Clients” would be a good start.

CLIENTS DRIVING INNOVATION.

Case Study

INNOVATIVE WAYS OF DELIVERING IMPROVED SATISFACTION – HOW CAN CLIENTS LEAD THE WAY?

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ABSTRACT

The customer focus and service delivery of EastPoint Property Management Services Ltd (EastPoint), a wholly-owned company of the Jardine Matheson Group, is a critical success factor for the business, like most service providers in this industry. EastPoint has for many years maintained multiple quality assurance accreditations to ensure that customer focus is a fundamental feature within its business processes but is disenchanted with the results. Modelling of customer satisfaction within the hospitality industry provides a better understanding of the issues. EastPoint has developed a multi-attribute methodology to take a holistic measurement of its performance including customer satisfaction to provide an objective comparative measurement of the delivery of a service quality that exceeds expectations.

Keywords: property management, service quality model, customer satisfaction.

1. EASTPOINT PROPERTY MANAGEMENT

EastPoint Property Management Services Ltd (EastPoint) was first established by the Jardine Matheson Group in the early 1980's as an offshoot of another business. It has been re-branded several times and steadily grown over two decades of operation. The company provides property-related management services in Hong Kong and Macau for a portfolio of 300 Hong Kong properties. Over ten per cent of the population of Hong Kong live or work within these properties based upon the numbers of residential, commercial and retail units contained within these sites. 3,000 staff are employed including 400 white collar staff managing the 2,600 blue-collar building supervisors/attendants and other frontline operatives at the properties typically two decades older than themselves. The professionals require a tertiary education as a prerequisite for employment. They are multi-lingual in Chinese, English and Putonghua. In contrast, the blue collar staff need a minimal-level education and be eligible to hold a Security and Guarding Licence issued by the government authority. Their principal language is Cantonese with basic skills in spoken English. The company is centralised for business efficiency but provides decentralised services at the many property sites it is managing. This operational differentiation requires a high degree of procedural integration to achieve high standards of customer service and to accord with ISO9000:2000 quality accreditation. IT business, communications, and management information systems are increasingly used to integrate the business at the managerial level.

Business efficiency and customer satisfaction is achieved if all personnel perform their duties well, individually and as part of the corporate entity. The management of the Company regards profitability, growth, and reputation as the principal goals for the business with stakeholder satisfaction being the fundamental prerequisite for this achievement. In this sense, staff engagement, customer satisfaction, and shareholder appreciation are the drivers for the business. The stakeholders for EastPoint are a large number of people, more than 3,000 employees that are working to exceed the customer expectancy of more than 5% of the population of Hong Kong – about 63,000 households. The nature of property management in Hong Kong is that to a large extent, contracts extend automatically, year-on-year unless dissatisfaction causes a termination. The ultimate test of satisfaction is in the retention of this customer base.

1.1 EVOLUTION TO A CUSTOMER FACING SERVICE INDUSTRY

In 1999, the Company, then a multi-real estate services company, reviewed its statements of 'mission' and 'vision' to align with the perception of senior management of the role of the business. The nub of this was the self identity of the personnel in being professional and highly qualified in the subject of the built environment. The vision was that the purpose of the business was to excel at providing professional expertise in the management of buildings. In 2000, the company was re-branded as a result of the de-merger of the joint venture. Out of this exercise came a valuable appreciation of our core values. Professional management of property infrastructures in all forms is a fundamental of our business but the critical success factor is caring for the communities of people within these infrastructures. We have re-aligned our strategies accordingly. These communities judge us – they are the customers to be satisfied. They are the individuals that we must communicate with. Community websites, customer benefit programmes, Total-Quality-Management circles are used to rapidly increase the customer contact involved in our work processes. We are aware that the business is shifting to a customer-centric

operation and that a distribution network of information and added value services with B2C connectivity will be the new business model for property and facilities management. We are positioning technologies and resources accordingly whilst continuing to service today's customer and to deliver shareholder value whilst we do it.

A further evolution of this thinking is focussed on the end-user of our delivered services. We estimate that about five percent of the population of the Hong Kong SAR is a direct customer of EastPoint. More than ten percent of the population per day receive a service from our staff. Our vision today is to provide 'lifestyle services' to this customer base. Our appreciation of the service to be provided and of the needs of the end customer has shifted from a technical orientation to be more akin to the hospitality industry. For these reasons, that industry provides a good theoretical basis to apply to other customer-facing service businesses.

1.2 CUSTOMER SERVICE MODELS FOR FACILITIES MANAGEMENT

Service quality is a measure of how well the service delivered meets customer expectations, resulting from comparing these with the actual performances on both the outcome and the process dimensions of the service. From the provider's perspective, delivering service quality means conforming to or exceeding these expectations consistently. (Jafari, 2000)

In terms of the services sector, 'service quality is a measure of how well the service level delivered matches customers expectations' (Parasuraman *et al*, 1985) Furthermore, 'perceived quality is also result of a consumers comparison of expected service with perceived service.' Their qualitative research in their initial study (1985), found that service quality had ten underlying dimensions. Later (1988), these were consolidated into a five-dimensional index:

- **Tangibles** – the appearance of physical facilities, equipment, personnel and communication materials
- **Reliability** – the ability to perform the promised service dependably and accurately
- **Responsiveness** – the willingness to help customers and provide prompt service
- **Assurance** – the knowledge and courtesy of employees and their ability to convey trust and confidence
- **Empathy** – the caring, individualized attention the firm provides its customers

In 1988, the same authors defined perceived quality as 'a global judgement or attitude relating to the superiority of the service'. When 'expected service (ES)' is greater than 'perceived service (PS)', then 'perceived quality' is less than satisfactory. When ES is equal to PS, then 'perceived quality' is satisfactory. While if ES is less than PS, then 'perceived quality' is more than satisfactory. According to the study of Ingram and Daskalakis (1999), we can use the five dimensional index described above to assess the gap between ES and PS. Organisations determined to attain a unique position and advantage in the competitive business world of today most likely realize the importance of delivering high quality service by meeting or exceeding customers expectations. Thus a means to measure customers' perceptions of an organizations service quality becomes necessary. Executives who are truly dedicated to service quality must work with a continuous process for monitoring customers' perceptions of service quality, identifying the causes of service-quality shortfalls and taking appropriate action to improve the quality of

service. (Zeithaml, 1990) It should be borne in mind the 'expected service' should also establish the cost to be paid i.e. the service value.

Service quality itself is an abstract construct because of three features in which it differs from goods in terms of production, consumption and evaluation: **services are intangible** as they are experiences rather than physical objects, **services are heterogenous** because services often vary from producer to producer, from day to day, and from consumer to consumer, and for many services the **production and consumption of services are inseparable and simultaneous activities** (Gronoos, 1982; Parasuraman et al., 1988; Zeithaml et al 1990). Service quality is a judgement about the superiority of a service (Robinson, 1999), quality refers to the extent to which a service is what it claims to be (Mudie and Cotton, 1993), it is the fulfillment of customers' expectations (Edvardsson et al 1994), and can therefore only be defined by customers (Palmer, 1994).

The service quality model (Figure 1) provides a means of appreciating the issues in delivering service that achieves customer satisfaction by closing the gaps (Payne, 1993).

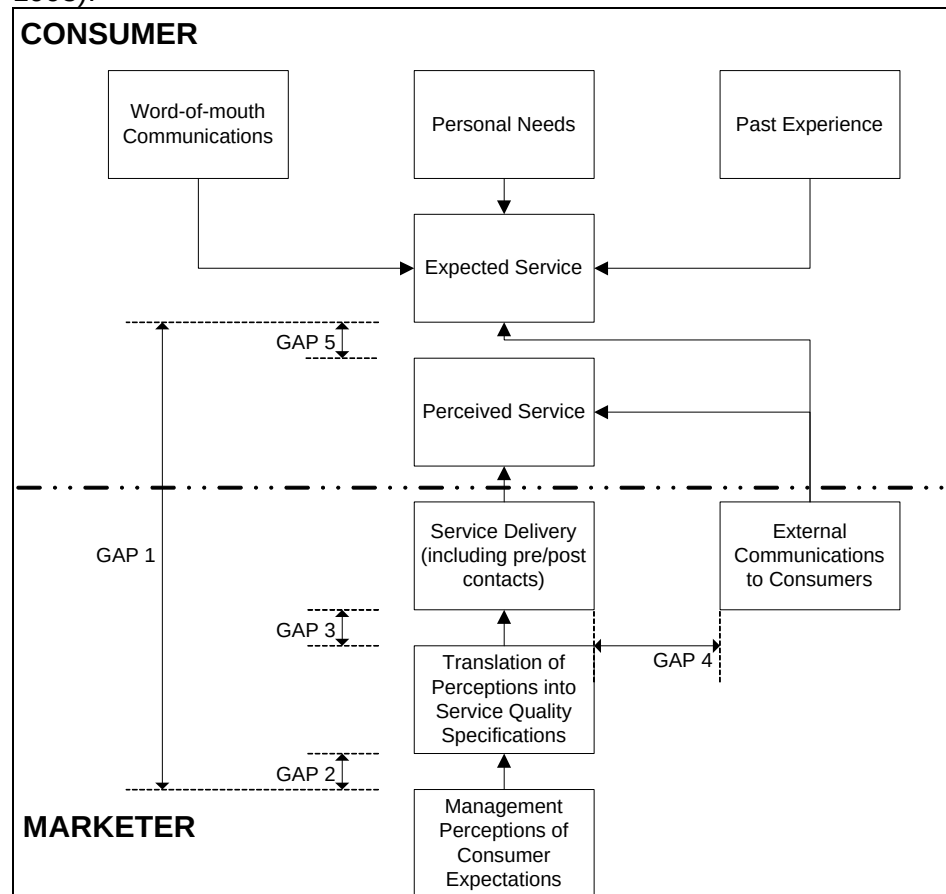


Figure 1 Parasuraman et al's service quality model

- Gap 5 - is fundamental, it is ES-PS and a function of the four other gaps. Key determinants of the service expected by customers include word-of-mouth communications, personal needs, past experiences, and external communications from the service provider (Zeithaml et al, 1990)
- Gap 1 – is the difference between the customers expectations and what the management perceives the customer expects (Parasuraman et al, 1985).

Management has to obtain knowledge and understanding of customer expectations (Zeithaml et al, 1990)

- Gap 2 – is the difference between management's perceptions of customer expectation and the quality specifications set for the service. (Parasuraman et al, 1985). When applying standards that actually project what customers expect, customer's perceptions of service quality can improve, minimising or even closing the gap. (Zeithaml et al, 1990)
- Gap 3 – is the difference between the service quality specifications and the actual service delivery (Parasuraman et al, 1985).
- Gap 4 – is the difference between the service delivery and external communications (Parasuraman et al, 1985). When more is promised than delivered. (Kotler et al, 1996)

The same researchers extended their definition of Gap 5 to include what they called 'a zone of tolerance' as shown in Figure 2.

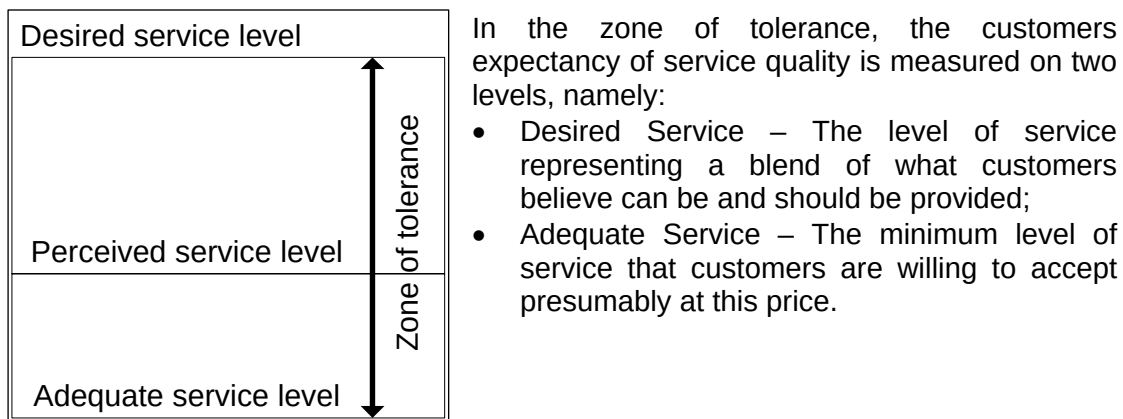


Figure 2 Parasuraman's 'zone of tolerance'

concept.

This work is useful in considering pricing and performance for built environment services. A review of the continuing validity of this early work and of subsequent greater detail produced by the original researchers is provided by Grapentine in 1998. This is further useful in bringing together concepts of value for money on both sides of a contract.

2. MULTI-METRIC PERFORMANCE ASSESSMENT

2.1 DEPENDENCE ON SURVEYS OF CUSTOMER SATISFACTION

EastPoint has maintained quality assurance certification to ISO9000 series since 1999. That certification has been upgraded since then to the latest 2000 version of ISO9001 and to include accreditation in 'occupational health and safety (OHSAS18001)' and also environmental control systems (ISO14001). Since 2000, EastPoint has carried out an annual Customer Satisfaction Survey in the form of standard format 'tick-the-box' questionnaire. This is a standard requirement for accreditation to ISO9001:2000 standards of quality assurance. It is also a feature of the Baldrige method of assessment of company performance used by EastPoint for self assessment of managerial performance and strategic development. It is, none-the-less, regarded by the company as an imperfect measure of customer satisfaction: due to less than 9% response from the population surveyed; a tendency for satisfied

customers to be passive and not motivated to respond; it is too coarse a measure, at too long an interval, for management to respond to adverse trends; and it is a reactive rather than proactive assessment. Table 1 shows the inadequate representation achieved in the surveys of 2001 to 2003.

Summary of Customer Satisfaction Survey results for 2001- 2003									
	2001 (August survey)			2002 (August-Sept survey)			2003 (Sept-Oct survey)		
	No. of returned questionnaires	Response Rate	Total nos. of Distribution	No. of returned questionnaires	Response Rate	Total nos. of Distribution	No. of returned questionnaires	Response Rate	Total nos. of Distribution
Overall	5,148	7%	67,509	6,777	8%	83,122	5,482	10%	53440
Commercial	100	6%	1,744	256	12%	2,170	277	12%	2,350
Residential	3,598	11%	32,667	3,878	10%	37,949	4,437	11%	40,490
Public Residential	1,285	4%	29,698	2,202	6%	39,951	286	4%	7,706
Shopping Centres	43	4%	1,202	386	32%	1,219	388	37%	1,060
Industrial	52	3%	1,817	55.00	3%	1,833	94	5%	1,834
No. of properties exempted from survey			35			60			68
No. of households exempted from survey			12,500			15,531			30928
Overall satisfaction rate from survey			55%			66%			74%
HK SAR statistics									
Population of the HK SAR			6,725,000			6,787,000			6,803,000
% of population in EastPoint care			5%			6%			4%
No. of households in HK SAR			2,101,000			2,162,000			2,198,000
% of households in EastPoint care			3%			4%			2%

Table 1 Extent and rate of response from Customer Satisfaction surveys

2.2 INNOVATION TO BETTER INDICATE ACTUAL PERFORMANCE

From an EastPoint point of view, the issue in knowing customer satisfaction is to achieve a rational measurement of performance from a stakeholder viewpoint that includes a broad range of objective measures to offset the natural bias in customer satisfaction surveys in which a majority do not respond. In this context, rational, means based on objective measurement; performance, means the actual standards achieved by EastPoint personnel and systems against benchmark minimum standards set by the Company and/or stakeholders expectations, and or norms for the industry. Whilst, stakeholders are the Board; the executive management; the operations management; operatives; direct clients, such as Incorporated Owners Committees or the Hong Kong Housing Authority; and indirect clients such as owners, tenants or visitors to managed properties. Wide-range of objective measures, means all practicable measures of performance in existence or to be innovated in 2003.

EastPoint introduced a methodology in 2004 that uses multi-attribute indicators of performance as a means to indicate more objectively stakeholder satisfaction. We currently measure twelve independent indicators of performance that are related to customer satisfaction. Table 2 places these measures of importance in order of their validity as a measure of customer satisfaction based upon the following nine attributes of each metric:

- Objective/subjective data is gathered;
- Is the data range broad (rich) and therefore more indicative of performance;
- Is the data consistent each time it is measured;
- Is the measurement monthly, quarterly, half yearly, or random;
- Is the measurement free of bias;
- Does the measured data come from a credible source;
- Is measurement process credible;
- Is the measurement representative of the portfolio;
- How is the metric related to customer satisfaction, (H/M/L)?

Metric	Attributes of the performance measure									
	Objective/ Subjective	Data rich (H/M/L)	Consist- ency	Routine/ periodic (H/M/L)	Bias- free (H/M/L)	Credible source	Credible measure	Represents portfolio	Valid for CS	Diff Wgt
CRM/Help Desk	Objective	H	H	H	H	H	H	H	H	1.0
External audit	Objective	H	H	M	H	H	H	M	H	0.9
Internal audit	Objective	H	H	M	M (-ve)	H	H	H	H	0.8
Directors Inspections	Objective	H	H	M	M	H	H	H	H	0.7
Customer Satisfaction Report by Service Centre	Objective	L	H	M	H	H	H	L	H	0.6
Annual customer satisfaction surveys	Objective	H	H	L	H	L	H	M	H	0.5
Client assessments	Objective	M	H	M	M (-ve)	H	H	L	H	0.4
Night Audits	Objective	M	H	M	H	M	H	H	H	0.3
Six monthly staff satisfaction surveys	Objective	H	H	M	M (-ve)	M	H	H	L	0.2
Property Managers Inspections	Objective	M	M	M	L	M	M	M	M	0.1
Customer complaints and commendations	Subjective	L	L	L	L	L	M	L	H	0
Contract Interim Survey/Exit Interview	Subjective	L	L	L	L (-ve)	M	M	L	L	0

Table 2 Performance measures in order of validity as a measure of customer satisfaction with corresponding weighting

On the basis of this evaluation, the Contract Interim Survey/Exit Interviews and the Customer Complaints/commendations are not included in the aggregation of the measures. Weighting between 1 to 0 is applied to the remainder to reflect relative validity as a measure of customer satisfaction.

The performance measures noted in Table 3 are recorded each month, or as appropriate, and reported in the Directors Monthly report accompanied by a trend analysis commentary.

Performance measure	Annual metric	Wgt	Score (metric x Wgt)
1) CRM/Help Desk	47%	1.0	8%
2) External audit by the HKQAA	68%	0.9	11%
3) Internal audit of the EastPoint integrated management systems	66%	0.8	10%
4) Directors Inspections	64%	0.7	8%
5) Customer Satisfaction Report by Service Centre	72%	0.6	8%
6) Annual customer satisfaction surveys	74%	0.5	7%
7) Client assessments	69%	0.4	5%
8) Night Audits	98%	0.3	5%
9) Six monthly staff satisfaction surveys	60%	0.2	2%
10) Property Managers Inspections	NA	0.1	NA
Total =	618%	Total =	64.4%

Table 3 Combination of measurements for an overall benchmark of customer satisfaction.

2.3 EASTPOINT'S MEASURES OF PERFORMANCE

2.3.1 CRM/Help Desk management-information-systems

At present, customer service requests are predominantly made on our 300 property sites. Previously these would have been recorded there using manual methods making it impracticable to measure performance. This arrangement is impracticable to measure customer satisfaction in terms of our response to these requests and in identifying indicative trends as part of our strategy to improve customer satisfaction and client retention through outstanding performance. Our earlier investment in IT-based information management systems using proprietary software provided by Management Reports Inc (MRI) provides a technological alternate to manual methods across our wide-area-network of computers. This was implemented in 2003/4 to enable centralised recording of customer requests and their timely closure. It provides a central resource for data mining of customer issues. This database is analysed to provide metrics on the speed of response and in measuring the satisfaction of pre-set Key Performance Indicators (KPI's) that are either implicit or stated service level agreements with the client.

One hundred sites are online with the CRM MIS. These represent the most important contracts and are prioritized on a pareto basis according to the CRM ranking described later in this paper. In this respect they constitute more than 90% of the value of the portfolio and include all valued CRM targets.

2.3.2 External audit by the Hong Kong Quality Assurance Association (HKQAA)

HKQAA, a Certification Body of ISO9001:2000, ISO14001:1996 and OHSAS18001:1999 systems, visits EastPoint twice a year to conduct external audit/ surveillance visit at 25-35 randomly selected properties which account for around 10% of all managed properties to check compliance against the ISO/OHSAS requirements and legal requirements. Performance is measured by assigning a mark of 200 per property for a faultless performance but 50 marks are deducted for each major non-conformity (M), 10 marks for each minor non-conformity (D) and 5 mark for each observation (OBS) identified during the audit. These are aggregated to produce a single measurement for the external audit based on of the total marks received for audit: by property and by portfolio.

2.3.3 Internal audit of the EastPoint integrated management systems

Internal Audit of the EastPoint Integrated Management System is conducted by Performance Management Unit (PMU) on a regular basis, at least twice a year for each performance system (ISO9001/ ISO14001/ OHSAS18001). The aim is to ensure the compliance of internal system procedures and legal requirements and follow up the effectiveness of corrective/preventive actions taken for the findings since last internal/external audits or through other performance inspection, such as director's inspections, night audit. A standard audit checklist is prepared by PMU to ensure full coverage of all system procedures and all managed properties within a 3-year cycle. In each internal audit, depending on the available resources, around 40 to 60 properties will be selected which usually lasts for a month and areas of concern will be identified as the main focus of audit. Performance is measured by assigning a mark of 100 per property for a faultless performance but 10 marks are deducted for each major non-conformity, 3 marks for each minor non-conformity, and 1 mark for each observation identified during the audit. These are aggregated to produce a single measurement for the external audit based on the total marks received for audit: by property and by portfolio.

2.3.4 Directors Inspections

Directors' inspections were started in February 2003 to enhance 2-way communication between management and frontline operations and to achieve continuous improvement in the property operations. Ten executive staff are each assigned with 26-28 properties to be inspected within a period of 6 months. A standard inspection report of twenty aspects of operational performance is used with each being marked on a Likert scale between 1 to 5. The results are entered into a single database and form part of the annual performance appraisal for the site management staff concerned. Any property received scoring less than 3 on any item, or with comments/suggestions for follow up, is required to prepare a proforma action plan. A total score of maximum 100% will be calculated in every inspection as an overall assessment of the operation performance and will then be reflected in the annual performance appraisal on a weighted ratio. A single measurement for the Directors/Managers Inspection is the average of the marks received for all inspections.

2.3.5 Customer Satisfaction Report by the Customer Service Centre (CSC)

The CRM/Helpdesk facility gathers two metrics over time by property and any other aggregation of property data i.e., by management team, division, or product line. First, the satisfaction of predetermined KPI's, these are quantitative judgments of our timely response to an issue/request that is automatically measured by the CRM module and a personal accountability of the assigned operative. Second, the results of random feedback solicited by the CSC through a telephone call initiated by the CSC. These solicit qualitative responses to a predetermined closed question survey that produces, in a consistent manner, a performance mark of the quality of the achievement between 0 and 10. Any result below 5 is deemed unacceptable and requires remedial action by the Director concerned. This feedback is gathered by Customer Helpdesk staff phoning Customers at random within 48 hours of the job completion.

2.3.6 Annual customer satisfaction surveys

Contracts or clients are categorised in terms of importance to the business for the purposes of customer relationship management and performance monitoring. The customer satisfaction survey is now available in paper or internet versions using a few number of better tailored closed questions to ascertain customer expectancy and perceived satisfaction. This modified instrument was first used in 2003. It includes:

- 1st an enquiry on overall satisfaction with EastPoint performance;
- 2nd an enquiry on specified performance attributes briefly covering our principal services, image and competences;
- 3rd an enquiry prioritising five areas of desired improvement; and
- 4th a Yes/No enquiry 'would you recommend EastPoint to others?'

2.3.7 Performance assessment/measurement used by certain Clients

Large public sector clients such as the Hong Kong Housing Authority, the Government Property Agency, and the Mass Rapid Transport Corporation use surveys of end user satisfaction as key performance indicators of the performance on their service contracts. They assess performance at monthly intervals, at each property/ station. These are integrated to provide a single metric of performance.

2.3.8 Night Audits

By regulation, property management companies in Hong Kong must arrange for a random night audit at properties in accordance with the legal requirement in order to ensure that they perform to mandated standards of security. EastPoint has outsourced the night audit services to a security guarding company on an annual contract basis and monitored by the company's Performance Management Unit (PMU) who reports directly to the Managing Director. PMU also conducts quarterly night audit with the outsourced security guarding company in order to monitor the quality of night audit as well as the standard of night operation at our managed properties. The result of night audit by outsourced security guarding company will be converted into score/property. The total marks received to evaluate the staff performance will be reflected in the annual performance appraisal on a weighted ratio. These are integrated to provide a single metric for the portfolio.

2.3.9 Six monthly staff satisfaction surveys

Employee satisfaction surveys are conducted semi-annually. Thirty-eight statements are to be answered on a Likert scale of 1 to 8. An 'Overall Satisfaction Percentage' is used as the single indicator of the survey. To better reflect the stakeholder participation in the success of the business, the survey will be changed in 2004 to an Employee Engagement Survey.

3. PARETO APPROACH TO CRM

EastPoint has adopted a two-attribute method of prioritising contracts for the purposes of client relationship management (CRM), primarily based value in dollar terms and value to the business for other defined reasons. Using this methodology the Company places its ongoing contracts and potential future clients into 5 classes of CRM from Rank A, to E as noted below. The Contract will be identified as having an 'Important' attribute if they meet one or more of the definitions listed below.

The EastPoint definitions of these categories are:

- **RANK A i.e., mission critical** - means contracts that are in the 20% by number of the highest value contracts and are additionally more than 60% important for other defined reasons;
- **RANK B i.e., protect at all costs** - means contracts that are in the 20% by number of the highest value contracts and are additionally less than 60% important for other defined reasons;
- **RANK C i.e., nurture** - means contracts that are not within the 20% by number of the highest value contracts but are more than 60% important for other reasons;
- **RANK D i.e., maintain** - means the remaining active management contracts;
- **RANK E** are contracts that are due to expire or have expired.
-

	Definition of important contracts
PR/Reference Sites	✓ 1 st , 2 nd , 3 rd priority most significant within a sector/ High Profile/ Blue chip or a leader in their sector/ Beneficial to be associated with them
Developer	✓ > 2 properties could be outsourced within 2 years
Growth Potential	✓ Generate increased income over two years, from same/ other contract
Cross Relationship	✓ Connection / influence (financial, political, family or colleague) to >1 properties
Valued	✓ Trust relationship and revenue above 50% of current market developed over time

Table 4 Contract Categorisation

The CRM effort is the personal accountability of the Executive Director in charge of Commercial Enterprise of the company. Minimum, the objectives and targets are defined for each category of contract/client. For example, for Category A contracts: the MD will fraternise with three influential persons for that contract; the Executive Director for that contract will be held personally accountable for business development and service delivery and will meet informally at monthly intervals on these topics; the Director for that property has a personal accountability for on-site performance; performance monitoring is at monthly intervals, quality audits are at quarterly intervals, and SixSigma will be operational at the site.

4. CONCLUSION

In a customer-facing, services business it is not sufficient to consider a customer satisfaction survey as a meaningful assessment of end-user contentment or as indicative of a successful business. It is better to combine many mutually exclusive, objective indicators of stakeholder satisfaction into a benchmark rating and matrix of performance indicators that can be used for trend analysis and performance improvement. In a portfolio management approach to service delivery, a Pareto methodology ensures that effort is expended in ensuring satisfaction for the most relevant customers as a priority above customer expectancy norms for the remainder. It also recognised that the service quality modelling of Parasuraman *et al* is also applicable to the service industry of the built environment as it repositions from professional technical services to a life style service industry.

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CLIENTS DRIVING INNOVATION INTERNATIONAL CONFERENCE

VECTORS, VISIONS AND VALUES – THE ESSENTIALS FOR INNOVATION

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ABSTRACT

This keynote paper attempts to outline the nature of innovation and the essential ingredients for the climate of self-improvement to develop. It looks at a common pattern of investment which leads to long gaps between the original research and the take-up by industry and asks why this occurs. It examines in outline two case studies, one in the water industry and the other in IT to see whether there are lessons to be learnt from the innovation which took place. It finds that necessity is a strong driving force. The paper then goes on to examine generic issues related to all innovation and finds the need to understand the value systems of society as being a key factor in taking ideas forward into practice.

Keywords: Timing of Innovation, vectors, visions, values, lessons for innovation, new product development, nature of research.

“It’s the willingness to say a new idea out loud which is most valuable in fostering creativity” (Professor Jennifer Chatman, Haas School of Business, University of California, Berkeley (Editorial, American Innovation, 2004))

1. A PERSPECTIVE ON INNOVATION

Innovation is dead – long live innovation! With apologies to the royalty of Europe which tends to use a similar phrase when one of their number is deceased and another takes their place! The line of the monarchy is preserved and continuity prevails.

Innovation has certain of the same characteristics – it is continuous, often operates within a specified framework, is almost inevitable, and has the potential to improve on the one before! The issue is not one of whether we will innovate or how we should innovate but when the innovation will occur. Human history is one of innovation both in products and processes and has continued from the dawn of time through evolution and the intellectual capacity which humans bring to the drive for self improvement. It will happen, it does happen, and the question we are asking ourselves at this point in time is 'how can we make it happen more quickly?'

Not all innovations are positive and the modern world is full of well-meaning innovations which have seemed to provide a route for improvement only to find that in the ensuing years other factors have made that innovation harmful to the planet or those who inhabit it. Much of what the world considered improvement in the past century is creating problems which the present generation is trying to resolve. These range from energy plants to economic relationships between countries to methods of governance and many more.

In the last century the dominant innovation area has been technology, often addressed as a series of independent initiatives without considering the impact on each other. The result has been a massive increase in our ability to use tools but with some concerns about where those tools are leading us in the way in which the future of the human race will proceed. Weapons, the use of non-renewable resources, the challenge to value systems through information exchange etc are all examples of where this reductionist approach has provided advantage for some, but disadvantage for others. Much of what we call innovation relates intentionally or unintentionally to power. Through a new tool, those who have it are empowered but others are not. Some will be economically advantaged and some will not. Some will be able to exercise force over another and some will have to submit. Often it is the viewpoint from which these matters are considered that determines whether a new innovation will be considered positive or not.

Property and Construction are not immune from these forces and the market economy will favour certain innovations above others. In a world where quality of life is thought to be paramount, the Built Environment plays a massive part in how people perceive their living standards. The demand for improved standards will affect market forces considerably. Innovation is not neutral when it comes to the impact on humanity or the value systems which we consider to be important. In any consideration of what drives innovation we need to understand the values which are being challenged or reinforced by the innovation under consideration. It is this aspect which will be briefly explored in this paper.

2. WHY DOES INNOVATION TAKE SO LONG?

In the context of history, innovation today is progressing at an alarming rate, possibly challenging the speed at which humans can evolve to match the changes that are occurring. Nevertheless, as this conference illustrates, many wish for the innovation to increase at even faster speeds to 'maintain competitiveness'. A common pattern of development can be seen in the following graph.

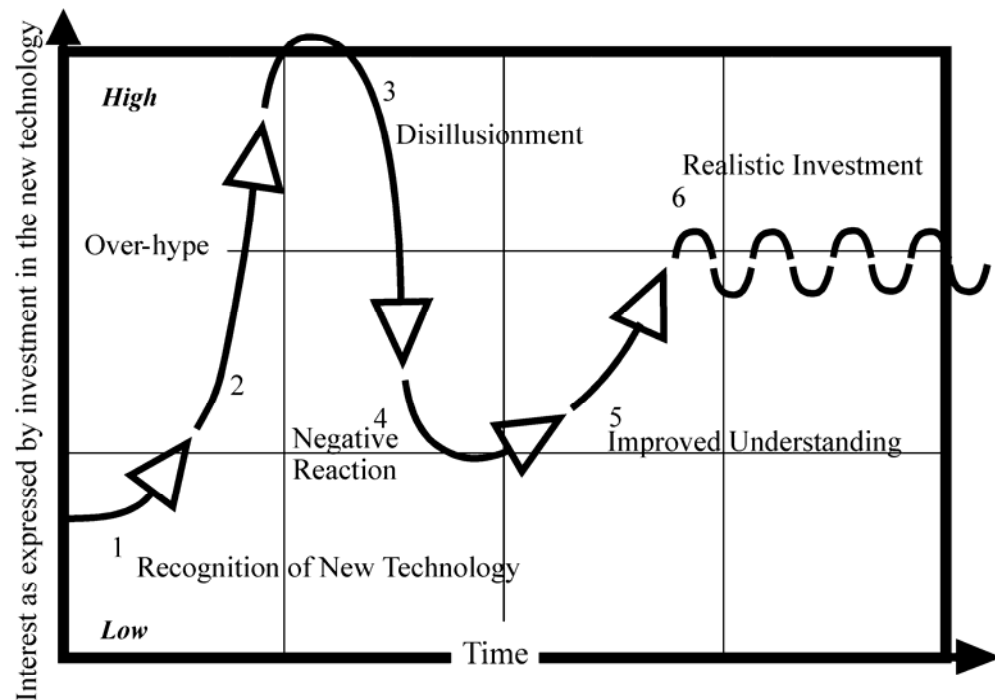


Figure 1: Common pattern of development of new technologies over time.

In this conceptual graph, a new technology is invented and recognised by those who wish to develop their competitiveness/performance. People become excited about the technology (especially research funding agencies) and investment pours in to the point where the potential is over-hyped for that point in time! The technology fails to meet the unrealistic expectations and disillusionment sets in followed by a severe negative reaction and investment dries up. In time it is realised that the potential is still there and we gain an improved understanding of what it will do and how it links to all sorts of other issues related to human development. Investment begins to increase until it reaches a sustainable level and is subsequently overtaken by the next innovation. Then the cycle begins again.

To those engaged in research and development this is a familiar pattern. There are far too many examples where the gap between recognition and sustainable development can be measured in decades and the question must be why this is so. We will all have our own views but it may be worth considering what one research study has revealed about the process of transferring ideas into practice. Undertaken by the Industrial Research

Institute. Inc. Washington DC (1999) it shows that in manufacturing industries it takes about 3000 ideas to generate a single new product or service and there are various stages along the way. In some organisations such as Boeing such a process is more formalised and at each stage of the process additional resource is added to take the development further. In the early stages it might be nurtured by involving a mentor/manager to explore the idea further. As time goes on more 'hand holding' might be added and then cash and other resources allocated to examine, test and create prototypes until the decision can be made to manufacture. An interesting comment made by the study is that it is almost never the original idea that is enacted. In other words it is the process which is important and there is learning and feedback throughout the innovation trail.

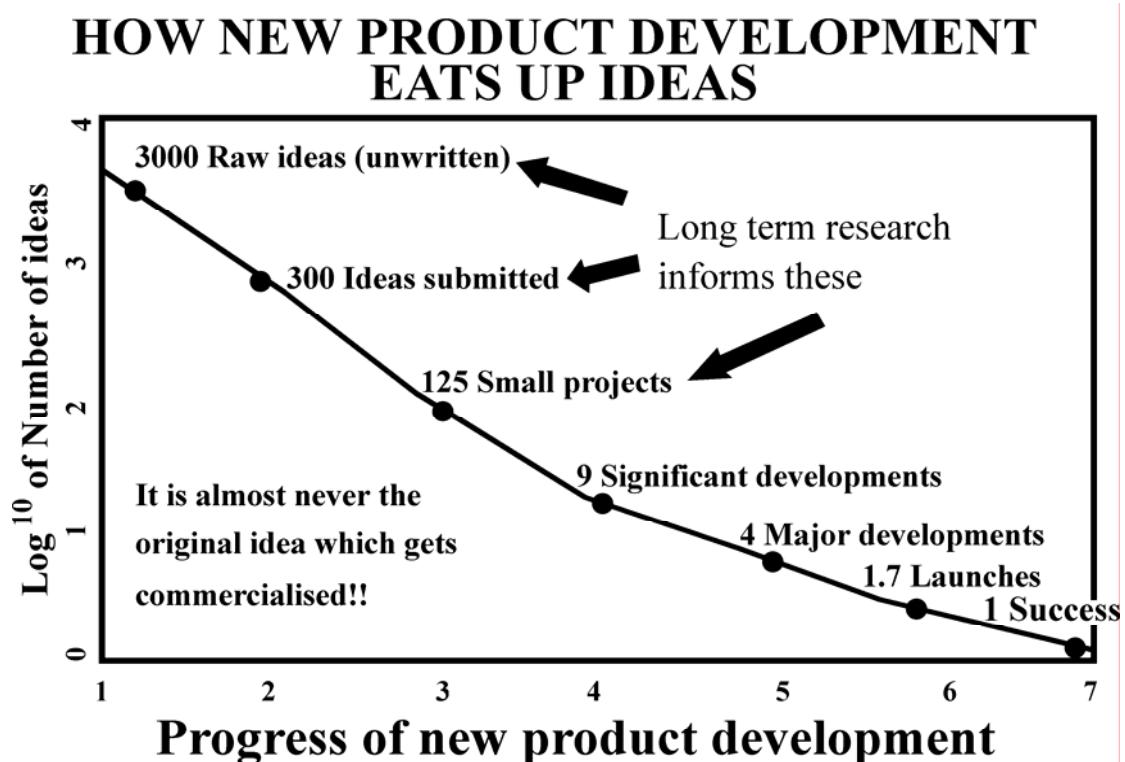


Figure 2: Progress of new product development (Industrial Research Institute Inc, Washington, 2000)

It is also important to realise that there are few ideas which are generated which are completely new. Most arise from other work which can lead to a new juxtaposition of ideas and which then leads eventually to the new product. The ideas arise from a complex inter-action between established knowledge, new research and a context of self improvement and practical experience and the balance between these aspects will depend on the individual with the idea and the nature of the problem being addressed.

Service industry improvement and innovation is likely to follow similar lines although the formal stage by stage approach is seldom there. However, the

filtering and investment requirements must exist even if they are not made explicit. One major difference may be that the linearity inferred in the graph may not actually be as clear as is shown. There tends to be an iterative process along the way involving feedback loops and new insights which may be the reason that the original idea gets modified to the point where it is almost forgotten by the time the product is commercialised.

Many of the books relating to innovation talk about the need to “Think, Play, Do” (Gann D. 2004) or words to that effect. In practice this means that ideas are presented, some kind of simulation where experimentation can be undertaken follows, and then implementation occurs. There are parallels in some other work such as Lester Thurow’s ‘Zero Sum Society’ (1980) where he uses the analogy of road building to identify different types of research. He describes the first stage as *Scientific Research* where the terrain is explored to see the direction a road might go. This is followed by *Engineering Research* which determines ‘How’ the road should be built and whether it is possible to do it. Lastly he suggests a form of *Implementation Research* whereby it is discovered whether it is possible to build the road effectively in terms of economic cost and time. There is inter-dependence between these different types and it would be unwise to assume that the latter can exist without the preceding types being enacted. In the case of the applied industries such as Property and Construction it is usually the use of generic research developed independently of the industry which is then harnessed for application in the applied domain. A familiar example would be the adoption of general software in the IT industry and making it applicable and useful for construction design and management professionals to use.

Nick Valery is quoted in an editorial (R&D Efficiency 2004) in his summing up of the 2nd Annual Innovation Summit for the Economist in San Francisco 2004 as suggesting that change can come in many forms:-

- From the unexpected
- From an incongruity between what is supposed to happen and what does
- From a refusal to accept the inadequacy of a product and process
- From a sudden change in the structure of the market

It is the third and fourth of these in which clients or stakeholders are largely engaged in promoting change and innovation.

Valery also echoes the content of Figure 2 when he describes one approach to an innovation strategy to be:-

- Scan the environment
- Select the ideas which give the best chance of giving a company a competitive edge
- Resource those ideas
- Implement the result
- Review the strategy to see if it needs to be altered. This he considers to be the most important!

He goes on to say:-

“The real test of an innovation strategy is sustained growth from continual innovation.”

3. CLIENTS DRIVING INNOVATION

The usual definition of innovation (Websters) is *to make changes by creating something new*. This is a rather all-embracing definition and does not distinguish between innovation and invention very well. The CRC in Construction Innovation in Australia suggests that it is to do with 'driving ideas into practice' but again this does not clarify the situation. The nature of 'clients' is also difficult to define as during the life of an asset many hundreds of people can claim to be the sponsors or users of projects to varying degrees. This is why the term 'stakeholder' seems to be gaining more acceptance. However the concept is one of the 'demand side' of the industry driving the 'supply side' to do better. Even this runs into problems when the demand requires something original from the service provider and therefore the appointment of a professional who has demonstrated that they can innovate. Who is doing the driving? In this case the demand side is responding to innovation already demonstrated by the service supplier. This is particularly the case with the appointment of signature architects. Many happy, but fruitless, hours can be spent discussing these issues! Looking at significant case studies can however be useful.

3.1 CASE STUDY 1: MICRO-FILTRATION MEMBRANES IN THE WATER INDUSTRY

In this example the client was the water supply company for the North West of England called 'United Utilities'. In 1996 there was a drought in the UK and current water stocks were exceptionally low. This required a quick response which needed to be cost effective. The problem they faced was that the conventional way of purifying water was basically to add chemicals to coagulate the impurities, then let the solids settle out by creating 'quiescent' or very still conditions. This requires the construction of very large open structures and it is not unusual for the construction and commissioning of these tanks to take two to three years. It was not possible to wait that long.

The response from United Utilities was to adopt the process of micro-filtration which had been researched and developed in the 1970s but it was not until the 1990s that it was taken up by the water industries. This required a completely different process and plant and was more like a chemical processing plant than the heavy engineering traditional approach.

In February 1996 a decision was made to build a 80 million litre a day plant. The plant was delivered in July 1996 and it was the world's largest micro-filtration plant at that time. It went into immediate use and the cost effectiveness of the technology was demonstrated. This innovation produced considerable savings in land use and the elimination of sedimentation. The modularisation of the process increased flexibility plus speed of construction and the water quality improved as there was a physical barrier to contaminants. In addition there was a retrofit capability allowing use of different membranes and a reduction in chemical usage.

Barriers to this innovation did exist. Previously there had been only limited large scale demonstration projects. It was difficult in a cost-cutting environment to investigate and develop the new technology. There was the

problem of social consensus – would the public trust the new technology? There was no risk-sharing mechanism as nobody wants to be the first example of anything which has an impact on health! There was insufficient training and education of the industry personnel to assimilate the new technology and the existing infrastructure was not suited to the new approach which was more related to production engineering. There were not many benefits for linear scale up and revenue costs were higher.

However the lessons for adoption of innovation of this type are clear:-

- A real need must exist
- The client must be prepared to shoulder a substantial portion of the risk and not be risk averse.
- The technology must be mature enough for an informed decision to be made.
- The potential for improvement must be significant
- In matters of public concern, health and safety must not be part of the risk.

3.2 CASE STUDY 2: INTEGRATED DESIGN, MANAGEMENT AND MANUFACTURE THROUGH IT

Design is the discipline which probably has more impact than any other on the process of innovation of the product and to some extent the processes of property and construction throughout the life cycle. Almost by definition a new and often novel solution must be found to a particular clients' problem. In this case the designer is the agent of the client bringing his or her skills to drive towards something new which satisfies the clients' requirements. Often there is a mismatch and the question of 'meeting client needs' arises as a key issue in many future studies (e.g. Hampson K and Brandon P (2004)). The role of information technology in understanding, communicating, recording, testing, simulating and demonstrating ideas and solutions is considered by many to be the key to real advancement of the industry and the role of clients.

One of the best exponents of the use of technology is the firm of Frank Gehry Associates who have taken established technology used by other industries. In this case it was the CATIA system developed by Dassault Systems, originally for the aircraft industry, and they applied it to new building design and construction. Frank Gehry is one of the world's foremost architects and has produced a string of exciting designs including the Guggenheim Museum in Bilbao and the Walt Disney Concert Hall in Los Angeles. Frank Gehry (Gehry, 1999) works through a number of phases which includes sculpturing, drawing, analysing function, determining needs and experimenting with new materials. The design process defies normal conventional design and the complexity of the product requires new methods of representation and manufacture. This is particularly so with regard to future planning and alteration of the finished product.

The designer, in this case, required a technology which would not hinder his process in producing original novel designs but also supported him in the method he adopted to realise his imaginings and to evaluate his proposals. It should also be linked to the manufacturing process so that materials and fabrication can be manufactured off-site to tight tolerances and be easily assembled. In addition the designs were so complex that it was important to

take the client with him on the journey of design and therefore visualisation was important. It was these significant factors which led to the choice of a technology from another industry where these matters were already being resolved.

Gehry (1999) makes the following point :-

“The new computer and management system allows us to unite all the players with one modelling system. It's the Master Builder principle. I think it makes the architect more the parent and the contractor more the child – the reverse of the twenty first century system.....In Europe there is a person called the mettier that takes off the quantities of the building. We don't need him anymore. The computer does that in an instant....as we design we have an instant mettier that takes off as we go. Consequently I am designing with specific conditions and I don't go out of bounds”.

Traditional CAD systems did not seem to meet the needs of the client's agent. As Lawson (2004) has said 'real computer aided design will support the *thinking* of designers rather than the superficiality of their drawing actions.' The CATIA system and its companion systems allow representation more easily, can use laser scanning to input physical models, evaluate from a variety of different perspectives, transmit data to manufacturing plant, can provide a common model for the whole of the design team, can simulate process, allow immersive visualisation, facilitate setting out direct from the model using laser technology and a variety of other tools.

The Gehry partnership, in which Jim Glymph is the technical partner responsible, is relatively small with perhaps 60 employees. However, it has transformed its process of design and opened up new avenues for creativity through technology which has not constrained the methods of the creative designer. This is an important point when it comes to innovative design. Changing the thought process of the designer to suit a technical requirement can result in poorer design or possibly complete frustration. As Gehry (1999) says regarding CATIA *“They're tuned into understanding the way architecture is practiced* and can make new buildings possible – more exciting shapes in the landscape instead of just plain boxes.”

The lessons for innovation from the use of CATIA by Gehry are as follows:-

- The need for technology to support imaginative processes to meet the client's demands was paramount to the client's agent, the designer. It could not be achieved by conventional means.
- It was necessary to go outside the construction industry to find a mature technology to meet the needs of the designer.
- The technology enabled risk to be understood more easily through visualisation and simulation to enable 'try before you buy'.
- Integrating models allowed a reduction in risk by designers and contractors in complex and new situations. The interface problem at this level was removed.
- The technology company was willing to adapt to the designer's need for flexibility and improved manufacturing tolerances.
- The culture of the company was one of continuing innovation. This latter point is key. As Jennifer Chatman is quoted as saying (Editorial, American Innovation, 2004) *“Sustainable innovation requires embedding the value*

of innovation in your company culture". She goes on to point out that a culture will form anyway and it is too important to be left to chance.

These were all important drivers for innovation and subsequently a new product is being developed known as Digital Project, based on CATIA, which will be specifically tailored to the construction industry.

4. **VECTORS, VISIONS AND VALUES**

The above case studies have illustrated some of the key factors that relate to getting ideas into practice. A key factor is necessity or meeting a particular need at a specified point in time. If there was not a drought, would the micro-filtration technology be adopted? If Gehry had not wanted to create new and exciting designs, would Digital Project be on its way? In this case necessity is the mother of innovation. The technology needed to be available but its application needed to wait until a whole series of circumstances were brought together in a benign union. The case studies are just examples but there are underlying generic issues which can be identified related to the innovation process.

Firstly, there needs to be tools available which are sufficiently mature to be adopted for commercial development and implementation. These tools are usually measurable and indicate a general direction for improvement. In a general way (admittedly rather loosely) they might be called '**Vectors**'. A Vector might be defined as 'a quantity completely specified by magnitude and direction'. Many of the technologies which are used for innovation are physical or virtual tools which can be represented and quantified giving a sense of direction to the improvement that can be expected. They have been created and tested and their performance can be assessed, perhaps not completely, but certainly in such a way that a level of confidence can be placed in their use. They provide a part of the kit which is absolutely necessary for the innovation and implementation to take place. Without them a vague wish list would be created without the means to realise the demands being made. In the two case studies it was the research and development which had taken place which produced tools which could not only do the job required but also give a sense of direction as to where the improvement might lie. It is not always evident what the total future benefit might be.

Secondly, there is a need for '**Vision**'. If the thought processes of the client or the industry are fixed on the current position in today's practice then it is unlikely that the potential for the future will be realised. The industry will fossilize around its own set of problems and solutions. Indeed, it could be said that the history of construction has been one of creating and solving its own problems without considering how technology could help. Too few people have looked up and seen what has happened in other industries and developed a clear vision of what can and should happen to property and construction. There is no reason why construction could not have been the lead industry on so much innovation but its structure and attitudes have made it a perpetual runner up. Many of the people now driving innovation in construction have come from other industries and seen the weaknesses of our processes. The length of construction's history and its craft nature are probably major factors in why innovation and sensitivity to research are not high on the construction industry agenda. Directions are needed and quoting

Steve Betros (CEO of the Facilities Management Association of Australia), *"I think it is pretty hard to get somewhere if you don't know where you're going"*. This is one of the reasons why the CRC undertook a 2020 visioning exercise engaging a wide spectrum of contributors. Innovation needs this understanding of the future potential to give it purpose, encouragement and a fertile ground for operation. Without this vision the industry will focus on tactical issues based on the here and now and forget the strategic potential for change that will give it competitive edge. In the case of construction it is not only competition in markets across the globe but also in attracting the best personnel who have the ability to move the industry forward.

Thirdly and finally, the industry must address the **'Values'** of the society in which it performs. If innovation is to take root then it has to be sensitized to the needs of those who can benefit from it. At the same time it must not undermine the interests of others, unless society too can see some longer term benefit related to its value systems and possibly make amends to those who suffer from the change. If the values are those of the market then meeting demand will prevail over all other issues. On the other hand, if society believes that the market forces need to be modified (e.g. to consider the needs of future generations as expected in sustainable development) then the market forces will be modified through a whole variety of social forces such as the legal and regulatory framework and the education system.

Potential Impacts:	Design & Communication		Process & Manufacture	
	ICT	Virtual Prototyping	Off-site Manufacture	Improved Manufacturing Process
Environmentally Sustainable Development	Strong	Medium	Strong	Strong
Market Environment (meeting client needs)	Strong	Strong	Weak	Strong
Business Environment	Strong	Medium	Weak	Medium
Working Environment	Strong	Medium	Strong	Strong
Research and Innovation	Strong	Strong	Strong	Strong

Figure 3: The relationships between the main themes of the CRC Construction Innovation visions. (Hampson and Brandon, 2004)

In the Construction 2020 exercise (Hampson K. and Brandon P. 2004) the prevailing visions were those related to meeting the needs of society and the industry and the remainder related to the technologies which would enable these value systems to be put into effect and improved more easily. (See Figure 3.)

In the diagram above the items on the vertical axis relate to values and in particular meeting different peoples' needs. Sustainable development is related to meeting the needs of future generations; market environment is meeting the needs of clients; business environment meets the needs of industry; working environment meets the needs of personnel; research and innovation meet the needs for self improvement. The horizontal axis on the other hand provides technologies which have the potential to facilitate the meeting of these needs. Without these value systems the technologies would have little value. It is these driving forces which provide for innovation to take place and drive ideas into practice.

One of the major problems today is that we live in a world which has technology and ideas available in plenty but they do not necessarily relate to the values which society (or in this case, the part of society relating to the Property and Construction industries) considers to be important. This link with societies values is seldom made explicit in research of whatever kind and therefore a gap exists between what is provided and what is wanted. We have our tools and we have a vision of what we would like to be but the value systems which underpin our choices are often understated.

In much research we create the tools and techniques but do not place them within the framework of society and the values which that society holds. Consequently the value of that research is not recognised until some time later when that connection is made. This brings us back to Figure 1. Why is there the gap between periods recognition and improved understanding in so many projects? If the above discussion holds good then it can be summarised as follows:-

- The research on the tools, technologies and techniques must continue and be made available otherwise the means by which the expectations can be realised, will fail. These provide the mechanisms by which progress can be made and give direction to what is possible in the future.
- To achieve take-up of these tools the industry needs a vision of where it wants to be and this provides the aspiration and driving force which will take it forward.
- The final cog in the wheel is the values which pertain to that society and which provide the fertile ground on which the innovation culture can grow. These also determine the value which will be placed on the innovation and the level of investment which will follow.

All three are essential for innovation to take place but the most important is understanding the values of the people and society from which the stakeholders for the built environment are found. If they have already or can be convinced that change is necessary for improvement then innovation will follow. Perhaps we need to overtly include in all applied research projects an

assessment of how the research is expected to impact on the values of society.

A final thought for those who want to remain with the status quo.....

“Soon you will attain the stability you strive for. In the only way it’s granted. In a place among the fossils of our time” (Jefferson Airplane)

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INTERNATIONAL INNOVATION

Key note paper

ON THE WAY TOWARDS A SUSTAINABLE KNOWLEDGE SOCIETY - THE EUROPEAN APPROACH

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ABSTRACT

The European Union member states have agreed a common strategy for sustainable development as an integral part of the strategy for transition to a knowledge economy. The European Commission Framework Programmes form the main research platform supporting the process reaching these objectives.

The Information Society Technologies (IST) Programme launched a call for strategic roadmaps for applied research to direct European progress towards sustainable knowledge society. Main findings and innovative components from four such IST Roadmap projects are presented from the city (Towards Intelligent Sustainable Cities), construction (Strategic Roadmap towards Knowledge-Driven Sustainable Construction), collaborative work (Design for Collaborative Virtual Organizations in Dynamic Business Ecosystems) and corporate (New Partnerships for Sustainable Development in the Knowledge Economy) perspective.

Then, two examples of innovative communities are provided. A self-organising European research and innovation community is presented as the first example. The second example describes a living laboratory concept where public and private investments meet in a city environment supporting the creation of sustainable businesses and improved well being for mobile individuals.

Finally, it is discussed how systemic innovation can be encouraged in an ambient intelligent environment to support the transition towards a sustainable knowledge society.

Keywords : **Ambient Intelligence, Knowledge Society, Systemic Innovation**

1. INTRODUCTION

This paper discusses international innovation in three ways. Firstly, examples of selected recent Information Society Technology (IST) research roadmaps are given to describe how different sustainable knowledge society landing points can be reached. Secondly, two communities are presented as innovation incubators, or catalysts for systemic innovation. Thirdly, the concept of cities as living laboratories is introduced as a stimulating platform for innovation processes. The built environment, especially cities are presented as a natural meeting point of public and private investments supporting sustainable business opportunities.

The given examples focus on experiences within European collaboration, based on a rich diversity and strong cultural heritage of individual countries and regions with different history, priorities and constraints. The presented European systemic innovation approach is placed in a global context.

The European Union policies (EC 2002) define the priorities

- to become the most competitive and dynamic knowledge based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion, by 2010
- to perform transition to a knowledge economy in a global networked society
- with sustainable development at the heart of integrated policies for growth, employment, social cohesion and the environment.

One key challenge is to understand better the systemic relationships between different dimensions of sustainable development; the dynamics of a service-oriented networked knowledge society and its relationship to sustainable development.

Today research and development is carried out in an increasingly complex environment. The interdependencies between goods and services increase and new concepts of product ownership appear. Global competitiveness needs innovative capability. Innovation is regarded as a key driver of competitiveness. This can be achieved through a comprehensive programme of integrated research activities (Liikanen 2004). The European Commission (EC) Framework Programmes form an important technology development platform to obtain a critical mass that enables reaching these goals.

Innovation dynamics and innovation processes have changed from sequential to concurrent. All kinds of innovations interact in a multidisciplinary innovation space. This involves collaboration across the traditional boundaries. Bringing the technology and application innovations together into systemic innovation supports the transition to new paradigms.

Cities and the built environment should provide a healthy and stimulating living, working and innovation environment for present and coming generations. Therefore, Facilities and infrastructure must be planned, designed, constructed, operated, maintained and refurbished to perform several decades, even centuries, to meet the needs of their changing users in varying circumstances. Living in cities and occupying buildings has health impacts, it creates the biggest environmental burdens and it has important social consequences. It is economically important to manage the asset of constructed facilities and infrastructure.

2. INFORMATION SOCIETY RESEARCH ROADMAPS

The EC 5th Framework Programme launched an IST Call in spring 2002 to shape roadmaps paving the way towards different landing points of the knowledge society. The roadmaps were commissioned to direct future research in the 6th and 7th EC Framework Programmes. Almost 30 such one year research roadmap projects were funded in summer 2002 covering all industrial sectors. Key findings from some of them are presented here as international innovation supporting examples. It must be noted that strategic research roadmaps differ from technology (Sipilä 2002), product or industry roadmaps.

A look at the international innovation playground is shown in the following figure where a sample of 20 countries is positioned into four quarters of a sustainable knowledge society matrix according to their country indicator values. The matrix axes correspond to Environmental Sustainability (ESI 2002) and Information Society (ISI 2003) indicator systems. In some countries the acceptability of ICTs, understanding the environmental consequences of different decisions, access to information or participation in decision making is different than in other countries. National or local development strategies vary as well. The future steps in the countries, shown low in this illustration, do not need to follow the same path as that of the current forerunners - some staging posts may be bypassed and other counties overtaken, even very quickly. In Europe, the potential is significant especially within the newly associated states.

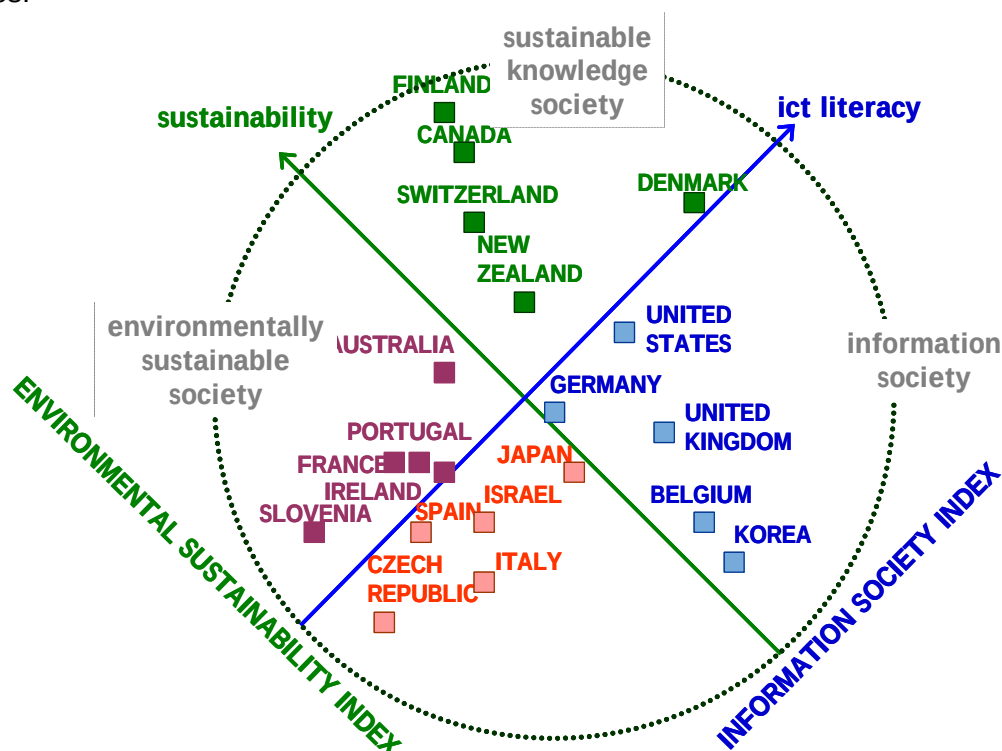


Figure 1. Environmental Sustainability and Information Society country indexes.

The previous figure is not sufficient for drawing conclusions about the progress of different countries. That would require a detailed analysis studying individual

indicators and their interrelationships instead of comparing aggregated country values as shown here.

ESI is a result of collaboration among the World Economic Forum's Global Leaders for Tomorrow Environment Task Force and the Universities of Yale and Columbia. It is a system measuring overall progress towards environmental sustainability, developed for 142 countries. The scores are based upon a set of 20 core indicators, each of which combines two to eight variables for a total of 68 underlying variables.

The other indicator system ISI was first launched in 1996 as the first global measurement of information wealth. Along the years new benchmarking variables have been added to reflect the technological progress. Broadband households, mobile Internet users and wireless telephone subscribers are examples of some newer variables, whereas some traditional indicators, like number of PCs or education level, still remain integral to the index.

2.1 SUSTAINABLE URBAN DEVELOPMENT AND INTELLIGENT CITIES

Intelcity roadmap faces the challenge of realising sustainable knowledge society visions in intelligent city environments aspiring in network of different communities from Sustainable Urban Development and Information and Communication Technologies (Curwell et al. 2003). Five alternative future visions and scenarios outline features of eDemocratic City, Virtual City, Cultural City, Environmental city and Post Catastrophe City. These city scenarios, intended as plausible alternative futures, both desirable and undesirable, were analysed to test the robustness of underlying questions or policy options.

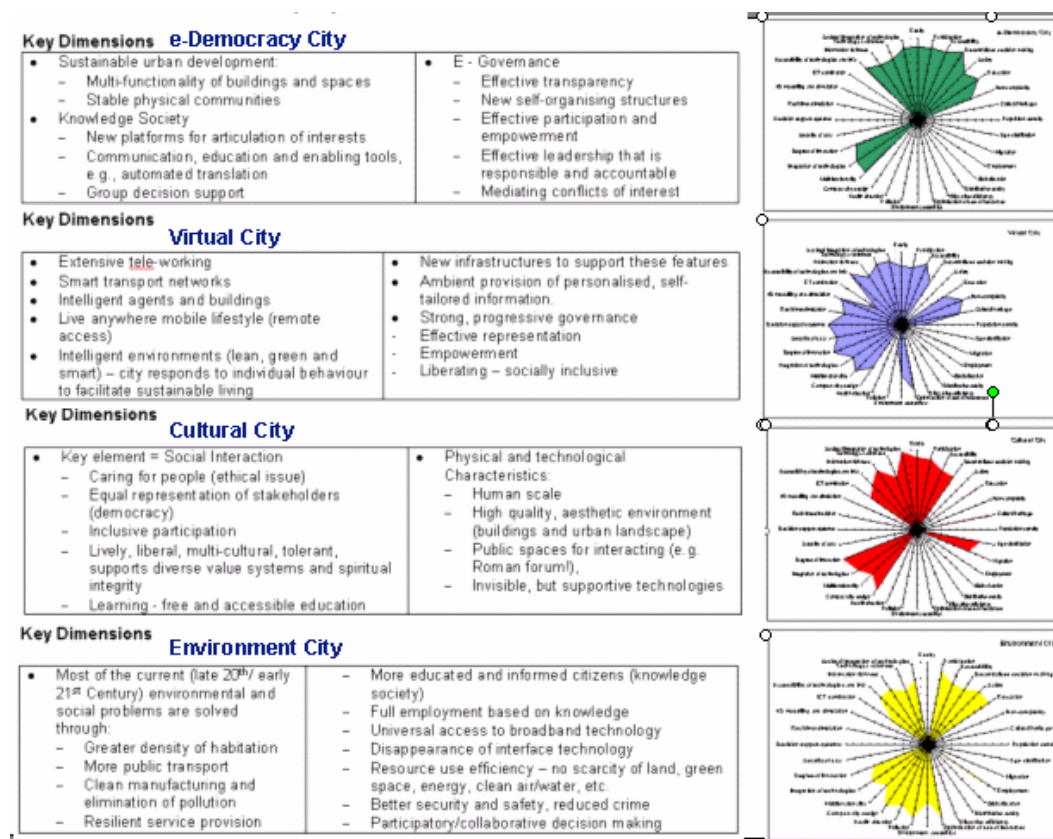


Figure 2. Intelligent sustainable city scenarios.

The stakeholder meetings in different European regions showed distinct priorities, boundary conditions and development paths in different countries. Varying scenarios were also combined in some city visions to have distinct development taking place simultaneously in various quarters in the same city. (Huovila et al. 2002) Finally, research priorities integrating Sustainable Urban Development and the ICTs were listed in 3 years (2006), 5 years (2008) and 10 years time (2013) to accomplish the Intelcity Roadmap.

2.2 ICT IN CONSTRUCTION

The Strategic Roadmap towards Knowledge-Driven Sustainable Construction (Hannus et al. 2003) is based on the vision that construction sector is driven by total product life performance and supported by knowledge-intensive and model based ICT enabling holistic support and decision making throughout the various business processes and the whole product life cycle by all stakeholders. The Roadcon roadmap aims at total life cycle support consisting of different dimensions, such as adaptive and self-configuring systems, ambient access, collaboration support for distributed virtual teams, digital site, flexible interoperability, knowledge sharing, model based ICT, smart buildings and embedded systems, and performance driven process.

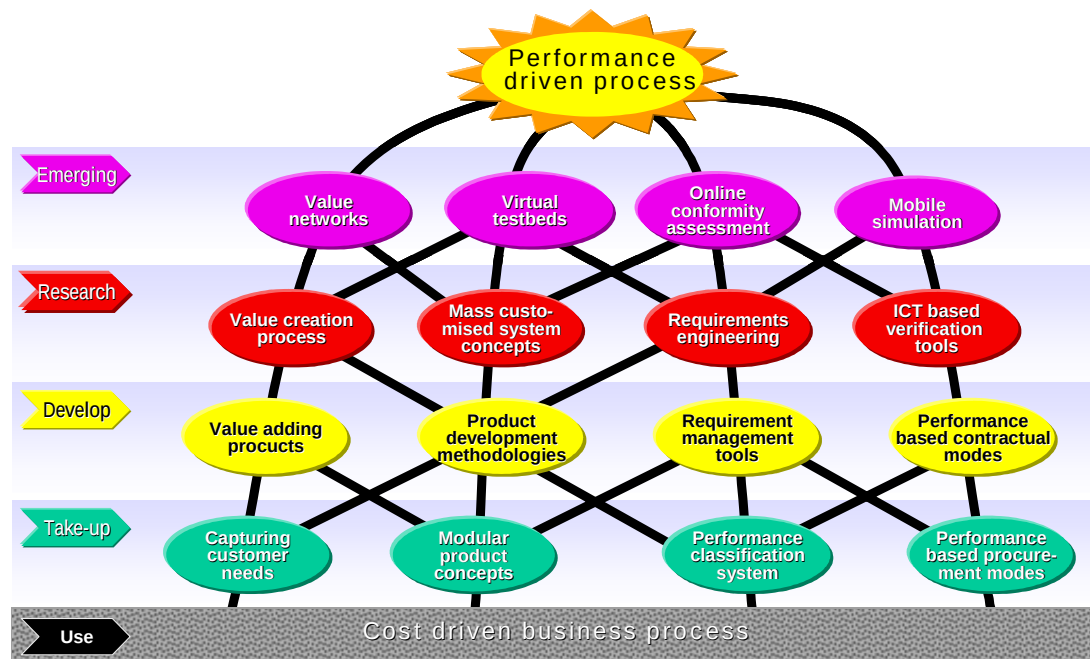


Figure 3. ICT supports the transition towards performance driven processes.

The current situation in construction is closer to the prescriptive-based than to the performance-based practice (Lee et al. 2003). Customers, however, are increasingly aware of whole life costs, perceived value and intangible assets. The vision is that performance driven process ensures conformity to customers' needs and emphasises on end user satisfaction and value. ICT solutions support for capturing and fulfilling predefined performance criteria. As the service component becomes an essential part of core business, the traditional value hierarchy in the sector will be transformed. Choices of material and the functionality of structures will be based on whole life considerations. Users choose service packages for housing, e.g.

increasing the flexibility. It is essential to understand customer needs and integrate them to production processes

2.3 VIRTUAL ORGANISATIONS AND BREEDING ENVIRONMENTS

The vision statement of Design for Collaborative Virtual Organizations in Dynamic Business Ecosystems (Camarinha-Matos et al. 2003) is that in 2015 most enterprises will be part of some sustainable collaboration networks that will act as breeding environments for the formation of dynamic virtual organizations in response to fast changing market conditions. As a result, a strong and cohesive social fabric is built in response to turbulence and uncertainty.

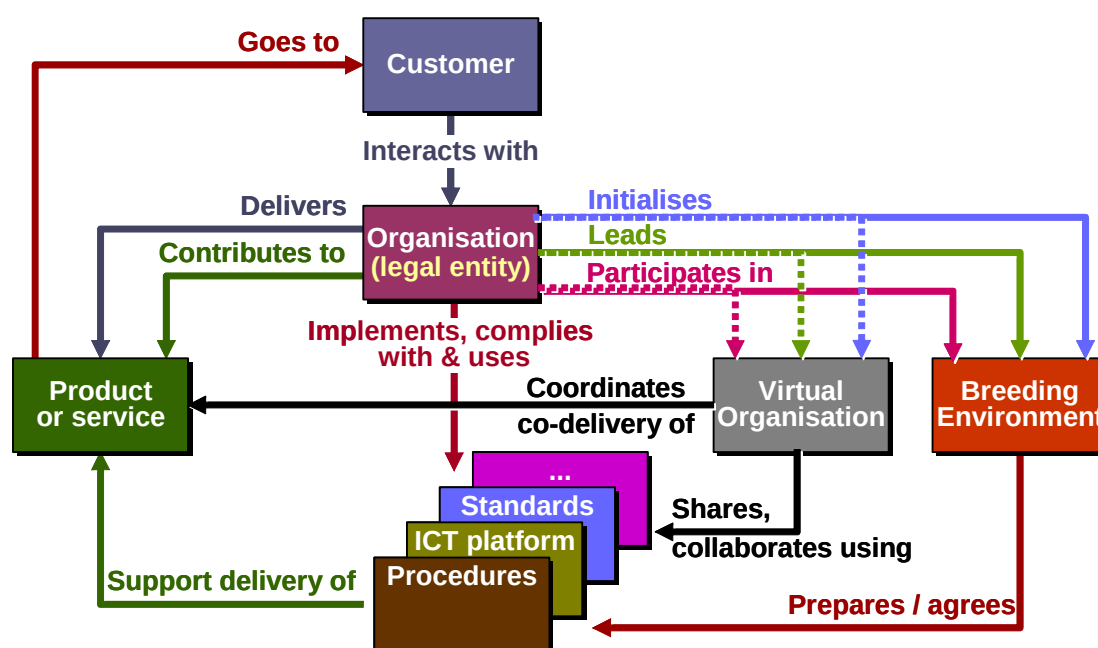


Figure 4. Breeding Environments and Virtual Organisations.

The key features of VOMap roadmap can be summarised as well founded collaboration models, management systems for breeding environments replicable to a large variety of sectors, generic and invisible infrastructure and re-utilizable service toolbox based on interoperability standardization, extensive use of pervasive computing, virtual organization management principles adapted to emerging behaviour in complex networks, accepted mechanisms to handle innovation and new value systems, social responsibility including life maintenance based on a suitable ethical code and comprehensive international legal framework for virtual organizations. Distributed innovation management will become a decisive task for virtual organisations. Efficient innovation processes are a clear competitive advantage for those networks (Eschenbächer et al. 2004).

2.4 CORPORATE RESPONSIBILITY AND STAKEHOLDER REPORTING

New Partnerships for Sustainable Development in the Knowledge Economy (Allee et al. 2003) Roadmap is about measuring progress towards a sustainable and inclusive society. It provides a systemic view of developing and integrating new measures for the assessment of qualitative aspects of economic, environmental, social and cultural dimensions. It emphasizes that the reporting systems developed and used by

corporations do not really correlate to the needs of cities or citizens. More transparency is requested by different stakeholders. Triple bottom line reporting considering also both economic and social and environmental aspects of companies' outcome may affect in decision making of individuals, organisations and governments.

The main statement in Neskey Roadmap is to increase the transparency of companies and cities in a compatible way. That requires enabling technologies that support social change and collaborative process technologies with an open source ICT platform for gathering, managing and disseminating data. The 360 degrees accountability of business and cities can be built on intangible indicators and valuation, sustainability reporting and measurement, and integration of methodologies.

From the built environment point of view (Huovila et al. 2003) in the short term it is possible to make a direct contribution to sustainability through the better management of existing buildings, using modern energy management technologies and services. In the medium term, it is possible to make a direct contribution to sustainability by investing in the improvement of the built environment on the basis of a lifecycle or total-cost-of-operation analysis. This should explicitly link changes to the built environment with work and work-force productivity due to flexible buildings and better working conditions. In the long term, it is possible to contribute to sustainable development by linking patterns in the evolution of telework, homework, mobile work with changing demographics of cities and the planning of future urban environments.

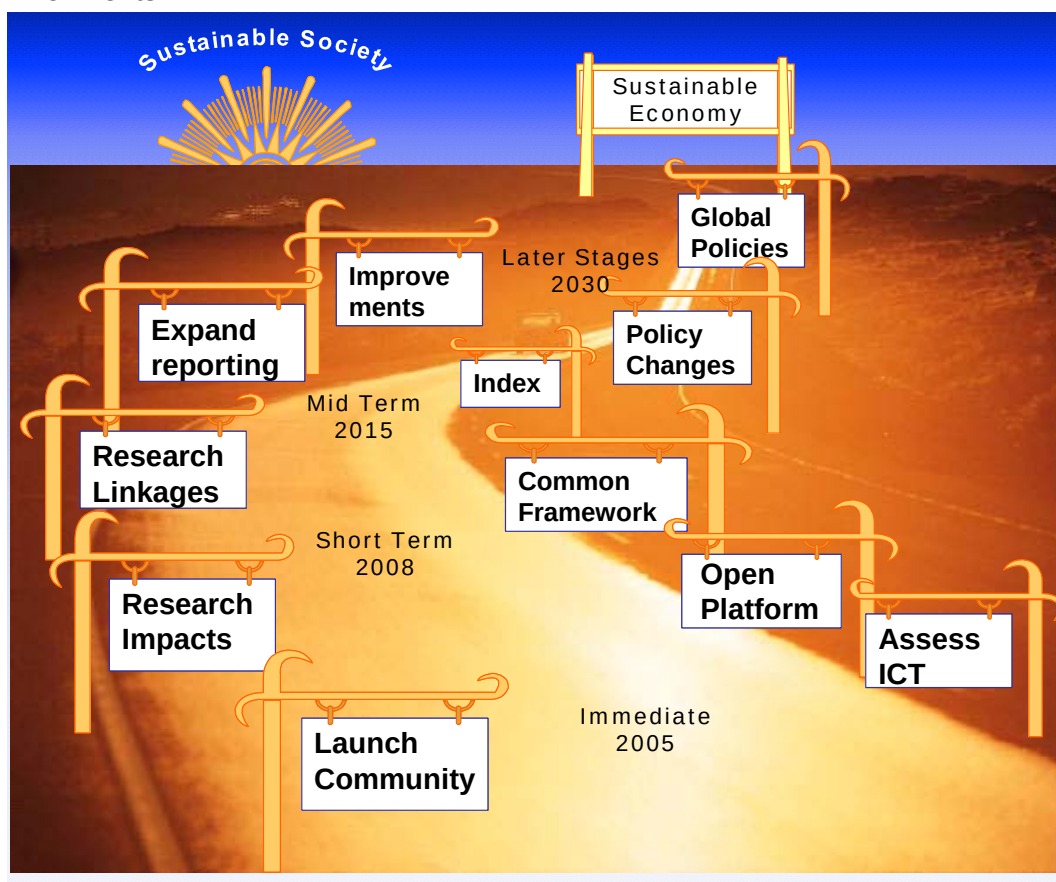


Figure 5. Sustainable society landing points in Neskey roadmap.

Decision making within companies is ultimately driven by a 'business case' rationale. In cities, on the other hand, decisions making is driven by a 'public service' rational that incorporates a 'business case' at the mezzo or macro-economic level, as well as a 'social case'. The two cases are not perfectly separable. They coexist in a system of trade-offs relating to the need for investments that support economic growth of the city and the need for investments that ensures the city provides a good quality of life for its citizens. It is possible in principle for enterprise and cities to contribute to a common cause such as 'sustainability' for entirely different reasons. However this requires a clarity-of-cause that does not as yet exist either at city or at enterprise level in most parts of Europe or the world.

In particular, a common language and a shared set of concepts will contribute to the design of policy level sustainability interventions that effect enterprise by helping to move debate beyond adversarial patterns of lobbying via networks of influence, towards a more rational democracy based on forms of open negotiation and enlightened self-interest.

3. INNOVATIVE COMMUNITIES

Two examples are given as innovative community building cases: the International Group of Lean Construction (IGLC 2004) and Ambient Intelligence at work (AMI@Work 2004). Their common nominator is a shared interest between experts on a novel collaboration field. Their institutional formalities are not highly visible, membership fees are replaced by enthusiasm and constitutions by innovative visions.

The International Group of Lean Construction gathered first time together at VTT in Espoo in 1993 and has met annually ever since (once in Australia and in Asia, three times in South and in North America and twice in Europe). The nature of its annual workshops is to call together researchers and practitioners sharing common interest towards lean construction philosophy. New findings are disseminated to end users and new research paradigms are discoursed within this informal research community. IGLC published a book (Alarcon 1997) of its early achievements as one concrete deliverable.

Ambient intelligence at work family of European Research and Innovation Area Communities is an initiative to catalyse systemic innovation. It is a European Commission initiated self-organising community in movement. It operates currently in eight interest groups, such as Engineering@Work, Mobility@Work, Well-being Services@Work and Knowledge@Work. The AMI@Work interest groups are facilitated by elected leaders. Those families, or tribes, share and develop further future objectives of key challenges in their domains. In some of them the platform is built on ongoing research projects funded by the Commission. In others the members prepare together new ones.

The concept was first tested in Brussels in July 2003 with almost 100 participants discussing the initiative and its communities. AMI@Work launch preparatory workshop was held in Brussels in March 2004 with over 200 interested participants. Budapest hosted the second launch preparatory Workshop in May 2004 and the main launch was finally in held Brussels in June 2004 with some 300 participants concluding the next steps for the coming year.

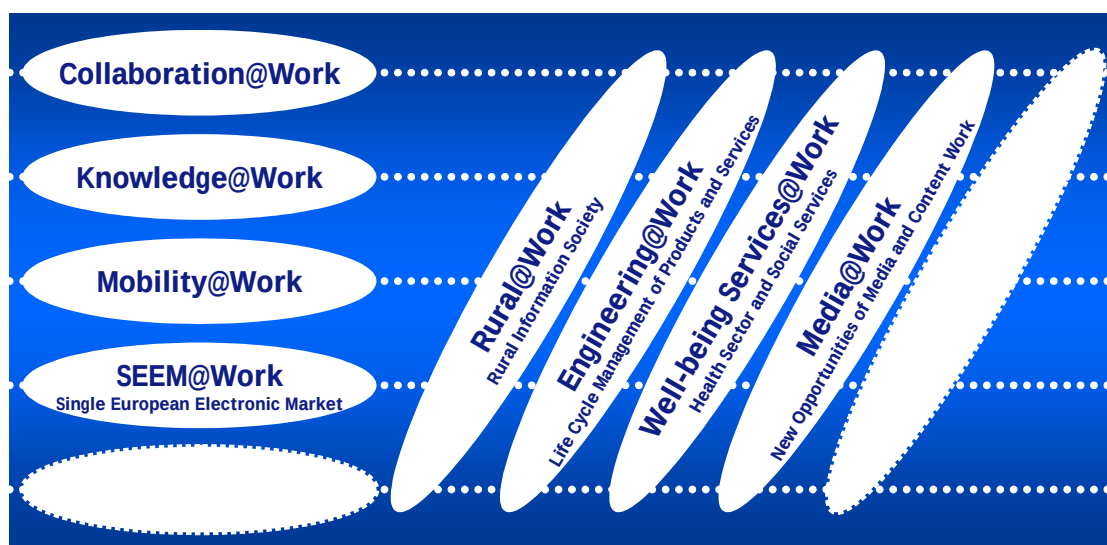


Figure 6. AMI@Work family members.

4. THE BUILT ENVIRONMENT SUPPORTING MOBILE INDIVIDUALS – LIVING LABORATORIES ACROSS EUROPE

Living laboratories are presented as a process innovation supporting concept. The idea is to provide self sustaining business opportunities in cities or neighbourhoods forming a natural meeting place for public and private investments and interests. From the research perspective, user studies may be conducted in that environment supporting niche development. The living lab approach empowers mobile individuals through the development, provision, deployment, training, and take-up of applications and services supporting the individualisation of both site independent and site dependent environments. It will create a paradigm shift enabling mobile work at all times, in all places, and in all contexts.

Innovation process and ambient Intelligence across interlinked cities and communities is the clear ambition. The impacts will be achieved through concrete steps connecting existing mobile work laboratories in various locations to interconnected living labs. These will serve as key hubs, integration channels, and show cases for further take-up. It uses an iterative thematic approach centred around delivery of context based applications and services to mobile workers and site specific applications and services to enable mobile work in the built environment. These serve as the catalysts for mobile workers and users in the living lab network. The living labs in turn act as the baseline and launch-pad for development of next generation mobile work environments.

The kind of work that can be done on a mobile basis, when truly enabled by the supporting infrastructure, user friendly applications and interfaces together with flexible spatial and desk solutions, could considerably decrease the need of traditional office space (e.g. 70 %). At the same time it may set new needs for flexible connectable work space at homes and public environments. The objective is not to stress individuals to work around the clock, but increase the quality of life e.g. by avoiding non value adding time wasted commuting.

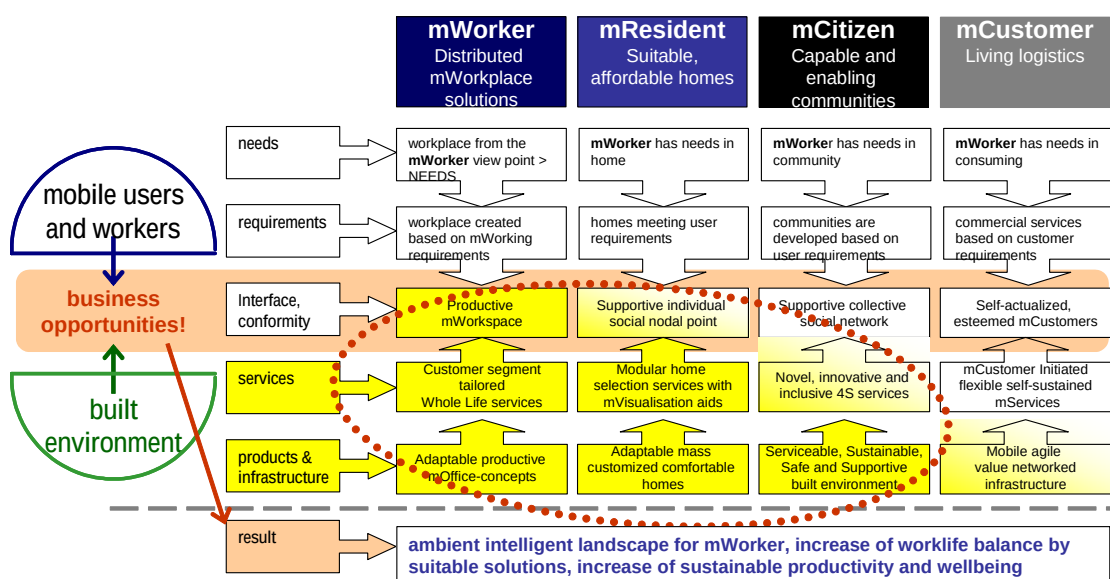


Figure 7. The built environment supports individual mobile life.

Contemporaneously with the potential of deliberating important quantities of office rooms of low rate of occupancy a huge global market is open for sustainable refurbishing of environments to meet the needs of the mobile individuals of future knowledge society. The big question still remains if the real estate and building sector is willing and capable of providing customer driven services over the whole life of constructed assets for their owners and users.

5. SUMMARY AND CONCLUSIONS

This paper proposes sustainable knowledge society as a common intended and desirable vision. International innovation is justified to be a prerequisite that enables reaching this objective supporting the seamless transition process. Four recent IST research roadmaps are presented from the city, construction, collaborative work and corporate perspectives. Two self organising interest groups are given as examples of innovative research communities. Finally, the living laboratory concept in cities is presented as a promising innovation breeding environment bringing customers and suppliers together integrating at the same time both public and private sector interests and investments.

These examples, described more in detail in the references provided, show the clear ambition towards not only technological, but also social and cultural innovation, processes which can lead to our future sustainable knowledge societies.

One challenge will naturally be how to bridge innovations with research and place. Since it is often claimed that innovations don't always take place in office kind of facilities we must think about how to transform workplaces to a more stimulating form and shape. The other dimension, supporting location and time independent access to information and communication, is of utmost importance.

The final conclusion is that investment in cities (e.g. sustainable ICT infrastructure) supporting systemic innovation has enormous potential to incubate self sustaining

business opportunities and to improve well being and quality of life of present and coming generations.

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CONFERENCE THEME

Case Study

INDOOR ENVIRONMENTS, DESIGN, HEALTH AND PRODUCTIVITY

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ABSTRACT

This report focuses on the research published on the topic of indoor environments and the impacts on worker productivity and health.

Traditional research on work spaces emphasizes the study of human factors, or ergonomic design of objects with relation to the human body, and human capabilities. In addition, research undertaken at a broad level of analysis in Environmental Psychology, or the study of transactions between individuals and their physical settings. In these transactions, individuals change the environment and the environment changes their behaviour and experiences.

Human factors or Ergonomics is an empirical science. The central approach of human factors is the application of relevant information about human capabilities and

behaviour to the design of objects, facilities, procedures, and environments that people use (Sanders and McCormick, 1992).

The work environment can be considered not only as a collection of physical stimuli (noise, light, temperature, etc.) but also as a physical structure (size, furniture, architectural design, etc.) and as a symbolic artifact (the meaning or image of the work setting). Fundamental psychological processes are invoked by employee/environment interactions: arousal, overload, affect, adaptation, personal control, and so on. This leads to outcomes that, in general, may be categorized into performance (or productivity), health (or stress), and satisfaction (or moral and interpersonal relations).

A clear conclusion drawn from this report is the need to undertake more research in an Australian context, in terms of both physical, cultural and social conditions, with the aim of verifying and quantifying the impact of key indoor environment variables on productivity and health.,

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Keywords: Indoor environments, work space studies, worker satisfaction

In much of the literature reviewed for this paper the concept that rates of office worker productivity have a direct correlation to worker psychological satisfaction is well established. Other factors also play into account such as management style and organizational behavior (Gifford, 1997). In the analysis of physical environments a number of interesting case studies have revealed interesting outcomes. The case study outcomes will be discussed in more depth later in this review. In concluding this paper recommends more focused research be undertaken within the Australian context of indoor environments. The work would be well suited to a collaborative research effort between industry and public sector agencies.

The Indoor Environments: Design, Productivity and Health report was written with funding from the Collaborative Research Centre for Construction Innovation and summarizes studies already undertaken in the field of indoor environments (worker productivity and health in buildings). In this report a wide range of areas are covered. An extensive literature review was undertaken to more clearly understand the diversity of fields of study, which overlap under subject of Indoor Environments. The four main areas reviewed here are; indoor air quality, thermal, visual and acoustic comfort. From this material the team that compiled the report has made key findings in gaps and opportunities for further research work needed to better understand the nature of encouraging higher productivity and work satisfaction.

Findings of the research reviewed here indicate that substantial improvements in productivity strongly correlate with improvement within an indoor environment (see ref: p. 35 of the report). Unhealthy indoor environments or "sick buildings" are accountable for a hidden health cost. A study undertaken in the United States shows that loss to productivity and hidden cost to be in excess of \$200 billion per year (Fisk, 2000).

Retrospective

The western world has progressed in the past century with a general movement away from labor-intensive activities. In the past twenty-five years the service economy has strengthened and driven a demand for commercial office space. Through the process of industrial restructuring we now have far greater numbers of people in urban centers than at any other time. This shift has meant a significant increase of people working in indoor environments. New theories of work place interactions and organizational ecologies have revealed important connections (Becker and Steele, 1995).

The character of work and the economies of tall office buildings have meant a growing importance of worker satisfaction and higher productivity relationships being more clearly understood. This project's focus is on the physical setting as a result of the development industry. This prospective are parts of the integrated system known as high performance workspaces. Results of these new research findings indicate designing and creating environmental conditions aimed to enhance the work experience, increase in work performance and worker satisfaction can be extrapolated

The nature of office work has changed over the years. A century ago the running and administrations of factories was carried out in centralized locations within the realm of the factory where the majority of the tasks were

those of paper handling. This predominantly passive mode of work took place in rudimentary spaces. Today, office work is increasingly concerned with the generation, recording and dispersal of ideas. With the aid of technology workers manage and analyze large databases of information, which is used to improve the most efficient and profitable interests of the organization. As a consequence of this historical shift office spaces have become the most integral part of the organization (Sanders, McCormick, 1992).

Current and Future Trends

In contemporary times office environments need to be designed as a responsive environment where work spaces encourage productivity and enhance task performance. This can be achieved by supporting user needs, by facilitating meaningful communications, healthy work relationships and a stimulating organizational climate. In the knowledge economy, the nature of work that is performed in offices is becoming more cognitive in character (Fried Y, 1990). Smart technology encourages a more refined role where workers analyze, conceptualize, and communicate with others and other machines. The ability to provide an attractive environment for more highly skilled workers is now in the best interests of the organization. (Florida, 2002) To be functional, office environments must support the physical activities and such as space, light and furniture as well as psychological environments of users which are perceptual, social and cognitive activities.

In the knowledge economy, workspaces are one component of integrated aspects of the overall output potential and productivity. In order to accurately evaluate the optimum work environment a number of areas of research should be undertaken. One of these is the analysis of the socio-physical perceptions of individual user groups. This is undertaken with six interdependent sub-systems: the type of people who work in the office; the work activities performed; the interaction and communication relationships; the organizational structure and culture; the type of technology used and the over all designed office environment.

Reporting Objectives

The objectives of the project were two fold; firstly, to gain understanding of the work performed to measure impact of indoor environments on productivity; and the other to gain specific knowledge relating the indoor environmental impacts on worker productivity. Over 500 literature resources have been reviewed in the report. Considerations within the literature review were made for the focus of the study, the research methods being applied in the study and the qualities of the building. In order to ensure legibility in the system a "literature Classification Scheme" was put forward. The six main classifications devised are; Geographic Location, Building Types, Data Types, Outcome Focus, Building Attribute, and Detailed Attributes. This system of classification became the basis of the methodology to manage the data.

In addition to this, the use of a "Data Type" classification was deemed necessary because of the high number of resources available concerning this topic. The different types of studies within the database vary from qualitative observational studies to detailed analyses of specific parameters of the indoor

environment. Six topics are used to help distinguish the study focus into areas such as health, productivity, comfort, response and well being. There are also categories that identify energy usage, maintenance and environmental aspects of the building design and operation. It is interesting to note that many of the studies did not lead to a specific outcome focus.

Maslow's Hierarchy of Needs

The majority of theories on productivity are found on worker and employee motivational relationships. A commonly used model is the motivational theory put forward in Maslow's Hierarchy of Needs, illustrated with a pyramid of hierarchy with Self-Actualisation at the pinnacle and Self-Esteem Needs, Social Needs, Safety Needs and Physiological Needs in descending order. This theory is based on the fundamental approach that individuals satisfy lower order needs before they move onto higher order needs. Application of this theory to productivity in buildings may or may not meet the higher or lower order needs of the occupant which in turn impacts on occupant productivity.

As it will become clear in this paper, the measurements of productivity and health outcomes is not a straightforward task. To better assess the impact of numerous variables it becomes difficult to discern between worker productivity, environmental impacts, work ethics and inter-corporate dynamics. In order to better define these variables the research group developed a graphical representation of the overall approach. Within the report on page 11, a diagram is provided to indicate what research has already been undertaken. In this we begin to see the emergence of a critical relationship between indoor environments and building occupants under a holistic approach. Understanding the inter-connectivity of these variables is essential when developing a methodical approach to the project objectives.

Effects of Building Related Illnesses and Indoor Air Quality

In discussing indoor environments of office buildings the term "Sick Building Syndrome" (SBS) is the term used to represent a collection of temporary variables that impact on occupant health. The symptoms of SBS can be sore throat, fatigue, dizziness, headaches, problems in breathing and other influenza type symptoms. SBS's are different from "Building Related Illness (BRI), which is a clinically verifiable diseases that can be attributed to a specific pollutant as the cause agent. Also the Multiple Chemical Sensitive (MCS) problems are generally thought to be acquired through contact with particular volatile organic compounds present in the workspace. These pollutants are of concern to organizations due to potential risk management for occupational health and safety standards, potential worker illness and corporate liability.

There is extensive research that has been undertaken to better understand the role that good indoor air quality plays in increased productivity. The universal conclusion for much of the research indicates that buildings need to be designed, built and maintained in ways to reduce the impact of airborne pollutants, provide sufficient exhaust and clean air ventilation by natural means.

Importance of Light

There is an important connection to be made between visual comfort and thermal comfort. The light levels provided within indoor environments can add heat to internal spaces due to the amount of energy required to provide the light source. This can be analyzed through determining the ratio of light output to the total power input. For example sunlight is one of the most efficient sources of light rating 94.2 lm/W (Illuminate Engineer Society, 1995). This concept is important to consider as lighting accounts for 15% of total energy used in Australian commercial buildings. Perhaps even more importantly this demand on energy generates 21% of the total greenhouse gas emission for commercial buildings in Australia (Australian Greenhouse Office, 1999).

Considerable research has been undertaken evaluating the relationship between luminous environments and productivity. Studies on the topic date back to the 1920's where research into the link between factory unit output and illumination were conducted by behavioral scientist. The literature review and report go into far greater detail on this subject. Examples of the types of factors impacting on the field of study are: spectral distribution, glazing type, diurnal illuminate variation, glare and color rendition. Much of the work carried out has been in school and office buildings.

In the literature reviewed, it has been strongly indicated that forms of data measurement, such as questionnaires, need to have well informed motives. By becoming familiar with the amount of research already undertaken there is an opportunity to create structures of measurements which are adequately developed and tested. The report offers several good examples of methodologies found in the literature review, in particular the PROBE studies (Leaman and Bordass, 2001). However these programs need updating and evaluating.

Conclusion and Recommendations

The report concludes with a number of recommendations for further research to be undertaken. The findings here expose a significant shortage of data in Australia and in particular field studies. It is estimated that only 8% of the literature found in this project was carried out in Australia. Although some studies are relevant to Australia there are a couple of reasons why work needs to be undertaken here: climate change and solar lamination levels are unique to this region of the planet; and cultural differences and the significance of social space and administrative nuances that are unique to Australian organizational behavior.

Further research is required in real working environments. It would be ideal to have the study take place in a climate of extremes such as Melbourne or Brisbane. The use of subtropical or Mediterranean climates may offer higher correlation to quantify the benefits of improved indoor environmental quality. A study may exist which measures the statistical significance of environmental pollutants before and after an office renovation, or one that measures indoor air quality, thermal comfort and lighting. Conducting a post occupancy evaluation in winter and summer to determine if there are changes from the participants could follow these up.

The underlying benefits from further exploration into this work can lead to a balanced outcome of lower overhead cost per workers and higher levels of moral and feelings of satisfaction. This combination will contribute to increases in productivity. Buildings can influence the Indoor Environmental Quality in ways where the overhead and capital cost come down as productivity increases (lower number of sick days claimed). More efficient technologies with effective applications (i.e. intelligent buildings) reduce cost associated with building operation and maintenance.

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PROCUREMENT AND RISK SHARING

Case Study

DEVELOPMENT OF THE 'COMPETITIVE TOC' ALLIANCE – A CLIENT INITIATIVE

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INTRODUCTION

Many will be aware that the Alliance concept was first significantly used in Australia (in terms of broader industry recognition) in the Western Australian oil and gas sector, with two notably successful Alliances being the East Spar development and the Wandoo Platform.

Of relevance to a particular theme of this paper, it is noted that the Alliance concept was introduced through the private sector. This contrasts with the introduction of partnering, which is usually attributed in origin to the US Army Corps of Engineers; and was widely promoted in its initial introduction to Australia by the Queensland Main Roads Department (who have more recently also been a significant user of Alliance formats).

The Alliance approach to project delivery, since it is fundamentally just about a different approach to targeting outcome and sharing risk, can be and has been applied to a wide variety of project types – from highly risky major capital infrastructure projects to relatively mundane term services contracts.

When introduced to Australia, and as still widely applied, the Alliance contract model was of a form that is now commonly known as the 'Pure' Alliance. This model has been widely reported and analysed, with papers by Jim Ross of Project Controls International amongst the most widely circulated.

In more recent times, particularly in public sector applications, two specific variants of the Alliance model have been implemented which have some significant differences to the 'Pure Alliance' model; and it is considered that these variants may offer a number of owners a project delivery instrument that is more suited to their particular situations. These two variants are:

- the 'Project Alliance'; and
- the 'Competitive TOC Alliance'.

In each case, all the key elements of the project delivery phase are very much the same as a 'Pure Alliance', including the key risk allocations and the project management structures. Indeed, in risk allocation, the 'Project Alliance' and 'Competitive TOC Alliance' models have more in common with the 'Pure Alliance' model than, for example, such well known Alliance variants as the National Museum of Australia project. These similarities distinguish the 'Project Alliance' and 'Competitive TOC Alliance' variants from other delivery processes that, whilst they have been described in headline documentation as Alliances, in reality have had as little similarity with the key principles of an Alliance as has the C21 Partnering Agreement (the latter, of course, standing on its own merit).

The principals of Southern Pacific Alliance Network ('SPAN') developed the 'Project Alliance' model in 2000 for the particular circumstances applying in local government use of Alliances, although the model has much wider applications. Subsequently, the same group released the first known Australian application of a Competitive TOC Alliance in mid 2001 – as part of the \$50M Bega Valley Sewerage Project in southern NSW; and have since facilitated or commenced work on another three 'project' applications and one 'program' application of the 'Competitive TOC Alliance' variant.

This paper:

- explores the reasons for the development of both the 'Project Alliance' and 'Competitive TOC Alliance' models by the authors;
- examines broader criteria for considering which project situations may be best suited to 'Pure', 'Project' and 'Competitive TOC' Alliance models; and
- provides an outline of the current structure and implementation of the 'Competitive TOC' Alliance model as practiced by SPAN.

DEVELOPMENT OF THE 'PROJECT ALLIANCE' MODEL

ALLIANCING IN THE PUBLIC SECTOR

Shortly after the Wandoo and East Spar project successes, the first (apparent) appearance of Alliance contracting was for the maintenance services outsourcing contracts by Western Australia's Water Corporation, in 1994. These relatively large service contracts (circa \$15M pa) seemed to industry observers to be using the Alliance model to achieve several objectives other than those normally associated with the performance improvement objectives of Alliances; not the least of which was ensuring that the services were only partially 'let go'; as the Alliance model used left a Water Corporation executive with a final say on all disputes, and had all assets captured in a Special Purpose company that could readily be taken over by Water Corporation in the event of any breakdown in the service relationship. Nonetheless, Water Corporation has subsequently become somewhat of a champion of Alliancing, with the success of the Woodman Point Alliance widely promoted; and, notably, the second known application of a Competitive TOC Alliance model.

Subsequent public sector applications included all major infrastructure sectors: water, rail and road. The Queensland Main Roads Department, as might be expected from its early championing of Partnering, became an early and consistent user of Alliances; on a range of projects with widely ranging objectives. Notably, all the implementing agencies were large State agencies or GBEs. Accordingly, none were constrained by detailed tendering regulations such as those that typically apply to local governments.

ALLIANCING IN LOCAL GOVERNMENT– THE GENESIS OF THE 'PROJECT ALLIANCE'

In early 2000, Maroochy Water Services – a business unit of Maroochy Shire Council – approached the authors for advice on the most appropriate delivery model for the proposed construction of a sewage treatment plant upgrade. When it was identified that the project required a high degree of integration between operators, designers and construction managers, an Alliance was suggested. Assessments of the potential applicability identified some particular issues that concerned the Council:

- that the participation by the Council under a normal 'Pure Alliance' model, e.g. as the 'owner participant', would cause the entire project to be captured by the tendering requirements of the Local Government Act and thereby losing the inherent flexibility provided by contractor procurement processes expected under a 'design and construct' project scope; and

- that the Council team, working with the usual very limited resources available to a local government engineering business, could contribute operations skills and experience but little else to a potential integrated project team.

Of course, the procurement issues arising from the Local Government Act had not been an issue for the corporatised GBEs, and obviously were not an issue for private companies, in applying the Alliance delivery model.

In addition, the relatively small size of the project meant that project-specific PI insurance was not available; and the usual 'no-sue' provisions of an Alliance would leave the Council exposed to post-completion design error risks in a manner that it was not usually exposed to, yet were typically a reasonably significant source of risk for a water business (in accepting externally designed and constructed treatment plant infrastructure).

As the Maroochy project was the first known local government application of Alliancing, the advisory team sought to develop tailored solutions to the identified issues, against a very limited budget.

The solution developed was the first generation of the 'Project Alliance' model, which has subsequently been refined over a number of other local government applications.

KEY FEATURES OF THE 'PROJECT ALLIANCE' MODEL.

Key features of this model are the establishment of a relationship between the Council and the 'Alliance Contractor' where:

- Council contracts for the delivery of the 'works' by the Alliance Contractor
- The Alliance Contractor is free to run an optimised procurement system unfettered by the constraints under which Council would normally operate
- Council offers limited resources (usually with operations and maintenance knowledge) for integration into the alliance teams
- The Alliance Contractor agrees to a management structure and process that incorporates Council staff on a part-time or full-time basis
- The Alliance Contractor owes the normal responsibilities of delivering the works to Council hence the normal indemnity insurance is accessed.
- The Alliance Agreement is structured to deliver the same outcomes as a 'Pure' Alliance in areas such as:
 - o Risk / Rewards
 - o Quality Pools and Key Performance Indicators
 - o Limitations on Liability
 - o A 'Best For Project' focus
 - o Relationship management
 - o Issue resolution
 - o High performance team development

OTHER APPLICATIONS FOR 'PROJECT ALLIANCES'

With the relatively recent collapse of the insurance market and the unavailability or lack of affordability of project specific Professional Indemnity insurance, the Project Alliance Model has potentially wider appeal. Points of attraction for the 'Project Alliance' Model are:

- Access to post-Alliance, Professional Indemnity insurance coverage; and
- The ability to enter into alliances despite the owner having limited resources to deploy into any prospective alliance team structure.

DEVELOPMENT OF THE 'COMPETITIVE TOC ALLIANCE' MODEL

Both the 'Pure Alliance' and 'Project Alliance' models select a single contractor team on a 'best for project' principle. At project commencement under these models, the team, including the owner's personnel, work together in a collaborative/alliance culture environment to develop the concept design for the project and to estimate the cost at completion of the project; and this cost is commonly termed the Target Outturn Cost (TOC).

CONTRASTING THE ALLIANCE MODEL IN THE PRIVATE AND PUBLIC SECTORS

As noted in the introduction, the (widely recognised) introduction of the 'Pure Alliance' model into Australia was through the Western Australian oil and gas sector – with early leading examples including the Wandoo Platform and the East Spar project. This 'route' to the Australian market reflected the initiation of Alliances through supply chain review in the Cost Reduction In the New Era ('CRINE') project within the North Sea oil and gas industry.

PRIVATE SECTOR PROJECTS – PRICE TENSION

The private sector nature of these key reference projects was, in the authors' view, a critical factor in the successful application of the Alliance project delivery model; and the relevance of this factor becomes particularly apparent when contrasted with some of the concerns expressed about Alliance project outcomes in some public sector projects.

In the private sector context, after selection of the preferred 'best for project' team the development of the Target Outturn Cost ('TOC') is invariably in the context of a business case development. That is, the Alliance was being charged with bringing a project in within the budgets necessary to achieve the business case hurdles for the project – *"don't get the costs and risks down to under the business hurdles, and the project simply won't proceed"*.

Alliance teams in this context are incentivated to achieve stretch outcomes (through the application of innovation, 'best for project' decision making, and a highly integrated team focus) in developing the TOC. Clearly, a key driver for achievement of highly competitive outcomes in the TOC development phase was the very real risk that the owner would not proceed with the project unless the identified corporate business case hurdles were met. The East Spar project is an excellent example of this principle in application, with the Alliance successfully delivering considerable innovation in order to surpass the hurdles.

PUBLIC SECTORS PROJECTS – PRICE TENSION

This 'business case driver' can be compared with the usual situation in public sector applications where the project is almost always certain to proceed. An example of a public sector project where the TOC significantly exceeded the owner's estimates but the project still proceeded (simply by way of example and without comment as to the inherent validity of either estimate) is the Port of Brisbane Motorway; where the TOC was nearly double the owner's pre-tender estimates. It is difficult to imagine that any private sector investment project would have sustained that type of cost increase and still proceeded.

However, it could be more broadly argued that, in the situation where a single team is developing the TOC estimate and is without a challenging business case hurdle to pass, the driving force that characterised the success of the early oil and gas Alliances has invariably not been present. The TOC development phase is simply establishing what the price will be: there is little doubt that the project will proceed. Readers could ask themselves a question to test this hypothesis: *how many public sector Alliances have been canned because the TOC was too high?* In such circumstances, and giving some deserved respect to the underlying

commercial incentive of private contractors, where can confidence be placed that a genuinely challenging or commercially competitive TOC has been achieved?

THE INDEPENDENT ESTIMATOR AND THE PRICE

Of course, the use of the independent estimator is a tool to provide some confidence to the owner that the TOC is reflective of current market practice. However, there are examples known to the authors where the ability of the independent estimator to argue a case for a reduced TOC has been curtailed, for any number of reasons, only to see the savings that were argued for almost immediately materialise after project implementation. In reality, can independent estimators really drive every productivity estimate, every parameter, and every rate to current market practices? The question then is – is the independent estimator mechanism not being properly used, or is it simply not effective?

The difficulty in arguing the case for the effectiveness of the Alliance application in public sector projects is that there have been project outcomes that have resulted in relatively large project savings against the TOC – e.g. Port of Brisbane Motorway and Awoonga Dam. In the context of the points made above, one should not be surprised that doubts are raised in public sector senior management about whether Alliances are really delivering value – whether the TOC was ever a price that genuinely reflected the kind of competitive pressure meant to be reflected in an Alliance TOC. For advocates of Alliancing there is a real threat that broader adoption by the public sector is at risk.

APPLICATION OF THE 'COMPETITIVE TOC ALLIANCE' MODEL

The matters raised above were important considerations for the clients deciding on their Project Delivery Strategy for the following projects:

- Merrimac Wastewater Treatment Plant Upgrade Project, for Gold Coast Water
- Beenleigh-Merrimac-Pimpama Wastewater Network Augmentation Program Alliance for Gold Coast Water
- Maroochydhore Sewage Treatment Plant, for Maroochy Shire Council, and
- Wetalla Wastewater Treatment Plant Upgrading, for Toowoomba City Council

In each case the client organisation has decided to use a Competitive TOC Alliance, facilitated by SPAN. All of these projects use a single client project manager and single, common client team to support each of the two tenderers.

The first known Competitive TOC Alliance development (developed by SPAN for the Bega Valley Sewerage Project) was not in response to issues raised above, but rather a situation where an overall competitive tender process for a \$50M capex project faced particular constraints with a part of the project needed to address the inherent uncertainty of environmental approval processes in NSW. These constraints seemed ideally suited to an Alliance; as that could avoid losing the potential innovation offered by scheme proponents but nonetheless circumvent the very high risks of the approval process. As a very sensitive public context for the project necessitated a competitive tender process, the Competitive TOC process was developed, with the strong relationship contracting elements from the Alliance then committed across all elements of the project. Despite significant doubts amongst some industry respondents, the concept was embraced by leading tenderers and is now being successfully implemented.

The Competitive TOC Alliance approach was subsequently implemented for the Subiaco STP upgrade by Western Australia's Water Corporation (SRDC were the facilitators), and then for the Burnett Dam by Burnett Water (Evans & Peck were the facilitators), both using either a client project manager or client team for each of the two tenderers. As noted previously, the SPAN team is now facilitating a further four 'Competitive TOC Alliances'.

STRUCTURING A 'COMPETITIVE TOC ALLIANCE'

CLIENT TEAMS FOR THE 'COMPETITIVE TOC ALLIANCE' MODEL

Client teams are required in the 'Competitive TOC Alliance' to support the proponents with information, knowledge and ideas throughout the TOC development period; although not quite to the same extent that they support a 'Pure Alliance' or Project Alliance' TOC development phase. An initial reaction may be to appoint separate client project managers or teams to support each proponent in order to respond to the high workload; however experience indicates that the single client team is a fairer and less costly option.

The single client team enables 'apples to apples' comparisons between the proponent teams and proposals as well as ensuring that the same information, ideas and knowledge are made available to both proponents. This puts significant demands on the time of the relevant client team staff. However, despite this much increased workload on client staff, the number of public sector clients embracing this model is increasing. This suggests that the competitive element is seen to more than outweigh any disadvantage.

OUTLINE OF A 'COMPETITIVE TOC ALLIANCE' MODEL

The 'Competitive TOC Alliance' used by SPAN can be viewed as three phases. The first phase involves the Expression of Interest (EOI) that has all the usual features of a 'Pure Alliance' or a 'Project Alliance' project initiation.

Two proponents are then appointed to undertake the second phase, the Competitive TOC Development phase, in conjunction with the Client's Project Team. This phase involves four parallel processes:

- Concept Design development,
- TOC development,
- team relationship development; and
- agreement of commercial terms.

At the end of this phase each proponent submits the Concept Design and associated TOC as well as a signed Project Alliance Agreement. The proponent with the 'best value' offer (based on price and non-price criteria) is appointed as the Alliance Contractor.

The Alliance Contractor, including the assigned Client team members, then commences the third Phase, an Alliance to deliver the project or program, that has all the usual features of a 'Project Alliance'.

OCCUPATIONAL HEALTH AND SAFETY...THE CARING CLIENT?

Case Study

MANAGING OCCUPATIONAL HEALTH AND SAFETY ON QUEENSLAND GOVERNMENT BUILDING PROJECTS – A MANAGEMENT SYSTEMS APPROACH

David Evans

Queensland Department of Public Works

BACKGROUND

In December 1999, the former Minister for Employment, Training and Industrial Relations established the Building and Construction Industry (Workplace Health and Safety) Taskforce (the Industry Taskforce) to inquire into and recommend strategies to improve occupational health and safety compliance in the building and construction industry in Queensland. The main objective of the Industry Taskforce was to address the industry's low levels of compliance as evidenced by a range of sources including the results of Workplace Health and Safety Queensland's 'blitz campaigns'.

Among other things, the Minister specifically requested that the Industry Taskforce provide advice "on the setting of prequalification or tendering requirements that support contractors with proven workplace health and safety management systems and committed to high compliance with their health and safety obligations". (DETIR, 2000)

On 30 August 2000, the Industry Taskforce submitted its final report containing seventy-eight separate recommendations addressing the areas of data collection, the legislative framework, enforcement strategies and compliance strategies. An Implementation Review Team consisting of representatives of employers, employees and government was established to oversee and coordinate the development and implementation of the recommendations in line with government policy.

In relation to the specific issue of occupational health and safety prequalification criteria for government projects, the Industry Taskforce recommended:

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"That the Department of Public Works introduces effective workplace health and safety criteria into the pre-qualification tendering process and the monitoring of on-site performance of principal contractors on government projects-----".

In supporting its recommendation, the Industry Taskforce was of the view that, "The design and adoption of a 'systems' approach to managing health and safety risk within the industry has the potential to generate sustained and meaningful change at all levels of the industry." (DETIR, 2000)

This paper outlines the Department's response to the recommendation of the Industry Taskforce and the resulting new occupational health and safety requirements that have been introduced for building industry contractors under the Queensland Government's Prequalification (PQC) System.

THE PQC SYSTEM

The Queensland Government's process for selection of building industry contractors is based on a system of prequalification known as PQC, administered by the Department of Public Works. Under the PQC System, contractors must be appropriately prequalified and registered to be eligible for invitation to tender on government building projects estimated to exceed \$250,000 in value. The PQC System was developed in consultation with industry and government stakeholders, consistent with the principles of the National Prequalification Criteria Framework (APCC, 1998) established by the Australian Procurement and Construction Council. The PQC System was approved for adoption by all Queensland Government 'Departments' in November 1998.

The PQC System provides a comprehensive assessment of a contractor's capabilities, financial capacity, and commitment to continuous improvement against prescribed criteria including experience, systems, people and business. The system features a degree of self-assessment and a review of performance history and statutory compliance after which the contractor is assigned to one of four levels ranging from base level (1) to world's best practice (4).

The various services required for the procurement of government building projects are correspondingly rated according to their complexity and risk. Contractors must be appropriately registered on the PQC System and have a PQC level that matches or exceeds the PQC service risk rating to be eligible to tender for a government building project. Performance evaluations are carried out during and at the conclusion of the contract and the information is fed back into the PQC System. There were 312 contractors registered on the PQC System as at June 2004.

THE MANAGEMENT SYSTEMS APPROACH

The Industry Taskforce's final report identified that the first iteration of the PQC System did not deal adequately with the occupational health and safety performance of prequalified building industry contractors (DETIR, 2000). Although compliance with relevant legislation was a minimum requirement for applicants, the self-assessed prequalification criteria regarding occupational health and safety relied on performance measurement techniques such as accident severity rates that, in the opinion of the Industry Taskforce, failed to provide an accurate performance appraisal from which improvement strategies could be determined.

The Industry Taskforce promoted a management systems approach to occupational health and safety on government building projects through the implementation by prequalified contractors of an effective Occupational Health and Safety Management System (OHSMS). The management systems approach requires an enterprise to have effective health and safety policies, effective management structures and systems for delivering the policy; a planned and systematic approach to implementation; and the measurement and systematic review of performance.

Deleted: The Taskforce's final report supports the management systems approach to workplace health and safety on government building projects through the implementation by prequalified contractors of an effective Workplace Health and Safety Management System (WHSMS).

A management systems approach to occupational health and safety is consistent

with the National Prequalification Criteria Framework (APCC, 1998) and is promoted as best practice in other Queensland Government publications including [the Queensland Code of Practice for the Building and Construction Industry](#) (DETIR, DPW, DMR, 2000) and the *Better Purchasing Guide* entitled “Industrial Issues in Supplier Selection and Management” (DPW, 2002). The latter is one of a series of guidelines that complement the State Purchasing Policy and assist agencies and suppliers to understand government purchasing practice. It suggests that “suppliers tendering for high risk contracts, such as a supplier tendering for the construction of a high rise building or contracts involving the use of hazardous substances, would be expected to have a formalised occupational health and safety management system to manage the risks associated with a highly complex and hazardous workplace”.

[The National Occupational Health and Safety Commission in its National Occupational Health and Safety Improvement Report](#) noted that “most States and territories have developed an occupational health and safety management model or guidance material regarding occupational health and safety management”. (NOHSC, 2000)

Experience in NSW points to the [effectiveness of a management systems](#) approach in improving the safety performance of building industry contractors. In 2001, WorkCover NSW released a [report into the health and safety performance of the building industry in NSW](#) titled “Safely Building NSW” (WorkCover NSW, 2001). The report [evaluated, among other things, the Construction Industry Memorandum of Understanding \(MOU\) that was agreed between the NSW Government and the Chief Executives of the industry’s principal contractors regarding the adoption and implementation of safety management systems on NSW government projects.](#)

[WorkCover NSW audits of signatory contractors’ safety management systems over the period of the MOU identified a 25% improvement in the way they managed occupational health and safety.](#) In contrast, [audits undertaken across a broader range of contractors by the NSW Department of Public Works and Services showed an improvement of 7% for a similar period.](#)

[Improved occupational health and safety management by contractors was also reflected by improved claims experience for the NSW construction industry. For the period 1998-2000, analysis of the claims experience of MOU signatory contractors identified a 32% decrease in incidence rate. In the corresponding period, the NSW construction industry’s overall incidence rate per 1000 workers decreased by 9%.](#)

[The improved implementation of signatory contractors’ safety management systems aligns with a decline in the overall incidence rate for the NSW construction industry from a ten-year high of 58.0 per thousand workers in 1995/96 to 39.9 in 1999/00, a reduction of 31%, and a decline in the subcontractor Special Trade Construction category since 1998.](#)

[The NSW research suggests that the major drivers of change in occupational health and safety management have been: increasing legislative obligations and changes to workers compensation payment and levy systems; client pressures especially government procurement requirements; and parent company pressures. Other key best practice initiatives identified by the report include the “regular appraisal and verifiable review of ‘actual’ work practices against documented safe work procedures”. This latter aspect is a key element of the new PQC requirements.](#)

THE PQC REQUIREMENTS

The Department of Public Works undertook a review of the PQC System in 2000, in consultation with industry and government stakeholders. [The review](#) acknowledged the final report of the Industry Taskforce and [concluded that the PQC System should support initiatives to improve standards of occupational health and safety, industrial relations and training in the building and construction industry and more closely link contractor compliance in these areas with access to government building projects.](#)

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The Department of Public Works partnered with Workplace Health and Safety Queensland (Department of Industrial Relations) and industry stakeholders including the Queensland Master Builders' Association and Construction Forestry Mining and Energy Union to develop the new model and supporting systems and tools. The model for the new occupational [health and safety](#) requirements for contractors under the PQC System may be considered in two parts as follows:

- a prequalification OHSMS requirement; and
- a project specific requirement that includes the assessment of Construction Workplace Plans and Site Inspections.

PREQUALIFICATION OHSMS REQUIREMENT

Over time, all prequalified contractors will be required to have a documented, implemented and maintained OHSMS in order to be eligible to tender for government building projects invited under the PQC System.

Contractors are free to choose the type, format or style of their OHSMS but, in order to meet the prequalification OHSMS requirement, it must as a minimum, satisfy the OHSMS criteria set out in *Australian/New Zealand Standard AS/NZS 4801:2001 Occupational health and safety management systems – Specification with guidance for use* as determined by a third-party certification body or an Accredited Provider (PQC (OHS) Auditor) appointed by Workplace Health and Safety Queensland.

The *Workplace Health and Safety Act 1995* makes provision for the chief executive of the Department of Industrial Relations to appoint accredited providers. A pool of PQC (OHS) Auditors has been established to carry out the functions of OHSMS audits, the assessment of Construction Workplace Plans and Site Inspections. Workplace Health and Safety Queensland will monitor their conduct and performance.

PROJECT SPECIFIC REQUIREMENT

The project specific requirement applies on government building projects with an expected minimum construction period exceeding 16 weeks. When a prequalified contractor is awarded such a project, it will be contractually required to engage a PQC (OHS) Auditor who will assess the contractor's Construction Workplace Plan, inspect actual construction activities against set criteria and report back to the contractor and the administrator of the PQC System.

The *Workplace Health and Safety Regulation 1997 (Qld)* requires the Principal Contractor to prepare a Construction Workplace Plan. The Construction Workplace Plan provides an important link between the contractor's OHSMS and actual

construction activities as they occur on the project. The PQC (OHS) Auditor will conduct an assessment of the contractor's Construction Workplace Plan and provide a report to the contractor that will indicate any areas of the Construction Workplace Plan that do not adequately address the criteria. The contractor must rectify any non-conformances to the satisfaction of the PQC (OHS) Auditor.

The PQC (OHS) Auditor will also conduct an inspection of the contractor's actual construction activities once for every 13 weeks of the expected construction period. The number of inspections required for any particular project will be specified in the tender documentation. The timing of each Site Inspection will be determined by the PQC (OHS) Auditor based on the type and level of activity outlined in the program of works.

The Site Inspection will focus on the contractor's management methods and performance in controlling risks associated with construction hazards contained in a Site Inspection Checklist which has been developed in consultation with the industry stakeholders.

The output of the inspection process is a Site Inspection Report that will highlight any areas of non-conformance against the items in the Site Inspection Checklist. The PQC (OHS) Auditor will also formally request that the contractor rectify any non-conformance via a Corrective Action Notice.

Copies of the Site Inspection Report will be provided to the contractor, the Contract Superintendent/Principal's Representative and the administrator of the PQC System. The contractor will be required to action any Corrective Action Notices within an agreed timeframe.

Any non-conformance reported by the PQC (OHS) Auditor during a Site Inspection will attract demerit points. If the number of demerit points on any one inspection exceeds a set limit, the inspection will be deemed to have been failed and a follow-up inspection will be ordered at the contractor's expense. Any failed inspection may also result in a sanction being applied to the contractor under the PQC System. Such sanctions range from a formal warning to, in the worst of cases, the cancellation of a contractor's registration.

CONCLUSION

The new occupational health and safety requirements for prequalified contractors are to be implemented progressively during 2004-2005. At the time of writing, however, it is too early to assess their impact and effectiveness. The initiative seems to be well received by most elements of the industry with many enterprises taking the opportunity to implement or upgrade their OHSMS. The impact on SME's is being closely monitored.

The important issue to be communicated to industry is that the rationale for the new requirements is to ensure that contractors have an implemented and maintained OHSMS in place and not just to satisfy another government requirement. This level of understanding is fundamental for both contractors and auditors and if achieved, should result over time in steady improvements in health and safety performance.

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CONFERENCE THEME - INTERNATIONAL INNOVATION

Case Study

GREENSMART HOUSING VILLAGE – INNOVATIONS AND LESSONS

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ABSTRACT

Three innovative residential houses built in Springfield Lakes 28 km SW of Brisbane have succeeded in setting a new benchmark for project house construction. Innovation, through passive design for small lots, rainwater capture and use, energy and water efficiency and inclusion of many simple design initiatives that improve social outcomes, have all set these project homes at the leading edge. This case study paper describes the design processes of the houses and their cost / benefit assessments for their key energy and water initiatives and social inclusions (safety, security and universal design) as well as the lessons learnt from the design and construction processes.

Keywords: residential houses, small lots, rainwater tanks, smart housing, cost / benefit assessment

1. INTRODUCTION

Three display houses at Summit Drive, Springfield Lakes were constructed on lots of varying area (332m², 415m² and 785m²) and were completed in early March 2004. They were the result of approximately 14 months of planning and construction and were to include passive design, “off the shelf” products, water and energy efficiency, minimum site disturbance and good site management. The houses were to also incorporate new and appropriate technologies (e.g. smart wiring, smart meters, and a solar ventilator)

The houses are the second HIA GreenSmart Village in Queensland with the first being completed in 2002 at North Lakes, 25 kilometres north of Brisbane CBD. This Springfield Lakes project was the result of a partnership team consisting of:-

- WESLEY MISSION under their “Homes for Hope” program - Project Manager
- HOUSING INDUSTRY of AUSTRALIA (HIA) – GreenSmart initiative
- DELFIN LEND LEASE - Developer
- CIVIC STEEL HOMES – Designer and Builder of all 3 houses
- DEPARTMENT OF HOUSING, ENVIRONMENTAL PROTECTION AGENCY and DEPARTMENT OF FAMILIES – State Government sponsorship
- IPSWICH CITY COUNCIL – Local Government Authority
- CRC-CI (Cooperative Research Centre for Construction Innovation) – scholarship support for research of the GreenSmart housing village
- CSIRO – technical support
- SUPPLIERS & TRADES – products and services were donated or substantially discounted

2. DESIRED OUTCOMES

Each of the houses strived to achieve the following outcomes and employed where possible, the detailed strategies to meet this end:-

2.1 Overcoming summer heat

Strategies – addressing house orientation to true north – insulation (roof, ceilings, walls) – eaves and overhangs – shading (external structures, other buildings) – windows (location, size, treatment, protection) – roof and external wall colours and materials – ventilation – room zoning – thermal mass

2.2 Overcoming winter cold

Strategies – addressing house orientation to true north – insulation (roof, ceilings, walls) – eaves and overhangs – windows (size, location, treatment, protection) – weatherproofing – room zoning – thermal mass

2.3 Achieving energy efficiency

Strategies – compact fluorescent lights – efficient 12 volt task lights – dimmers – smart sensor lights – natural day-lighting – high star rated whitegoods – smart meters to show energy use – solar or instantaneous gas hot water systems

2.4 Achieving water efficiency

Strategies – 3A or 4A rated whitegoods, shower roses and tap-ware – dual flush toilets – mixer taps in showers and baths – well mulched native plants – limited lawn – rainwater tank(s) for house and garden use incorporating water quality design – smart meters to show water use

2.5 Minimise long-term maintenance costs

Strategies – use of good quality materials, paint and finishes – hardwearing floors and coverings – use of galvanized steel framing and light organic solvent preservative (LOSP) treated timbers

2.6 Adaptability for changing needs

Strategies – level door entries – hobless showers – location and size of power points and light switches – wider door and hall ways – lever or D-shaped handles – rounded bench tops – availability of communication points – open plan living – areas for home office or bedrooms – safety and security inclusions

2.7 Achieving good air quality

Strategies – non-toxic paint – low formaldehyde carpentry – non-toxic timber finishes – natural product blended carpets – good ventilation

It was anticipated that all the above outcomes and strategies, when compared to current housing approaches, would result in –

- Better comfort and quality of life (without retrofits)
- More disposable income for the occupant(s) each year due to reduced operational and retrofit expenses
- Adaptable homes that are “easier to sell”
- Future proofed homes that will increase in value above the current average

NOTE - All future Queensland houses are likely to require energy and water efficient features as standard and so, like cars, resale houses will most likely need a “house-worthy certificate” before listing. Energy ratings are already required for resale in Canberra. Victoria has adopted 5 star rating for all new housing (http://www.buildingcommission.com.au/asset/1/upload/media_release_5_star_30_June_04.pdf) and New South Wales are introducing a legislated building approval environmental and social checklist for all future houses (<http://www.iplan.nsw.gov.au/basix/>).

3. COSTS OF DESIRED OUTCOMES INITIATIVES

A summary of some key costings for the three houses is given below. The results should be considered indicative and it must be emphasized that this information is based on these particular house designs, their inclusions and current pricing –

- The average cost of the passive design elements (insulation, glazing, higher ceilings and shading) was 2.4% or \$6,250 of the total house costs. Offsetting this were annual savings of \$523 compared to conventional approaches, if adopted for the houses
- The average cost of the energy efficiency elements (lighting, fans, appliances and water heating) were 1.0% or \$2,610 of the total house cost. This did not include the photo-voltaic cells which cost an additional 2.2% or \$7,350 of the largest house cost

- The average cost of the “smart housing” design elements was 0.2% or \$582 of the total house costs
- The cost of rainwater tanks, water quality devices, and pumps for whole of house supply was 2.3% or \$6,300 of the total cost of the 2 houses on which they were placed. The quality of water supply can be maintained at safe levels with currently available devices and minimum maintenance
- The payback periods for
 - o passive design (insulation, glazing, higher ceilings, shading) – 12 years
 - o Energy efficiency (lighting, fans, whitegoods) – within the first year
 - o Water heating (2 x solar, 1 x instantaneous gas) – 7 years
 - o Water efficiency (AAA shower roses & taps, dual flush toilets, AAA+ whitegoods) – making savings from day 1
 - o Water supply for the whole house (i.e. tanks, water quality devices, pump, irrigation) – does not currently have a payback period
 - o All combined initiatives including rainwater supply systems – 12 years
- Insulation was 5 times more cost effective than glazing treatments (i.e. tinting, “low-e” glass and films)
- Annual predicted reduction of 4.3 tonnes of Greenhouse Gas (GHG) for operational costs from each house
- Good site and waste management during construction saved \$100 per house
- There was no additional cost for superior air quality as a result of using non-toxic paint and very low toxicity floor and timber finishes

4. PROJECT INNOVATIONS

4.1 DESIGNS ON SMALL LOTS

Orientation for two of the lots (areas and widths being – 332m² and 10m – 415m² and 12.5m) was rotated to within 20 degrees of true north, thereby giving better solar access. Fortunately this was possible before the final survey plans were lodged at Council by the developer. For narrow lots, a north-south orientation is usually the optimum because it allows for northern zoning of living areas and uses the close proximity of adjoining housing as summer shade for the eastern and western walls. It is generally less feasible to incorporate northerly solar access along the longer side boundary due to the close proximity of the adjoining house.

For small narrow lots, the influence of adjoining housing is huge and if not known at the design stage needs to be predicted. Adjoining lot widths, identified zero lot line boundaries and the developer covenants were influential in these small lot house designs. Insulation, glazing, through-flow ventilation and the installation of fans in the living area and bedrooms were all critical elements for achieving good thermal comfort. The house design on one lot incorporated a covered double car

garage in a tandem formation with 50% of one side being open to the entry courtyard for the house

The sloping land (1:8, 12% or 4m drop over 33m) resulted in the design adoption of a small amount of concrete slab combined with elevated floors, to minimise earthworks and site disturbance. The elevated floors provided space below for the location for rainwater tanks and possible future storage.

4.2 ACHIEVING WATER EFFICIENCY

A 74% saving of an average home's water requirements are predicted through the combination of rainwater tanks, efficient devices and appliances and appropriate landscaping.

4.2.1 Rainwater tanks

Two of the display houses (lot 894 and lot 895) have 12,000 litres of rainwater storage each, in two 6,000 litre squat polyethylene tanks located under their back "summer room" decks. This tank water is pressure pumped for all internal and external house uses. This is *UNIQUE* for any residential display home in Queensland.

Four main issues needed to be addressed:-

Water Quality - There were several components involved in maintaining water quality:-

- Pre-painted steel roofing and guttering, being stable inert provided a safe collection surface
- Gutter guards and rain heads on downpipes provided filtering of most objects and the rain heads included screens to keep out mosquitoes
- First flush devices to remove small impurities which would build up on the roof and in gutters between rain events. These were sized to allow for about 1mm of rain to flush the roof and gutters. The first flush devices were placed underground thereby creating "dry systems" – this was made feasible because of the sloping lots
- Drinking quality standard and chemically stable polyethylene tanks
- A carbon filter was placed on the cold water tap in the kitchen to provide better tasting drinking water
- On-going maintenance would include "bottom of tank" flushing (every 10-15 years), regular checking of gutter guards, rain head screens, first flush device outlets and pump operation with the replacement of pump when necessary

Guarantee of supply – the unique pumping system uses a seamless switching process to allow pressured town water to bypass the tank water system when there is a power failure, pump problem or the level in the tank reaches a pre-set low threshold. The system returns to tank water once the level rises above the minimum threshold. This guarantees supply as well optimizing tank water use

Local Authority approval – the unique pump switching system incorporates a backflow prevention device but the Ipswich City Council also requested another backflow prevention device (dual check valve) at the property boundary.

Council considers tank water as a low hazard (class A) quality as they have a large number of households in their jurisdiction for which stored rain water is their only supply.

Costs – there are two main costs – the initial system components and the on-going pump energy, system maintenance and replacement costs. The system components were \$6,300 (gutter guards, rain heads, first flush devices, tanks, pump, switching device and additional labour) with predicted annual electricity and maintenance costs of \$98 and water cost savings of \$81. Obviously, significant subsidies and mandating by governments and/or developers are required to support broad-based introduction of effective rainwater tank systems.

4.2.2 Devices and Appliances (internal features)

The first two of these are essentially standard in all new houses:-

- AAA shower roses and taps
- Dual flush 3/6 litre toilets -
- Flow restrictors and aerators for selected taps and mixer taps for long flow situations
- 3A or 4A whitegoods (washing machines and dishwashers)

4.2.3 Appropriate landscaping

- Well mulched native gardens with little or no lawn
- Pumped sub-surface irrigation with an automatic controlled irrigation system.

NOTE - it was envisaged that selected greywater (showers, basins and washing machine) would be kept available for sub-surface use when legislation allowed. Plumbing for this direct dispersal was incorporated in each of the houses and so remains an option for the future.

4.3 “SMART HOUSING” DESIGN FEATURES

(responsive to people’s housing needs during their life – “ageing in place”)

Each of the three display homes incorporate these simple, minimal or zero additional cost initiatives:-

- Wider door and hall ways
- Level thresholds (floor), where possible
- Hobless showers
- Lower light switches and higher power points (both large rocker style)
- Lever or D style door handles for doors and drawers
- Logical layouts with kitchens not used as thoroughfares
- Outside venting of range-hood and refrigerator
- Compact fluorescent lighting and efficient 12 volt task lighting where appropriate
- Water and energy efficient appliances and whitegoods

- For SAFETY & SECURITY – large visible street number, well lit and street visible door entrances, security glass and visitor viewing at a solid core front door, locks on windows and doors – keyed alike, catches for swing doors, hard wired smoke detectors with battery backups, lockup cupboards for poisonous products, adequate storage to prevent clutter, visible children's play areas away from driveways, no poisonous landscaping, sturdy, narrow and vertical balcony railings

Lot 896 was specifically designed to be accessible for people with a range of abilities (wheelchair). Key additional design elements for this house were:-

- a ramp from the street (accessible paths)
- easy access from the garage into the house – special wide sliding door
- easy access to main toilet
- reinforcement in the bathrooms for future grab rails
- lower benches and vanities with access under for sitting position

The Queensland Department of Housing's web site is available for a comprehensive list of all universal design, safety and security inclusions (http://www.housing.qld.gov.au/builders/smart_housing/index.htm).

5. LESSONS LEARNT

5.1 Possibly the most significant yet subtle lesson – there is no perfect house for a particular block -

There are always conflicting design elements to rationalize (e.g. shaded outdoor living and solar access – views and glazing exposure — car access and house zoning – ventilation and privacy). There are many variables to balance but an open minded, ethical, educated, “do the best you can” approach is going to lead to a great outcome, from which one will no doubt still learn.

5.2 Preparation of a simple “services plan” would have identified problems -

This was not done for the display houses but would have been an ideal tool to draw attention to the locations, linkages and then possible problems for installing the smart meters, rainwater systems, hot water systems, photo-voltaic cells and landscaping. It would have focused all those concerned on the concepts and interconnection seeking to be achieved. Most sub-contractors (plumbers, electricians, and landscapers) literally construct to or modify the plan or system on site as they go. With any new process there are always challenges and better planning via a services plan would provide the shortcut and minimise problems

5.3 Car access onto sloping lots needs a conservative approach -

The car access onto lot 896, while complying with the statutory code, appears or feels too steep. In hindsight, the floor level of the house could have been raised for minimal additional cost. It should be noted that the design was based on engineering design levels as the road was not constructed when the design was substantially completed but a conservative slope calculation would have overcome this steep access problem

5.4 Various passive design elements were considered a high priority for thermal performance but additional simulations showed their interrelated importance was mixed -

After completion of the houses, many subsequent thermal simulations showed that some marginal improvements in annual energy use could be achieved by changes contrary to the normal passive design strategies. All houses were well insulated and ventilated to combat summer heat but insufficient passive solar heating was available during winter. Each house required significantly more winter heat energy than summer cooling energy and removal of some glazing treatments to northern facing windows would have improved passive winter heating. Not venting eaves would have reduced the energy required during winter. Annual energy use would have reduced slightly with use of dark roofs and external walls in some instances. Reductions in the large expanses of living area windows would have certainly reduced the need for expensive glazing options to achieve low annual energy use. This would be a compromise with architectural and aesthetic decisions. For project home builders it is not practical to carry out simulations of the countless inter-related options for every house but achieving an honest 4 or 5 star rating would ensure a good thermal result

5.5 Windows and glazing treatment impacts and costs need to be carefully monitored -

Window treatments are expensive and could be offset with different window sizing, placement and additional external shading. There was a premium paid for the glazing treatments ("low-e" glass and films and tinting) which positively assisted the energy ratings for the three display houses. A significant price reduction could have been achieved if there was some reduction of the large window areas, glazing treatments were applied to selected windows only and additional external protection was added to some windows.

5.6 Adjoining buildings are influential on house design and need to be taken into account -

Having three houses adjoining gave control over their relationships but the designs on either side were not known. Shading influences and privacy issues from adjoining buildings need to be predicted and planned for in each house design

5.7 New products are continuously appearing in the marketplace and need investigation -

Time to thoroughly investigate some new products would have allowed some better results from different product selection. Sponsorship restricted some choices

5.8 The size, style (wet or dry system), supply requirements and location of rainwater tanks and first flush devices should be included with the early house design -

This was not the case with the display homes as the rainwater tanks were an evolutionary process but it would have been beneficial. Initially the tanks were to be for garden use but this was upgraded to whole house use. With the end in mind, planning and integrating a rainwater system would present minimal problems, especially with a plumber's early involvement

5.9 Sloping sites provide the opportunity of "dry systems" for roof water -

The three display houses initially had "wet systems" (water remaining in underground piping after rain). These were converted to "dry systems" with the

first flush devices being placed underground at the tanks and ultimately being drained to the rear of the properties. This was only possible because of the sloping sites. This “dry system” reduced the amount of water needed to be flushed

5.10 Rain-heads on downpipes should be placed for easy cleaning and inspection -

This was the case for a few of the rain heads but many could have been located close to ground level for practical future maintenance

5.11 Non standard landscaping elements need close supervision -

Landscaping detention ponds were placed within the rear gardens of each of the three houses but their effectiveness was compromised because the contouring did not focus overland storm water towards the ponds. The landscaper and the plumber both needed to fully understand the proposed concept before its construction. Time pressure to complete the landscaping was also an influence

5.12 Signage is important to convey the education message -

The signage in and around the display homes appears to be limited given the background information and new products included in the houses. Additional signage may have been appropriate

5.13 Energy and water efficiency inclusions are becoming standard while universal design elements need to be further promoted -

Talking to product suppliers and trades people during the construction process revealed a reasonable understanding of energy and water efficiency products and their purpose but “smart” housing and universal design elements were not well understood or appreciated. This is probably indicative of the general public’s perception of these initiatives and shows that more education is required for their better acceptance

5.14 Good communication leads to better understanding and less problems -

This is an obvious statement but with the new processes and products involved in the three display homes many problems were discovered and solved early but many could have been avoided with more initial communication. The construction process occurred during “boom” conditions and so many other pressures also hampered communication. For new products and processes there is a process of education which is one of the main purposes of the houses

5.15 The most cost effective additions were -

- Passive design elements – solar orientation, window size and location, external shading (eaves), insulation
- solar hot water
- resource efficiency elements – water (3A & 4A products and appliances, flow restrictors); energy (lighting, fans, 4 & 5 star rated appliances)
- smart housing elements (wider doors and hallways, level entry thresholds (all doors and showers), lever door and tap handles, safety and security design approach)
- non-toxic paint and timber and floor finishes

5.16 The least cost effective additions were -

- Window treatments – low emissivity glass or films or tinted windows. These products do become useful if large expanses of glass are desired or if direct summer sun on windows, especially western, can not be avoided. Special glazing treatments can be avoided or minimised with careful window design and external shading
- Rain water tank systems – given present water pricing, the additional \$6,300 for this whole of house system will not be adopted by choice. Government, developer or even builder incentives (rebates, subsidies, covenants, policies, legislation) are required to instigate the broad scale adoption of rain water tanks. For effective use, storage of at least 10,000 litres should be adopted and a system installed to ensure the water gets used.
- Photo-voltaic roof panels – this product could be greatly reduced in price via a corresponding increase in its demand, which could be government and/or developer driven.
- Automatic irrigation systems – use of controllers to automatically trigger pumping to the underground dripper system could have been replaced by a manual system incorporating a self timer. This would also require the occupier to remain in-tune with the garden status
- Higher ceilings – with a current additional cost of \$30/m², this element may questionably be deleted with minimum decrease in thermal comfort but attention to through-flow ventilation becomes critical. In two of the display homes, higher ceilings were an integral part of their design

5.17 Site management success is directly related to builder attitude -

Site management was an important element that did not have a significant financial return but rather environment and social returns. The intent of the site management plan was for 80% of building waste to be recycled, the three sites to remain clean, tidy and safer during construction, silt and erosion to be managed and delivery locations and site entries to be used and monitored. These were all addressed with varying degrees of success with the conclusion being that their effectiveness and success is directly related to the attitude of the builder.

5.18 There are no official indicators for assessing how good or bad a house may be relative to an agreed benchmark and the marketplace needs the feedback for effective change -

There are national energy rating tools and various recommended strategies for residential house design to move towards sustainability but Queensland does not have a legislated measuring indicator to consider the environmental and social impacts of houses. The Sustainable Housing Code (SHC) is an on-going draft option which is taking a long time to evolve and which appears to have thresholds that are set too low

6. CHECKLIST - INDICATOR

An assessment of each display home using the Sustainable Housing Code version 8 (SEQROC 2004) criteria was completed with results shown below (Table 1). All of the display homes satisfied the “graded points” requirement (Table 2) such that the ultimate level set for 2013 was easily reached. This fact may indicate that the scale of the assessment has been set too low for conventional project housing.

LOT	LOT AREA m2	HOUSE GFA m2	REQD POINTS	SOCIAL (blue)	ENVIRO (red)	TOTAL
894	785	271	18	25	36	61
895	415	218	14	16	23	39
896	332	154	14	36	19	55

Table 1 – Display home results for the Sustainable Housing Code (version 8)

SUSTAINABLE HOUSING CODE MINIMUM POINTS REQUIRED			
YEAR	GFA OF HOUSE		
	<130M2	< 260M2	> 260M2
2005 – 6	10	14	18
2007 - 8	12	16	20
2009 – 10	14	18	22
20011 - 12	16	20	24
2013 +	18	22	26

Table 2 – Sustainable Housing Code (version 8) graded points requirements

Department of Housing’s “Smart Housing” and the HIA’s “GreenSmart” criteria are guidelines and do not result in a points assessment or measurable indicator. As such they do not give any feedback on “how good” the house may be in its resource efficiency and minimizing its impacts.

There is an urgent need for an indicator for Queensland houses. At present there are only the lowest standard Building Code of Australia (BCA) requirements which relate to minimum building materials, processes and initial energy efficiency standards. To lift Queensland’s new residential housing towards a “Smart” status, a tool is required which can at least give an indication of a building’s environmental impact, resource efficiency and livability.

7. CONCLUSION

The main conclusion derived from the three display homes is that incorporating all the above described inclusions and resource efficiencies does have additional cost (average 6.7% over the three houses) but pays for itself within 12 years. This additional cost and payback period could be substantially reduced with elimination or modification of the more expensive elements.

Good house design that reduces environmental impacts and resource consumption is more a matter of common sense and commitment to a better result, than technical know-how. Project houses can achieve 4 or 5 star ratings with relatively small additional cost which would payback in a few years. The creation of these resource efficient houses will be a result of public education, government prodding and critically, industry will.

The three Springfield Lakes display homes are good examples of thermally comfortable, energy and water efficient project housing in the middle to upper price range, constructed on sloping land in sub-tropical south-east Queensland.

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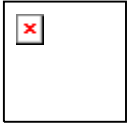
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Queensland Sugar Limited

Conference Paper

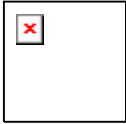
Report

November 2004



Contents

1.	Introduction	3
2.	Development of Project	5
3.	Controlled Risk Approach to Design	7
3.1	Desire for Change	7
3.2	Project Objectives	7
3.3	Geometry and Layout	8
3.4	Foundation Improvement	9
3.5	Floor Slab	9
3.6	Roof Design	10
3.7	Conveyor Systems	10
3.8	Fire Protective Services	11
3.9	Storm Water Drainage	11



1. INTRODUCTION



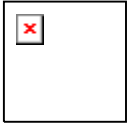
Raw sugar in Queensland is produced from sugar cane grown on farms which stretch along 2,100 kilometres of Australia's eastern coastline. The cane harvest on the approximate 6,500 cane farms (approximately) begins in June of each year and normally finishes in November, depending on seasonal conditions.

The harvested cane is transported by road or a network of cane railways to where it is crushed by one of Queensland's 25 sugar mills. The raw sugar is then transported by road or rail to one of seven Bulk Sugar Terminals to await shipment or directly to Australian customers for refining.

Queensland Sugar Limited (QSL) with its head office located in Brisbane is the exclusive marketer of the State of Queensland's annual raw sugar production. Each year, the company sells the state's entire raw sugar production on behalf of Queensland's cane growers and mill owners to customers in Australia and around the world. QSL is a company limited by guarantee, owned by the growers and millers of Queensland.

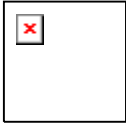
The bulk sugar terminal network plays a key role in the high level of service provided to customers. Queensland is a leader in the bulk handling of raw sugar with some of the largest, most advanced bulk storage and handling facilities in the world.

The seven terminals are located at Cairns, Mourilyan, Lucinda, Townsville, Mackay, Bundaberg and Brisbane and are specifically designed to receive, store and out-load raw sugar to domestic and export markets. Given the limited harvesting period, the 2.4 million tonnes



storage capacity of the seven bulk sugar terminals enables Queensland Sugar to schedule customer deliveries year round.

Sugar Terminals Limited (STL) owns the seven bulk sugar terminals which have been constructed and financed by the sugar industry. STL represents the owners who are either Queensland cane growers or Queensland mill owners. Trading in STL shares is restricted to industry participants. QSL manages the terminals under a leasing arrangement with STL.



2. DEVELOPMENT OF PROJECT

There had been no increase in storage in Queensland in line with the production growth that occurred in the 1990s, and as a result the proportion of the total raw sugar production which could be supplied outside of the crushing season had been reduced. This reduced supply flexibility had constrained the industry's approach to marketing and had changed the nature of the marketing package offered to many customers.

This led to change in the marketing strategy to respond to logistical considerations (i.e., the need to move sugar early), rather than in response to customer requirements.

Without additional supply flexibility, Queensland was constrained to selling a larger proportion of production as it was produced and not at a time of the industry's choosing. The change in structure of the world market over the past 13 years has seen the production of almost 70% of world sugar for export in the second half of the year. The major proportion of Queensland production was entering the market place at a time when competition for destinations was at its height. In this environment the Queensland industry risked securing insufficient outlets to move the required volume of sugar by the end of the crushing season.

There was a wide range of alternative storage possibilities available to the industry to achieve a more flexible supply regime. The possibilities included permanent storage solutions such as traditional facilities, temporary storage such as storage "under canvas", storage at mills and storage at regional hubs or at customers.

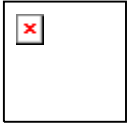
A review team was established by QSL in February 1999 to examine alternative storage solutions in Queensland. The team identified and evaluated 47 options before producing a short list of five which met all evaluation criteria and had the lowest comparative cost rankings compared with the traditional design and cost structure.

Of the options considered, increased port storage was found to provide the most cost-effective means of providing additional storage capacity. Construction of additional capacity at mills was found to have relatively higher cost structures than would port-based storage to achieve the same storage capacity.

Additional storage capacity to enable delivery in the non-crushing season would enable the industry to maximise the benefits flowing from the co-ordinated sale of Queensland's raw sugar.

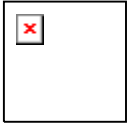
Townsville was chosen because of all the terminals in Queensland, Townsville had the greatest strategic requirement for more storage capacity. Townsville had significant scope for further expansion in its supplying districts and the terminal had the highest stock turnover ratio of 4.5:1 (1,300,000 t production: 290,000 t storage). The development of an additional 400,000 tonnes of storage at Townsville provides increased supply flexibility at this terminal as well as to the network as a whole.

In December 1999 expressions of interest were called for the design and construction of a 400,000 t storage facility situated on available land within the original terminal's lease. After



assessing the expressions of interest, concerns were raised with respect to the impact of such a large building given the urban development adjacent to the port and the city's urban renewal project.

It became obvious that it would be impractical to build the new facility on the available land. With the assistance of the Townsville Port Authority and agencies of the Queensland Government an alternate site was identified. This site required the amalgamation and modification of five different properties having four separate owners. Given the obvious complications, it was decided that the quickest way to deliver the project would be for QSL to progress the design phase whilst land tenure was secured. STL appointed QSL as its agent to deliver the additional storage. QSL appointed GHD as its Engineer.



3. CONTROLLED RISK APPROACH TO DESIGN

QSL went to pains to develop a relationship with their project consultants (particularly the designer) which enabled a culture of complete openness to pervade the design environment. At every step of the design process, GHD gave feedback to QSL, QSL digested and understood the issues surrounding the design, and in an informed manner provided direction back to GHD on the basis of a balanced risk assessment.

Some of the design solutions arrived at would not have been possible in an environment of total reliance on the designer's judgement. By assuming ownership of the technical risk (rather than assuming it was transferred on appointment of the designer) as well as making strategic project decisions, "best for project" solutions came to the fore. This is the desired outcome within an Alliance project framework, however was facilitated in a "traditional" consultant-owner relationship through QSL's careful but wholehearted involvement in the decision making process.

Following is a description of a number of the technical solutions achieved through this relationship process. It is demonstrative of the outcomes possible when clients understand and embrace their ultimate ownership of project risk.

3.1 DESIRE FOR CHANGE

QSL approached this project, looking for quantum improvements in the unit cost of handling bulk sugar.

Utilising the project team's combined experience in handling a wide range of materials, available technologies that could be adopted from other industries were identified and assessed. This work centred around the use of automated mechanical reclamation machines for the outloading of sugar.

Based on this comprehensive review, it was demonstrated that the current material handling techniques employed by QSL were the most cost efficient, and possessed a more attractive risk profile. It was found that:

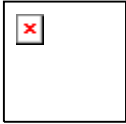
- Initial capital cost would be in the order of \$10-15M more than a traditional retrieval system (including building costs).
- There was a risk of product degradation.
- The ability of automated machines to move "hard" sugar was unknown.

The subsequent design was developed with the current means of sugar reclamation as a basis, although subject to continued improvement.

3.2 PROJECT OBJECTIVES

QSL's major design objectives for the project were as follows:

- Create 400,000 tonnes additional raw sugar storage;



- Create storage for at least 5 separate stockpiles of sugar of different “brands”;
- Facilitate the blending of sugars from any of the independent stockpiles;
- Increase the terminals in-loading rate to 1,800 tph;
- Increase the terminals out-loading rate to 2,800 tph .

Other important requirements of the project included:

- Ensuring the new storage facility be no higher than the existing storage buildings within the Townsville Bulk Sugar Terminal;
- Creating physical linkage between the new storage and the existing storages, both for materials handling and for vehicular and pedestrian movement;
- Improving efficiency in sugar handling, particularly in out-loading,
- Control of mechanical equipment through the existing Terminal Control Room.
- Minimising impacts to the community and environment.

3.3 GEOMETRY AND LAYOUT

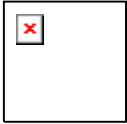
The geometry and layout of the TBST had to achieve each of the client’s objectives, with the primary challenge being the creation of a design that satisfied community and town planning concerns.

The Townsville CBD and tourism precinct is immediately to the west of the current terminal and the original QSL site for the expansion project. QSL and other stakeholders examined the potential of alternative sites to provide a more socially acceptable location for such a massive development. The chosen site is nestled within the industrial port precinct, on otherwise under-utilised land, but still within appropriate proximity to the existing facilities.

Numerous geometric parameters were analysed to arrive at a cost effective solution that achieved these objectives. QSL was involved at every decision point in the process to ensure the success of the final geometry.

The result was an innovative building layout allowing the TBST to house two adjacent stockpiles under one large over-arching roof. The key advantages of this were:

- Significant reduction in cladding area.
- Blending and recirculation of sugar was facilitated.
- Improved operational efficiencies as layout enabled both stockpiles to be viewed at once and made movement between them easy.
- Roof able to be profiled and aesthetics improved.
- No central drainage required between two roofs (would be needed if stockpiles housed separately).
- Provision for emergency storage in the void between the two longitudinal stockpiles.
- Reduced wind loads at the ends of the building enabled reductions in structural steel quantity.



The appearance of the TBST also played a significant role in securing project acceptance from authorities and community. It was difficult to hide a building 30m tall and covering an area the equivalent of 5 rugby football fields. The single faceted roof design reduced the visual “bulk” of the building. The alternative site allowed GHD to orient the building façade sympathetically to the prevailing vistas available from the CBD and tourism areas.

3.4 FOUNDATION IMPROVEMENT

The economic viability of this project was threatened in early stages when it was found that almost the entire site was overlain with a layer of inconsistent fill over marine sediments. In its natural state this foundation would present problems with settlement and stability beneath the stockpile and walls and would be prone to liquefaction in a seismic event. The conventional treatment for foundations of this nature involves piling the floor yet this is both costly and brings time penalties. To overcome this problem, QSL and their designers went through a process of risk-based evaluation of alternative treatments to identify cost and time effective solutions.

This evaluation revealed that a ground improvement technique known as Dynamic Compaction/Dynamic Replacement (DC/DR) could be used in lieu of piling to provide structural support for the TBST. This technique combines the dynamic compaction of landfill with the reinforcement of foundations (alluvium and fill) by dynamic columns of either sand or stone. Although DC/DR had been used internationally, this project represented its first application in an Australian building construction.

The adoption of the DC/DR technique:

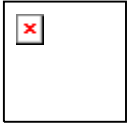
- Saved QSL approximately \$8M over the cost of piling.
- Allowed the progressive handover of the site for building works.
- Overcame the problem of preloading whereby the site is inactive for substantial periods of time.

3.5 FLOOR SLAB

The use of a non-piled foundation had a flow on impact on the rest of the structural design:

- Elastic (reversible) settlement will be a feature of the facility each time the shed floor is loaded with sugar and unloaded;
- Plastic (permanent) settlement during the first loading.

GHD looked at a range of solutions for the storage facility floor, including provision of temporary floor surfacing, conventional concrete, and prestressed concrete. Taking into account the significant settlement movement that the floor would have to endure over its life, a prestressed concrete solution was favoured by QSL. The additional strength, and low thickness of such a slab system, provided the flexibility to move with the foundations without cracking.



3.6 ROOF DESIGN

The roof always represented a substantial portion of the project's total capital cost. QSL recognised that incremental improvements in design efficiency would prove lucrative in terms of total savings.

Wind tunnel testing could be used to predict the wind loads that would be imparted by a cyclone. This would do away with the need to rely on the standardised Wind Code loads, ensuring that the roof structure was not conservatively designed. It was demonstrated that around 10% lower wind loads than specified by the Wind Code would actually occur, and led to savings of nearly \$1M (for an outlay of around \$30k to do the testing).

Durability concerns were overcome by the use of RHS closed truss sections. This eliminated the need for corners and crevices that encourage the collection of sugar dust from structurally important joints.

Mechanical equipment access problems were overcome via an approach that is unique to Queensland's sugar terminals. The space in-between the trusses in conventional "A" frame roof structures used at other terminals for conveyors, was not available in the TBST due to structural limitations of the over-arching roof. Conveyor systems were housed within the truss section to minimise building height and building access ways and maintenance points were also built into the geometry of the trusses. The very long length of the roof also necessitated special detailing of conveyor/structure interfaces to ensure the expansion and contraction of each element was compatible.

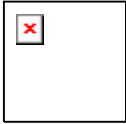
3.7 CONVEYOR SYSTEMS

GHD had to design original in-loading and out-loading systems for the TBST as nominal building size limitations and performance improvement objectives meant traditional methods could not be used. The configuration and system control permits ready "blending" of sugar within the storage, that is, the simultaneous removal of sugar from two or more separate stockpiles, and placement as a blended mix in another.

The in-loading system features reversible travelling shuttle conveyors, so as to eliminate conventional "trippers" which would have increased the overall shed height by another 3.1m. The shuttles are 130m long and consist of eleven modules, and are too long for conventional belt take-up technology. GHD designed a special take-up using helical coil springs.

Another innovation that reduced building height involved conventional flip-flop gates being replaced by pivoting chutes at transfer points where variable feed direction was required. Replacement of the flip-flop gates necessitated the incorporation of a moving head on one of the conveyors and this was achieved via a large pneumatic cylinder.

Traditional methods of sugar reclaim are associated with significant spillage and feed rate difficulties. GHD's innovative out-loading system solves these problems by choke feeding sugar, which virtually eliminates spillage. The system features six mobile hoppers that are positioned under reclaim gates in the floor. Hopper outlets are tapered in the direction of belt



travel and each hopper is slightly higher than the previous unit. This results in the sugar being fed uniformly onto the belt, with almost no spillage or dust generation.

The hopper train is also able to be split to enable recovery of sugar from multiple stockpiles. This gives QSL almost infinite control over the blending operations they might wish to implement to meet their markets.

Each of these innovations was made possible by the close involvement of QSL staff during the design process.

3.8 FIRE PROTECTIVE SERVICES

Sprinkler based fire protective systems that are traditionally used in industrial buildings are expensive due to TBST's building size and layout. The unique fire protection solution provided QSL with an efficient and cost effective solution to fire protection, saving some \$2M from the project budget. The system also provides benefits to the Fire Brigade by enabling fires to be fought from a safe distance, external to the building.

The system features closed circuit cameras and remote operated articulated monitors (water cannons). The strategically placed articulated monitors enable fires to be fought from a safe location while a system of well positioned cameras gives visual feed back to those fighting the fire.

QSL's drive for a cost effective project, and high level of involvement and proactivity, facilitated this innovation. A number of external stakeholders had to be brought into the decision making team, and convinced of the merits of the system, to ensure approval.

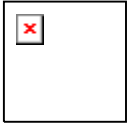
3.9 STORM WATER DRAINAGE

Townsville is subject to tropical downpours and local flooding throughout the wet season. An effective stormwater system for the facility needed to address the following issues:

- Absolutely prevent stormwater from entering the building.
- Pollution control within runoff.
- Greatly increased runoff given the huge expanse of impermeable roof area, compared to the pre-existing condition of the site which was undeveloped (runoff from the roof alone would fill an Olympic swimming pool in around 15 minutes).
- Low elevation of the site, giving limited natural assistance to the removal of runoff.

The stormwater design featured the following innovations:

- The TBST's roof water was kept separate from other site run-off. As the water was essentially clean it could be removed from the site without further treatment and directed into the Ross River with no environmental impact.
- The roof water drainage system was designed as a sealed "pressure" pipe system, so that under normal operating conditions, roof water would back-up the downpipes, providing much



greater “driving pressure” within the pipes. This led to a very substantial decrease in pipe sizes to get the water to Ross River.

- ▶ All other stormwater from ground level was directed through a detention pond between the building and the street. This pond effectively controlled the rate of the water’s release and did not overload the Council’s existing drainage system. It also allowed polishing of water quality, and screening of gross pollutants.
- ▶ The building floor level was established taking account of potential ponding of water on the site, influence of tides on standing water level, and the expected long term settlement of the building.

Lateral thinking in respect of the stormwater drainage identified up to \$300,000 in savings over the cost of a conventional solution.

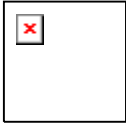
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SCHOLARS THEME

Case Study

CRE WORKSHOP PART 1: COMPREHENDING THE CONTEXT

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ABSTRACT

CRE (Corporate Real Estate) decisions should not simply deal with the management of individual facilities, but should especially be concerned with the relationships that a facility has with the corporate business strategy and with the larger real estate markets. Both the practice and the research of CRE management have historically tended to emphasize real estate issues and ignore the corporation's business issues, causing real estate strategies to be disconnected from the goal and priorities of the corporation's senior management. With regard to office cycles, a large number of econometric models have been proposed during the last 20 years. However, evidence from historical data and previous research in the field of real estate forecasting seem to agree only on one thing: the existence of interconnected property cycles that are concentrated on vacancy rates (demand).

Vacancy also represents the linkage between the inadequacy of existing CRE strategies and the inability of existing econometric models to correctly forecast office rent cycles. Business cycles, across different industry sectors, have decreased from 5-7 years to 1-3 years today, yet corporations are still entering into leases of 5-10 years, causing hidden vacancy levels to rise. Possibly, once CRE strategies are totally in tune with the overall business, hidden vacancy will fade away providing forecasters with better quality data.

The aim of this paper is not to investigate whether and when the supply-side will eventually evolve to provide flexible occupancy arrangements to accommodate corporate agility requirements, but rather to propose a general framework for corporations to improve the decision making process of their CRE executives, while emphasizing the importance of understanding the context as a precondition to effective real estate involvements.

Keywords: CRE, Hidden Vacancy, Office Cycles, System Complexity

1. INTRODUCTION

This research was funded by the Cooperative Research Centre for Construction Innovation, part of the Australian Government's CRC Program.

In many industry sectors today, the leaders of business cannot predict where they will be marketing their products, which business units will be added and which will be sold off, whether they will merge or be taken over by a competitor, or even what the nature of their products will be. However, the long-term nature of real estate commitments restrains the ability of an organization to be agile and ready to adapt to new market conditions (Timm, 2004). While waiting for property owners to come up with more flexible occupancy arrangements, corporations can still improve their real estate decisions in other ways:

1. By understanding the office market in which they operate – external analysis
2. By incorporating CRE strategies in their overall business strategy – internal analysis

Linking corporate property/real estate strategies with the overall corporate strategy is necessary to accommodate changing corporate business needs, but firstly CRE executives need to have a good understanding of the larger real estate market in which their facilities are located. As a matter of fact, *“comprehending the context is a precondition to effective real estate involvements”*. (Roulac 1995, p.499)

Initially an ideal framework in which CRE decisions should be made is proposed and thereafter the mapping of a model for a generic office market is illustrated. While model testing for the Brisbane office market is still underway, structural design and selection of the explanatory variables are discussed in detail.

Demand for office space in a metropolitan area is subject to its economic growth, but identifying the drivers of economic growth is a complex task. There are a large number of interrelated variables to be considered that exist at different levels that sometimes conflict with one another. Those at the local regional (white-collar employment growth, construction costs), and the state (business investment, consumer spending) levels have often been identified as the most influential determinants, but also variables at the national (inflation, interest rates, drought), and even international (oil price, wars, USD) levels should not be overlooked. Having a large number of variables to deal with is not the only challenge, in fact the identified variables are in continuous motion; many are unpredictable – especially those that derive from International geo-political events; and different lag times apply.

The design of the forecasting model for office property cycles is done by joining qualitative data, in the form of the findings of previous researchers, with quantitative data from the Brisbane metropolitan area. Particular attention is also given to the concepts of dynamic complexity and data quality, two issues that previous research has identified among the most difficult to overcome (Phyrr, Born, Manning, and Roulac, 2003).

2. THE CRE EXECUTIVE PERSPECTIVE

Real estate represents the environment in which business operations are conducted and in which different categories of players interact. Customers, employees, suppliers and internal processes are all profoundly impacted by CRE decisions (Roulac, 1995; Apgar, 1995; Timm, 2004). The successful implementation of appropriate corporate property strategies can impact positively on shareholders, internal operations, business opportunities and employee satisfaction, while cheap and delayed real estate strategies will more than likely induce the opposite effects.

A particular perspective for business real estate decisions in a strategic planning context is graphically presented in Figure 1. The diagram shows only two of the CRE strategies that have been identified by previous researchers (Nourse and Roulac, 1993; Roulac 2001; Nourse, 1994), while Table 1 summarizes them all. The arbitrary selection of CRE strategies had to do with the fact that contribution from lower occupancy costs and higher flexibility to corporate competitive advantage seems more direct and easy to estimate than any of the other six strategies. Furthermore, recent research shows that business executives, under pressure to deliver bottom-line results to shareholders, are chasing CRE solutions that allow flexibility and cost reductions. (Timm, 2004)

1. Minimize Occupancy Costs
2. Increase Flexibility
3. Promote Human Resource Objectives
4. Promote Marketing Message
5. Promote Sales and Selling Process
6. Facilitate Production, Operations, Services & Delivery
7. Facilitate Managerial Process
8. Capture Real Estate Value Creation of Business

Table_1. Real Estate Strategies

The big challenge for future research remains to be able to quantify the effects of implementing CRE strategies, in terms of risk reduction and increased net income. A study of the interrelationships that exist between real estate and other corporate infrastructure support groups is currently underway, considering the use of a dynamic balanced scorecard to strategically map and quantify how an organization can create value through the implementation of real estate strategies that are consistent with the organization's strategic goals and vision. The four perspectives – learning and growth, internal process, customer, and financial – identified by Kaplan and Norton (2004) are possibly all impacted by real estate decisions.

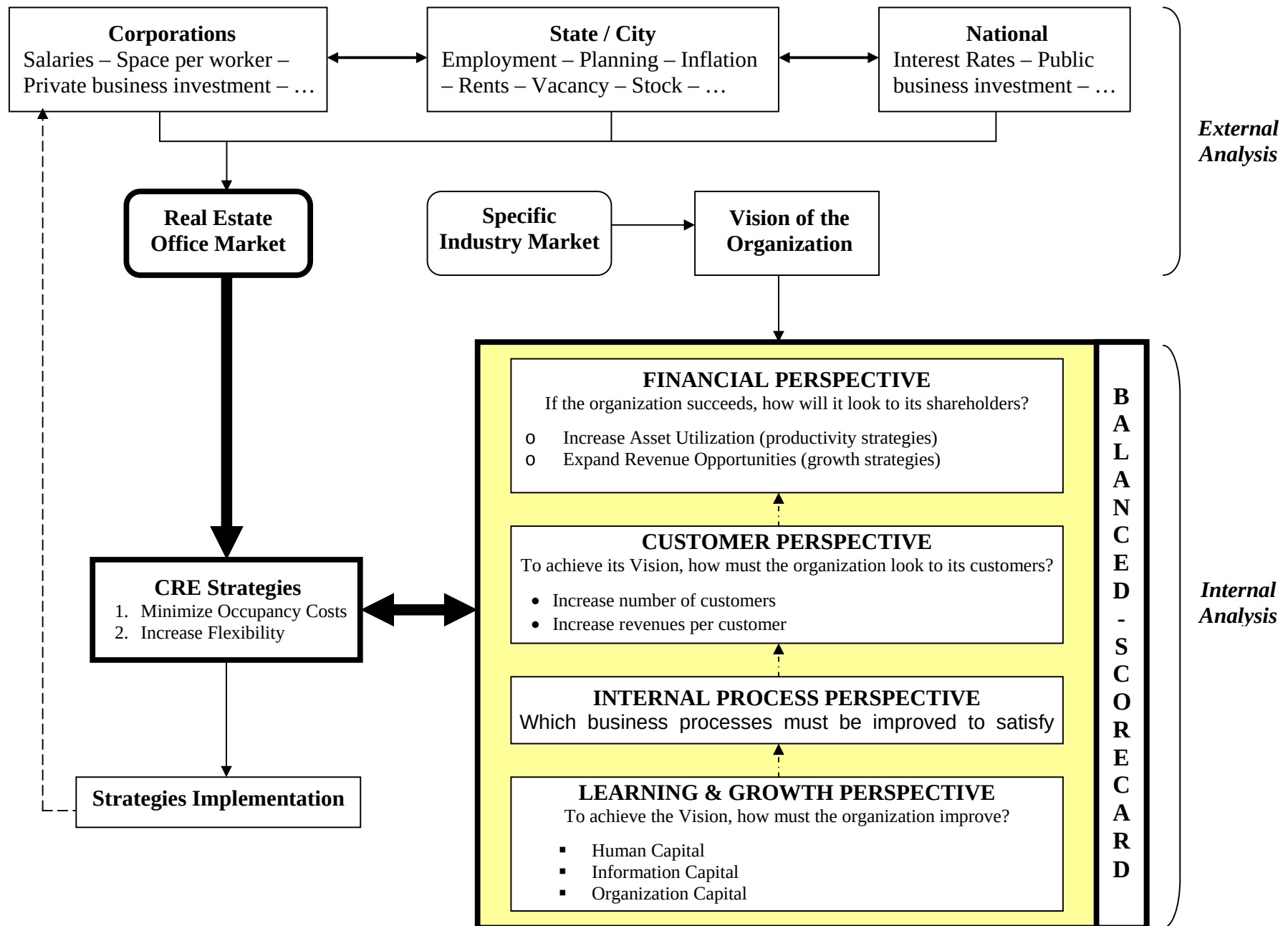


Figure_1. Framework for CRE Strategic Planning

3. UNDERSTANDING THE CONTEXT

According to Lyneis (2000), the use of forecasts in decision-making is inevitable as it usually represents a basis for taking action (DeLurgio 1998). But he also argues that even if the forecasting industry is widespread across different sectors, models generally should not be used for forecasting the future. His view follows that of many others. Forrester argued that “... *forecasting is not an appropriate or valid test for either an econometric model or a system dynamics model*” (Forrester 1980, p.574). According to Greenberger (1976), the first principle of modeling is that “*models are to be used but not to be believed*” (Theil 1971, p.vi.)

The main reason for limiting the use of models to purely forecasting purposes is that forecasts are likely to be wrong as they do make assumptions on historical and future events. As Forrester clearly demonstrated, even an accurate model can produce point predictions that diverge from reality as a result of unknowable random elements impinging on a system (Forrester 1961, Appendix K). Higgins (2000, p.16) pointed to the fact that “... *forecasts based on past and current knowledge are limited, as any unexpected natural, economic and political event can provide unanticipated shocks and so restrict the relevance of past similarities*”.

CRE executives are major players in the office property market and therefore should have a clear understanding of real estate cycles before making any real estate decision. Even if precise forecasts are unlikely, whatever methodology is used, some models can still provide a good understanding of office market interactions, the necessary ground to build up an educated guess of where the market is today and where it is going to be tomorrow.

Before heading into the development of a forecasting model it is important to clarify a few concepts. The causes of failure in forecasting office market cycles are probably many, but two seem to be the main reasons: incompleteness in the model structure and poor quality of the data (Jones, 1995; Mitchell and McNamara, 1997; Tsolacos and McGough, 1999; Mueller, 2002; McFarlane *et al* 2002). If a softer methodology like system dynamics may allow for a more complete acknowledgment of the complexity of the system, data remains a major issue. Many businesses lease office space which is neither occupied nor marketed as available for sub-lease, thus not accounted for in overall vacancy data. Until improved CRE strategies will drastically reduce the ‘hidden’ vacancy level, the demand signal for new office space will not be ‘real’, causing a continuous state of oversupply.

Models from around the world do not even agree on the most basic supply-demand relationship for office space, the reason being that regression models purely rely on historical data, causing different variables to be the most influential for different markets. This inconsistency represents the major challenge in designing a common model that could be easily adaptable to different markets throughout the world. Tonelli, Cowley & Boyd (2004) performed an analysis of most of the existing office rent models that have been developed over the past 20 years. Figure 2 shows the wide array of explanatory variables used by the different authors throughout the years and the frequency of adoption.

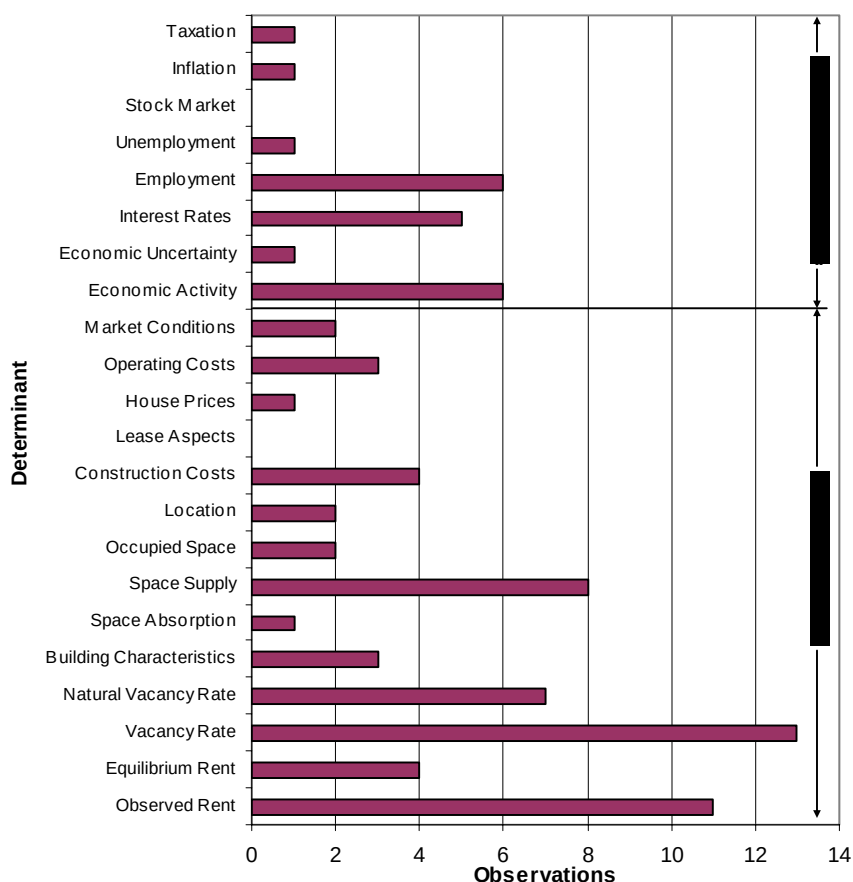


Figure_2. Explanatory Variables – Frequency of Adoption by Researchers

SOURCE – Tonelli et al (2004)

On the other hand, qualitative forecasting uses little or no quantitative information, relying heavily on qualitative knowledge in order to select the determinants and link them together. Statisticians often criticize and/or express doubts towards qualitative approaches. Makridakis *et al* (1998, p.12) emphasizes how *“it is more difficult to measure the usefulness of qualitative forecasts. They are mainly used to provide hints ... rather than to provide a specific numerical forecast”*. However he also argues that *“The big challenge in arriving at accurate forecasts is to utilize the best aspects of statistical predictions while exploiting the value of knowledge and judgmental information, while also capitalizing on the experience of top and other managers.”* In his conclusions Makridakis again emphasizes that *“Judgmental forecasts are indeed indispensable, for they present the only alternative to predicting systematic changes from established patterns and/or existing relationships. At the same time, we must be careful in avoiding the biases and other limitations that characterize our judgment while reducing their negative consequences on forecasting. The challenge is to exploit both advantages of statistical predictions (including their low costs) and the unique ability of human judgment to deal with systematic changes in patterns/relationships which statistical methods cannot predict as they can only extrapolate the continuation of such patterns/relationships. (1998, p.508)”*

4. THE FORECASTER PERSPECTIVE

Acknowledging the complexity of a system is the starting point to move towards the understanding of the interactions of its agents over time (Sterman, 2001). The variables and the relationships necessary to map the office property market within a defined urban area are pretty straight forward. The real challenge instead arises when we look outside of the basic demand-supply loop and we try to forecast demand. Forecasting demand is the real challenge because it is a consequence of economic growth, which is complex, volatile, and often subject to unpredictable events. However, the purpose of this ongoing research is not to forecast economic growth, but simply to identify those macroeconomic variables that, kept exogenous to the model, will still link economic cycles with local property market cycles.

A model like the one described below (Figure 3), which looks at the macro-economy and tries to map and predict its behavior to quantify the effects on the office construction industry within the local market is full of challenges. At a least, model developers would have to acknowledge that a growth in employment would cause greater productivity, which, together with rental growth, would increase tax revenues. An increase in tax revenues would probably induce governments to reduce taxes and/or invest more money in business development. Lower taxes would then translate into more consumer spending and therefore more economic activity, which would then lead to lower vacancy, higher rents and even higher tax revenue. On the other hand, increasing consumer spending would also drive up inflation, which would trigger changes in monetary policy. Higher interest rates will in fact slow down the economy and eventually (2-3 years later) bring inflation back to the target.

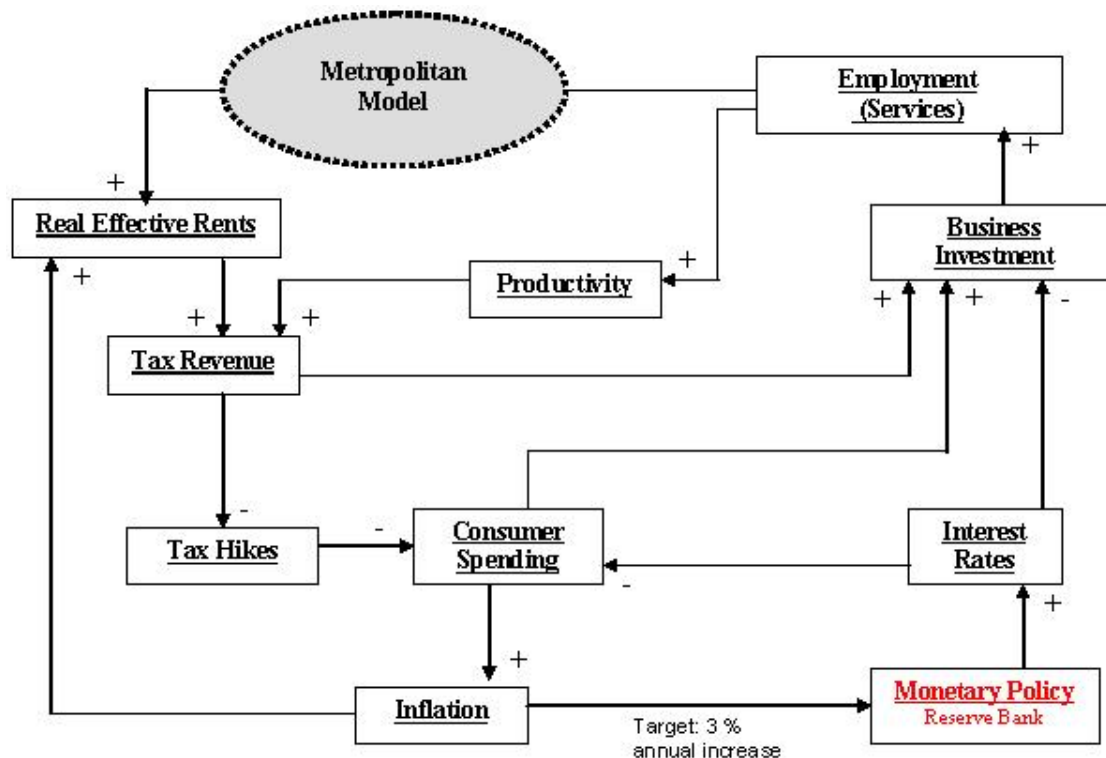


Figure_3. Conceptual Map of Selected Macroeconomic Variables

Furthermore, a multitude of other variables would probably have to be added into the model to have something more than a purely educational tool. Such additional variables would probably include import/export activities, immigration, farm economy, private housing investment, local currency, but also events that have an impact on the world economy such as fluctuations of the American dollar, wars, oil price, terrorism, etc.

In order to confine the model to a manageable size, inflation and private business investment – together with building costs index – have been kept exogenous to the system. The result is a metropolitan office market model that is very basic, but logical and complete within its simplicity (Figure 4).

Practical reasons for choosing this approach rather than building an enormous model that encompasses all aspects of the national economy include the following:

- CRE decision makers are simply interested in growth within the selected urban region, while events that occur outside of the delimited area of study may or may not have an impact.
- By using an extremely large number of variables forecasters would be faced with huge amounts of data, direct and indirect relationships, and additional lag times.
- Precise data is not always available.
- Strong subjective assumptions would have to be made for most of the qualitative variables.
- At one stage model developers would have to “pull the plug” anyway and define the boundaries of the model. Even the most complete national models still have to rely on exogenous variables.

This study does not look at the micro focus of the individual property, therefore variables such as location, lease aspects, building characteristics, and operating costs have not been included. Of the explanatory variables identified in Figure 2 also house prices, market conditions, taxation, stock market, and unemployment have not been used because they seem too detached from the office property market and, as previously discussed, their inclusion would have significantly complicated the model. Nevertheless, the top nine explanatory variables identified by previous researchers are in the model and three of those belong to economic/behavioral cycles.

The need to include macroeconomic variables that directly and indirectly impact real estate cycles is stressed by Phyr, Born, Manning, and Roulac (2003), who also agree on other important aspects of model design:

1. Cycles are dynamic, complex, and interrelated. Available theory on the interdependency of real estate related cycles is not well developed. Future research should look at the integration of macro and micro cycle theory in a decision-making framework.
2. Available market data is generally of poor quality and often unreliable.
3. Qualitative variables need to be integrated into realistic frameworks for forecasting of economic and market scenarios.

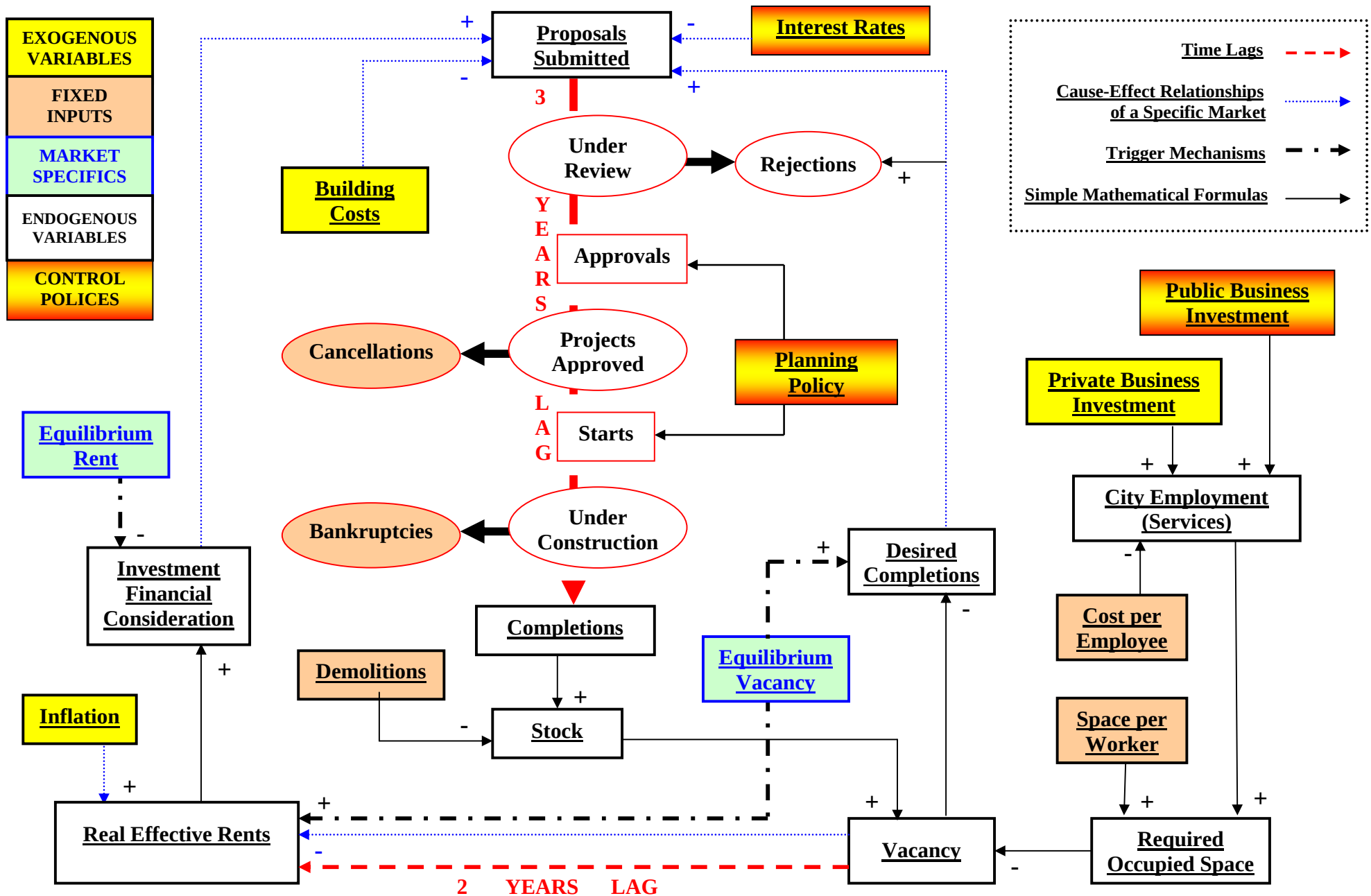


Figure_4. Conceptual Map of Office Space within a Metropolitan Area

The relationships among the explanatory variables were tested in the Brisbane metropolitan office market and for the most part co validated the findings from the mental and written databases (qualitative data). Interest rates and number of submitted proposals showed an unexpected positive correlation, but the coefficient was too small to support any case against the logical relationship illustrated in Figure 4. Same consideration can be made regarding the correlation between rental growth and inflation.

Correlations of Variables for the Metropolitan Office Market Model		National		State			City				
		Inflation	Interest Rates	Private Busi Invest	Public Busi Invest	Submitted Proposals	Employment	Vacancy	Rent	Building Cost Index	Completions
N a t i o n a l	Inflation	1							-0.242		
	Interest Rates		1			0.297					
S t a t e	Private Busi Invest			1			0.950				
	Public Busi Invest				1		0.780				
	Submitted Proposals		0.297			1		-0.406	0.745		
C i t y	Employment			0.950	0.780		1				
	Vacancy					-0.406		1	-0.899		
	Rent	-0.242				0.745		-0.899	1		
	Building Cost Index									1	-0.723
	Completions									-0.723	1

Table_2. Correlation Coefficients of the Explanatory Variables in the Brisbane Metropolitan Office Market

5. CONCLUSION

Research is currently underway to define the mathematical equations of the office market model described in this article as well as to select the testing procedures for its actual forecasting within the Brisbane metropolitan area. However, it is already clear that its application can help CRE executives in making more informed real estate decisions.

Then again, CRE executives should not only account for the relationships that exist between their individual facility and the larger real estate markets, but also for those with the overall corporate business strategy. Understanding the context is the prerequisite for successfully linking corporate property/real estate strategies with business strategies, but once performed an external analysis, the emphasis should shift towards identifying ways in which places and spaces can contribute to competitive advantage and possibly be able to quantify the effects of specific real estate strategies.

To date there has been little published research on strategic approaches to corporate real estate, yet the prospective payoff of an improved CRE strategy is enormous since it has impact in different directions, including but not limited to wealth creation, business growth, customers, innovation, and human resources.

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OCCUPATIONAL HEALTH & SAFETY – THE CARING CLIENT

Case Study

IMPLEMENTATION OF THE NATIONAL OHS STRATEGY 2002-2012

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ABSTRACT:

The National OHS Strategy 2002--2012 (the Strategy) is a landmark development signifying the commitment of all Australian governments, the Australian Chamber of Commerce and Industry and the Australian Council of Trade Unions, to work cooperatively on national priorities for improving OHS and to achieve minimum national targets for reducing the incidence of workplace deaths and injuries.

The five National Priorities are to: Reduce high incidence/severity risks; Improve the capacity of business operators and workers to manage OHS effectively; Prevent occupational disease more effectively; Eliminate hazards at the design stage; and Strengthen the capacity of government to influence OHS outcomes.

Statistics concerning the construction industry and its OHS performance include: the construction industry employed approximately 5% of the Australian workforce and accounted for 10% of new workers' compensation claims in 2001/2002; the incidence of workplace fatality in the construction industry in 2001/02 of 9 deaths per 100, 000 employees is more than double the Australian average for all industries of 3.6 deaths per 100, 000 employees; and by the year 2005/06 the construction industry will be the lead contributor to work-related deaths. A number of major activities already under way to achieve improvements in the Australian construction industry include: regulatory material for the construction industry, including a national standard and the integration of safe design into national standards. Such material, when given effect by all jurisdictions, would improve the industry's OHS performance by addressing major OHS problems in this industry.

Keywords: **Construction industry, OHS performance, national strategy, standards.**

INTRODUCTION

The paper will provide an overview of three important national occupational health and safety initiatives that will directly impact on the building and construction industry. These are the National Strategy, the development of national regulatory material and role of safe design in reducing construction related accident and injury. Socially, politically and economically, Australia is in a fortunate position. The population is well educated, we have a good health system, there are effective social services and the rule of law applies. The population has reached twenty million, with a workforce of about ten million, so Australia has a strong internal market. Internationally the country is a significant trading nation.

Every year however, one in twenty workers will probably suffer a work related injury or disease. There will be over two thousand work related deaths this year, most from work-related diseases. Billions are spent by the nine governments, by employers and by the community in trying to reduce this toll. In a recent study¹ the cost of workplace injury and illness to the Australian economy for the 2000-01 reference year was estimated to be over \$34.3 billion or 5 per cent of Australian Gross Domestic Product (GDP). The economic cost of pain, suffering and early death is at \$48.5 billion. Australian employers paid \$7.5 billion in workers' compensation premiums in the 2000-01³ financial year. In the construction industry the cost of insurance premiums (standard & self insured) for 2000-2001 was \$733 million.

The building and construction industry is high-risk. It is estimated that around 50 building and construction workers are killed at work each year. Data⁴ in relation to people working in the industry suggest that they are more than twice as likely to be killed at work than the all-industries Australian average.

There is no quick solution to these problems. The challenges are compounded by many interrelated factors. The age and composition of our workforce is changing. The industry mix is altering rapidly and today over 90% of Australian businesses are small businesses. International trade and globalisation are making both borders and local regulation less relevant. Economic forces are changing the balance of power. New technologies are creating new industries and making many old ones and the skills associated with them irrelevant and unwanted. New ways of working are producing new hazards and risks. Increasingly, regulators, employers and workers are struggling to keep up with the pace of change. Many duty holders at workplaces do not know or understand their obligations, nor how to identify and address hazards and risks. Even where they do, there are frequently competing business pressures on them.

THE NATIONAL STRATEGY

Against this background, in 2002 the National Occupational Health and Safety Commission (NOHSC) developed and adopted its National OHS Strategy (see

¹ Costs of Workplace Injury and Illness: reviewing the estimation methodology and estimates of the level and distribution of costs, Report by Access Economics P/L, March 2004.

³ The Workplace Relations Ministers Council (WRMC) Comparative Performance Monitoring report (CPM)

⁴ *ibid*

Figure 1), which will operate for ten years⁵ up to 2012. We also received the express commitment of all Australian governments and the ACCI and the ACTU to the Strategy.

Why did NOHSC decide to take this step? Australia's constitutional arrangements distribute regulatory responsibility over nine governments. This puts us at risk of missing opportunities to align our efforts and share solutions and resources. The National Commission has always provided a forum for fostering this type of cooperation. Cooperation usually relied on a coincidence of interests at any given time rather than a planned program of activities that focused on the biggest problems. NOHSC felt confident in developing a National Strategy because it involved the efforts of members drawn from all Australian governments and the peak industry and union bodies. Since the Commission is accountable to the Workplace Relations Ministers' Council, we were also able to secure their support.



Figure 1 - National OHS Strategy 2002 - 20012

THE STRATEGY'S VISION

Our starting point for the Strategy was a shared national vision, namely, Australian workplaces free from death, injury and disease.

IMPORTANCE OF DATA AND DEVELOPMENT OF TARGETS

NOHSC examined the available national data to identify the greatest causes of work-related injury and disease and we agreed on key emerging issues. The National Commission considered the trends and developed two initial minimum national targets for reducing the incidence of work-related deaths and injuries.

⁵ NOHSC, *National Occupational Health and Safety Strategy 2002-2012*, Commonwealth of Australia, 2002.

The targets are to reduce the incidence of such fatalities by at least twenty per cent by 2012 and the incidence of work related injuries by at least 40 per cent. By 2007, the Commission expect a minimum improvement of one half of each target.

BENCHMARKING AUSTRALIA'S OHS PERFORMANCE

There is an additional informal target. This reflects the concern about the shortcomings in benchmarking against Australia's own past performance. NOSHSC aims to have the world's best OHS performance, measured in terms of work-related fatalities and injuries. Therefore, the aim is to benchmark Australia against the rest of the world. This is very difficult as there are many gaps in the data used by various countries and differences in definitions, hazards and risks.

Even so, using non-standardised data, the ILO ranks Australia as the seventh best in the world.⁶ If as a nation we are to become the world's best, making our Strategy work is even more important. This aim will only be achieved when everyone in Australia's workplaces takes the necessary action to make them the world's safest. To attain this outcome, improved hazard identification and control skills will be required in the workplace.

PRIORITIES UNDER THE STRATEGY

After deciding on the formal targets, the National Commission used them to assist in settling on priorities for national action. In each case, the threshold question was how much action in a particular area, or in a combination of priority areas, would help to achieve the targets. This was a very powerful criterion. It allowed the Commission to bring greater objectivity to the decision-making on the priorities.

Five National Priorities were developed, relating to.

- reducing high incidence and high severity risks;
- giving business operators and workers greater capacity to manage OHS effectively;
- the more effective prevention of occupational disease;
- eliminating hazards at the design stage; and
- making governments better able to bring about good OHS outcomes.

NINE AREAS THAT UNDERPIN NATIONAL ACTION TO ACHIEVE THE PRIORITIES

The Commission also decided on nine areas to be the focus of our work consisting of;

- comprehensive OHS data collections;
- a coordinated research effort;
- a nationally consistent regulatory framework;
- strategic enforcement;
- effective incentives;
- support for better compliance;
- practical guidance;
- OHS awareness; and
- OHS skills development.

They are mutually dependent, improvement in one area should lead to improvements in the others, and, equally, failure in any area will be a barrier to improvement in the others. These are substantial challenges for NOHSC. So how does this all impact on the OHS performance of the building and construction industry?

⁶ International Labour Organisation, *Yearbook 2002*, ILO, Geneva, 2002.

REGULATORY MATERIAL DEVELOPMENT FOR THE CONSTRUCTION INDUSTRY

The Cole Royal Commission made a number of comments and recommendations in relation to the poor OHS performance of the \$46 billion building and construction industry. Although there are many problematic issues in the industry, one issue that NOHSC is giving a high priority to is the development of uniform national OHS standards and codes of practice. In June 2004 NOHSC released for public comment the draft National Standard For The Construction Work (National Standard) and the draft National Code of Practice for the Prevention of Falls from Height in Construction. The National Standard aims to identify and foster the uniform adoption of best practice approaches to OHS in the construction industry.

NOHSC has also seized the opportunity to develop draft codes of practice that support the National Standard in the high risk areas of demolition and tilt-up construction, and construction induction training. The National Standard is the first tier of a national package of material for the building and construction industry, and contains the essential elements to be implemented by the jurisdictions. The proposed second tier of the national package is a series of national codes of practice addressing high-risk construction activities (for example, prevention of falls from height). The proposed third tier is a range of guidance material for performing specific construction tasks (for example, roof tiling). The National Standard is only enforceable by law when it is specifically included in a State/Territory health and safety regulation. An OHS regulatory compliance continuum including the hierarchical application of National Standards and Codes of Practice is set out below.

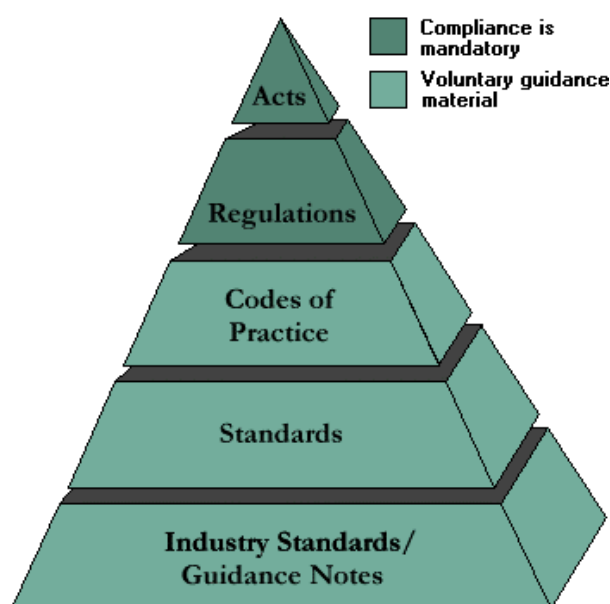


Figure 2 - The Australian OHS Legal Framework⁷

Australian health and safety law is governed by a framework of Acts, Regulations and support material including codes of practice and standards, as illustrated above. Each State/Territory has a central piece of law, the principal occupational health and safety Act.

⁷ The Australian OHS Legal Framework - NOHSC 1998

The objective⁸ of the National Standard is to provide a framework to assist in the protection of persons from the hazards arising from construction work by requiring duty holders to eliminate the hazards. Where this approach is not practicable, duty holders will be required to take steps to minimise as far as practicable the risks arising from the hazards, by ensuring that the hazards are identified and the risks assessed and controlled. The standard will also require the provision of information and training and will;

- form part of a construction work regulatory package and provide the basis for national codes of practice and guidance material;
- provide nationally consistent construction specific performance based requirements suitable for adoption by the States and Territories;
- require relevant persons in the construction workplace to identify hazards associated with construction work and minimise risks of injury, illness or fatality in construction work; and
- to allow for structures to be safely erected, maintained, repaired or altered, cleaned and demolished safe design information and obligations will be incorporate.

The draft National Standard proposes account be taken of emerging issues, such as the changed composition and mobility of the construction workforce. The need for a uniform standard for induction training, and mutual recognition of induction training across jurisdictions, has been identified, as has the need to address the safety issues of workers engaged under labour-hire arrangements.

It could be suggested that there is already a great deal of OHS regulation in place. However, a closer analysis of jurisdictional regulation would reveal that it is not only inconsistent, but there are large gaps in the coverage of hazards and risks. The adoption of uniform construction standards and codes of practice should reduce costs to industry, reduce uncertainty with compliance requirements and should have a tangible impact in reducing the industries high accident and injury rate. A number of industry consultative forums have expressed support for the development of standards and codes. One recent forum in June 2004 was the 'Improving Safety in the Building and Construction Industry Conference'. Participants included major construction companies, unions, employer associations, state and territory governments and architects. The principal aim of the conference was to strengthen industry commitment to work together to bring about significant and sustained improvements to safety performance in the building and construction industry. At the conclusion the conference released a communiqué setting out a number of agreed outcomes;

- safety is a priority for all participants in the construction industry. The industry wants to have a safety culture which makes it one of Australia's leaders in good health and safety performance;
- all parties support the National OHS Strategy and agree to reduce fatalities and serious injuries by at least 10% by June 2007;
- the industry should adopt a 'life cycle' approach to OHS in building and construction projects – recognising that designers should provide for the safety of those building, working, refurbishing and demolishing structures;
- governments need to use procurement processes to actively improve OHS, the current approaches do not significantly improve safety;
- the industry will raise awareness and understanding of the health effects of exposure to chemicals used in building and construction;

⁸ Draft National Standard for Construction Work – NOHSC June 2004

- all states and territories should work together to ensure a national approach to regulation of the building and construction industry across Australia;
- NOHSC will convene a number of forums on construction specific issues, including a CEOs forum.

THE INTEGRATION OF SAFE DESIGN PRINCIPLES INTO NATIONAL STANDARDS

Construction Sector Injuries As A Result of Poor Design

Some statistics concerning the construction industry and its OHS performance include: the construction industry employed approximately 5% of the Australian workforce and accounted for 10% of new workers' compensation claims in 2001/2002; the incidence of workplace fatality in the construction industry in 2001/02 of 9 deaths per 100, 000 employees is more than double the Australian average for all industries of 3.6 deaths per 100, 000 employees; and by the year 2005/06 the construction industry will be the lead contributor to work-related deaths and injuries in Australia if the industry continues along current trends for the ensuing years.

A recent study⁹ found that design related issues were definitely or probably involved in at least half of all serious and fatal injuries in the construction industry. Although the OHS focus has traditionally been on the construction phase it is sometimes forgotten that building owners as end users inherit the legacy of an unsafe construction design that may only be discovered as the result of an accident or injury, which sometimes only occurs many years after it was built. As a consequence, the design deficiency may not become apparent until a particular work activity occurs such as maintenance or refurbishment. The building owner may then be potentially faced with the legal liability for the accident arising out of poor design. However there are other sound reasons for design decision makers upstream to adopt a systematic approach that incorporates safe design approach.

The Business Case

Applying the Safe Design approach means controlling risk early in the design process. A Safe Design approach results in:

- simplified risk control;
- a more informed ability to meet legislative responsibilities;
- a greater ability to predict and manage production and operational costs across the life cycle of the designed-product;
- a greater ability to predict and minimise costs associated with injury and environmental damage; and
- a reduced need for redesign and retrofitting, and its associated costs.

Costs associated with unsafe design can be significant (e.g. retrofitting, workers compensation levies, environmental clean up costs). If these costs can be identified and avoided in the pre-design phase, then there is a clear business case for adopting the Safe Design approach. Figure 3 shows the relative cost advantages of applying a Safe Design approach.

⁹ The role of design issues in work-related injuries in Australia 1997-2002, NOHSC: July 2004

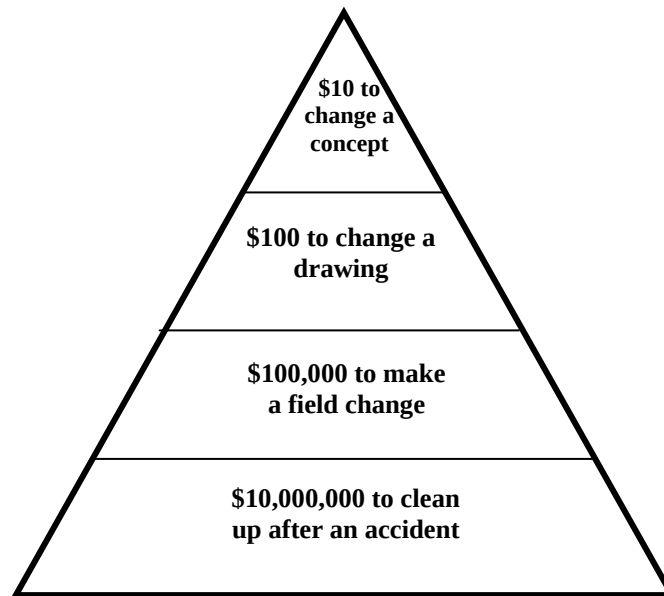


Figure 3 - Cost effectiveness of early intervention on safety problems in construction¹⁰

ENHANCING OHS AWARENESS

By raising awareness of the need to proactively identify and eliminate potential unsafe design issues at an early stage NOHSC hopes to minimize the number of construction and building industry incidents and injuries. The challenge for the Commission was to develop a strategic approach that would focus on risks involving design at a number of different levels.

To facilitate this the Commission has developed the *Safe Design Action Plan 2004 – 2012* (National Priority 4 of the National OHS Strategy) to guide the implementation of safe design into key national standards. Three high-risk national standards have been initially identified for the integration of the safe design concept. These are manual handling, plant and the National Standard for Construction Work. Underpinning the Safe Design Action Plan is a set of four Safe Design Principles the will be used to guide the integration of safe design into National Standards;

- (i) assign responsibility to parties with real control over particular design functions.
- (ii) adopt a life cycle approach to the designed-item to improve OHS for a range of people who will use or interact with the item.
- (iii) a 'designer' must ensure that a systematic OHS risk management process is implemented and ensure that those involved in design have the necessary, or access to, OHS knowledge and capability.
- (iv) ensure that key information is transferred from the design/planning phase and that those involved at later life cycle stages are informed about any residual risks that may affect their health and safety.

Nested within the Safe Design Action Plan are a number of regulatory framework initiatives that will lead the integration of safe design through;

¹⁰ adapted from Wakeling, H. & Knight-Jones, P. 2000, 'Site Safety by Design', in Gibb, A.G.F. Designing for Safety and Health Proceedings, 26-27 June 2000, London, European Construction Institute, Loughborough, UK, pp. 199-206.

- the development and promulgation of Safe Design Principles and definitions and the development of practical guidance on safe design;
- the review of regulatory framework and development of improvement options;
- encourage the introduction of safe design principles into management systems; and the incorporation of safe design principles into national, state and territory standards and codes of practice.

At the industry level key activities derived from the Safe Design Principles that will assist the integration of safe design principles into business management systems include;

- promoting the 'life-cycle' approach to OHS in building and construction projects – recognising that designers should provide for the safety of those building, working, refurbishing and demolishing structures;
- identifying opportunities to influence and incorporate safe design and OHS into key standards such as the Building Code of Australia (BCA) and the Future Building Code (FBC);
- the integration of safe design into higher education and professional development curricula for design professionals;
- the engagement of parties with real control in the design, planning and construction work particularly those with OHS risk management obligations, such as design professionals, building contractors and clients;
- ensuring that foreseeable risks are proactively and systematically addressed at the source throughout the construction or building lifecycle, but particularly as early as possible in;
 - o the design stage;
 - o procurement of materials and methods;
 - o planning and organization of work; and
 - o selection and coordination of contractors
- making sure that those involved in the design and planning of construction works have the necessary OHS competencies and knowledge to adequately address foreseeable risks that may arise;
- development of a culture of communication and cooperation that ensures that relevant OHS information is maintained and made available to parties involved in the service, maintenance and use of the building or construction.
- ensure that any residual risk is documented/filed and transferred from owner to owner throughout the lifecycle to the decommission/demolition of the building or structure.

From this approach NOHSC seeks to deliver a message that buildings and structures throughout their lifecycle are used as workplaces and therefore must not only be safely constructed but remain safe for those that work in them. To achieve this NOHSC seeks to encourage architects, designers, planners, contractors and clients to take a proactive and leading role in the recognition and implementation of safe design has an integral part of the construction design process.

CONCLUSION

In conclusion the National Strategy, the advancement of safe design initiatives and development of regulatory material for state and territory jurisdictions is a systematic approach which NOHSC believes should deliver a focused and uniform outcome that will result in tangible improvements to OHS performance in the building and construction sector.

INTERNATIONAL INNOVATION

Case study

WAY-FINDING IN THE BUILT ENVIRONMENT

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ABSTRACT

Purpose

There is an urgent need to address the problem of unaided access to (and egress from) buildings and facilities for the vision impaired.

Design/methodology/approach

The project aims to identify technologies and systems that will make it easier and safer for people who have a sensory impairment, to find their way around large public areas.

Findings

This paper will examine existing technologies being used in major venues and new electronic technologies that may be incorporated into a building's management systems considering economics and end user requirements.

Research limitations/implications

The Commonwealth's Disability Discrimination Act ("DDA") makes it unlawful to discriminate against a person because of their disability. Current and draft building law (DDA, BCA, Premises Standard, Australian Standards, common law) do not address access for the vision impaired and little or no research exists on way-finding systems to permit unaided access for the blind.

Practical implications

There are potential benefits to the Australian community of such research both in social and economic terms. An opportunity exists to apply and integrate technologies and systems which will assist the construction industry to make premises comply with current legislation and to be accessible to people with a vision, sensory or print disability.

EXECUTIVE SUMMARY

Project objective

The project sought to identify alternative systems and/or technologies that may assist people with sensory impairment to integrate further with society as a whole. This involved a comprehensive review of research developments internationally in the area of way-finding technology and systems. The project was primarily aimed at people who are blind or vision impaired, but with consideration of other groups of people.

The challenge

People who are blind or vision impaired often have difficulty negotiating public spaces, such as university campuses, public squares or sporting venues, especially when the area is crowded or noisy. Consequently there is a significant impact on their capacity to independently and confidently use public resources in a refusable, unaided and discreet manner. Building legislation in Australia has not addressed an holistic approach to Way-finding systems and/or technologies in the built environment.

The process

Phase 1 of the research was the identification of way finding technology and systems. Future phase 2 is the evaluation of the findings of phase 1 and recommendation of a preferred system to be trialed. Future phase 3 is the opportunity to install, trial and evaluate technologies and/or systems as part of the 2006 Commonwealth Games.

Outcomes

The research found that way-finding systems and/or technologies could be grouped into three areas:

- **passive systems** - provide feedback to vision impaired users without using power sources or involving power or communications infrastructure requirements.
- **dynamic systems** - provide audio and/or tactile feedback to vision impaired users but require (battery) power sources to operate although no additional fixed or network infrastructure is required to be provided by the broader community.
- **infrastructure based systems** - require the broader community (via public and/or private facilities) to install and maintain permanent or fixed communications and/or network infrastructure which can then interact with vision impaired users - providing them with additional audio and/or tactile feedback.

Building legislation

The research found no international or Australian examples of specific way-finding legislation, which requires building owners and/or public bodies to build in systems or technology to assist people with a sensory impairment to navigate around buildings and other spaces or to exit to a safe place in the event of a fire or other emergency.

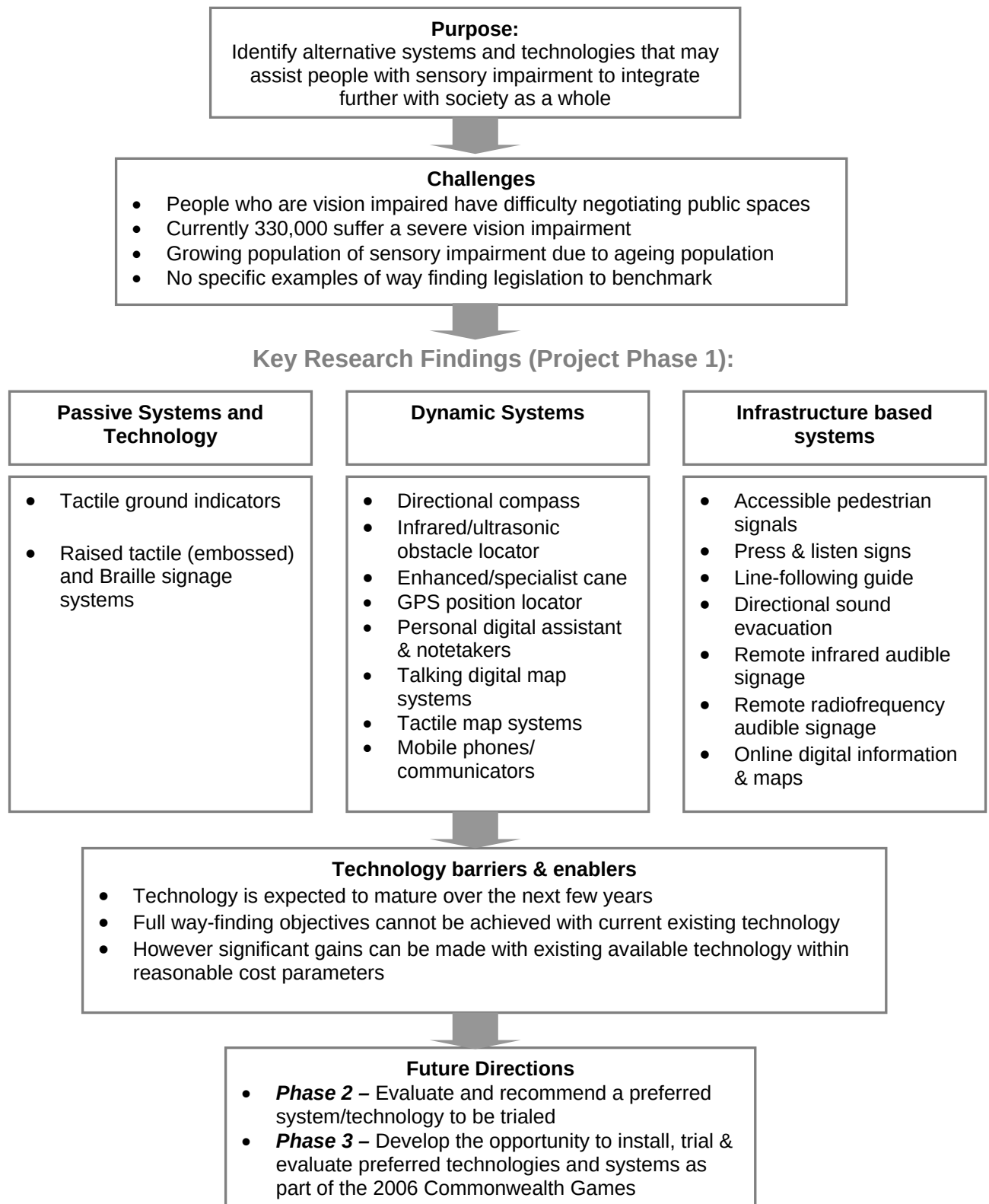
The future

Many systems and technologies which have potential application in the area of way-finding or mobility and location assistance for vision impaired persons are expected to mature over the next few years. The research findings will provide valuable

information in the future development of building legislation in the area of way-finding.

The project map below outlines the key highlights of this paper.

Way-Finding Project Map



1. INTRODUCTION

The objective of way-finding is to ensure that people with a sensory impairment know where they are in a building or an environment, know where their desired location is, and know how to get there from their present location.

“Way-finding” is a term used to describe a system, the object of which is to give unaided access to the services offered in buildings to people who are blind or who’s vision is impaired. The provision of tactile indicators, which are well developed and available on the market, is insufficient. Further it is not only a system of egress in the event of an emergency (as historically has been the focus of building control) which is required, but also a system of ingress to give unaided access to buildings and services is required. Presently, the complete achievement of this goal may be difficult because the technology needed may not be economically viable.

Mobile portable devices or electronic travel aids (ETA), electronic mobility devices, mobility aids, obstacle detectors, navigational aids as well as tactile signage and other inbuilt physical features may be employed as to achieve the way-finding objective. The project therefore involves consideration of systems that may be employed in both buildings and other external public places. Systems that are considered include physical electronic or tactile items that interact to perform a task, such as interactive hand-held electronic devices and administrative procedures, such as building management procedures.

2. RESEARCH METHODOLOGY

The research was carried out by a project team, which included three industry partners and two research partners. Representatives from the Building Commission (Vic), Queensland Department of Public Works (Qld), Australian Building Codes Board (ACT), Queensland University of Technology (Qld), and CSIRO (Vic) made up the membership of the project team.

The project team recognized at the first meeting that there was a need to have a greater understanding of the way-finding needs of users. A community reference group was formed consisting of representatives from Blind Citizens of Australia (Vic), Human Rights and Equal Opportunities Commission (NSW), Office of Commonwealth Games Co-ordination (Vic), Disability Council of Queensland, and Innovative Access Systems P/L.

The initial meeting between the project team and the reference group provided vital information for the research team. It was apparent that way-finding could include a wide range of technology and systems including passive systems and systems that would become part of the built infrastructure of a building. This information highlighted the need for the research to be confined to the scope of work originally developed for the project.

That scope of work for the project included seeking to identify alternative systems and/or technologies to assist people with sensory impairment to integrate further with society as a whole. Phase 1 was a comprehensive review of research developments internationally in the area of way-finding technology and systems. The highlights of this research will be discussed in this paper.

3. LEGISLATIVE ASPECTS

3.1 A SUMMARY OF THE LAW IN AUSTRALIA

In Australia the Disability Discrimination Act 1992 (DDA), Building code of Australia (BCA), and Australian Standard AS1428 (Design for access and mobility), regulate access for people with disabilities. Under the DDA, people with disabilities have the right to make a complaint against a building owner or operator if they believe they have been discriminated against in terms of access to, or use of, any building. The HREOC attempts to conciliate an agreement between the parties, but if that is not possible the complainant may proceed to the Federal Court or Federal Magistrates Service.

3.2 HISTORY OF THE DDA LEGISLATION IN AUSTRALIA

All states and territories introduced anti disability discrimination legislation in the early 1980's. The *Human Rights and Equal Opportunity Commission Act 1986* (Cth) ("HRC Act") established the National Human Rights and Equal Opportunities Commission (HREOC) with jurisdiction by reference to a number of international instruments, including the Declaration on the Rights of Disabled Persons. Essentially the HREOC Act established the means by which people with disabilities could be given the same rights as previously enjoyed by people without disabilities.

Throughout the 1980s organisations representing people with disabilities lobbied for their rights to be enforced and subsequently the *Disability Discrimination Act 1992* (Cth) ("DDA") Act was enacted.

3.3 BUILDING CODE OF AUSTRALIA HISTORY

BCA 96 currently includes energy efficiency and other provisions for access for people with Disabilities, which may be characterised as, not required principally for the health and safety of the occupants of the building. However, recent drafts out for comment go one step further. They include proposals to control emerging contemporary issues of concern to the Australian public and the pressing issues of international community. For example additional environment controls and enhanced provisions for access for people with Disabilities are proposed. The inclusion in building regulations of these additional controls not arising principally from the need to safeguard the health and safety of the occupants of the building is occurring globally throughout developed countries largely through pressure exerted by the United Nations and international conventions.

The ABCB and Standards Australia issued multiple drafts for comment on 1 Feb 2004 including BCA amendments and referenced Australian Standards for Design for access and mobility. AS1428 Parts 1 and 4 propose to include *Disability Discrimination Act 1992* (DDA) objectives to –

- Eliminate discrimination against people with disabilities
- Promote community acceptance of the principle that people with disabilities have the same fundamental rights as all members of the community, and
- Ensure as far as practicable that people with disabilities have the same rights to equality before the law as other people in the community.

Complaints are the clearest and surest way of illustrating cases of discrimination. Complaints address inconsistencies between building law and anti-discrimination law

and assist regulators, practitioners and property owners in assessing what is required and how to deliver it whilst successfully reducing conflicts with clients over access requirements.

Approximately 330 000 Australians suffer a severe vision impairment and many more have some reduction in effectiveness of their sight (AS1684.4 draft dated 12/1/04) and pressure in mounting for their needs to be recognised.

3.4 AS1428 DESIGN FOR ACCESS AND MOBILITY

Proposed amendments to AS1428, Parts 1 and 4 seeks to enhance access for new building work, interior fitouts and purpose-built buildings, outdoor access, adaptable housing and aged care facilities, communication systems to assist the hearing impaired, and tactile indicators for the vision impaired.

AS1428.4 regulates tactile ground surface indicators (TGSIs), raised pavement markers at strategic places within a building. Draft changes include their provision for public areas external to buildings and public transport infrastructure.

3.5 GOVERNMENT INITIATIVES

On 16 April 2004, Acting Disability Discrimination Commissioner Dr Sev Ozdowski welcomed the announcement by the federal Government to inject \$99 million over the next four years into providing quality services and good working conditions to people with a disability working in business services." While we have no statistics on the number of blind and vision impaired workers, it follows that of the 330 000 Australians with such a disability many will be in the workforce and would benefit by improved access to their workplace and facilities within public buildings.

4. RESEARCH FINDINGS

The research set out to identify systems and technologies that could be used to make it easier and safer for people with a sensory impairment to find their way around buildings and large public areas. The systems and technologies needed to be suitable for people who have a sensory impairment including people with both a visual and a hearing impairment.

The findings of the research were grouped in to types of systems and technologies that are available: passive systems, dynamic systems and infrastructure based systems. The following details give a brief outline of the technologies that are available, without attempting to provide a comprehensive product list. Any product brands mentioned are for illustrative purposes only and do not imply any endorsement, and no attempt is made at assessing the benefits of one over another.

Technology Area 1: PASSIVE SYSTEMS AND TECHNOLOGY

Description:

The following systems and/or technologies are considered “passive” in the sense that they provide feedback to vision impaired users without using power sources or involving similar infrastructure requirements. These types of systems are widely used in Australia at traffic intersections, within and around major buildings.

Selected Examples of Technology in Action:

Tactile ground indicators

In Australia, Tactile Ground Surface Indicators (TGSIs) are typically square tiles with series of regular raised areas which can be laid in various patterns at key points where surface levels or directions change. They are detectable via the sole of the foot, or with a sweep of a long cane, and they come in two types - warning and directional. Warning TGSIs indicate that there is a hazard ahead, while directional TGSIs assist in way-finding by directing people along a safe and direct path of travel from one point to another.

Raised Tactile (embossed) and Braille Signage Systems

The use of tactile/raised/embossed signage systems is becoming more widespread throughout buildings. Signs are available in aluminium and acrylic with various combinations of flat or tactile/raised lettering – with or without accompanying Braille dots.

Technology in Focus:

A range of specialist signs known as BrailiantTouch® Accessible signage are available locally through BrailiantTouch Australia. Incorporating optional coloured text and embossed Braille dots, these (layered) signs are available in a wide range of finishes; and can include background colours/textures and optional logos, while a variety of metal and plastic substrates for the signs can also be selected.

Technology Area 2: DYNAMIC SYSTEMS AND TECHNOLOGIES

Description:

The following systems and/or technologies are considered “dynamic” in the sense that they provide audio and/or tactile feedback to vision impaired users but require (battery) power sources to operate although no additional fixed or network infrastructure is required to be provided by the broader community. Such dynamic devices are designed to typically be used by a vision impaired person in conjunction with a traditional long cane or guide dog.

Selected Examples of Technology in Action:

Directional compass

Several brands of directional compasses are available - ranging from larger tactile devices with Braille lettering to ones which speak the direction via a speaker or through an earpiece. These include both tactile and talking compasses.

Infrared / Ultrasonic Obstacle Locator

Often known simply as Electronic Travel Aids (ETAs), such devices are designed to use light or sound wave technologies (invisible to the human eye or ear) to detect an obstacle and provide feedback as to the obstacle's approximate location and distance from the user. Products on the market include: Sonic Pathfinder, NavBelt, Miniguide, Hand Guide™, Polaron™

Enhanced / specialist cane

The GuideCane is a wheeled device based on an ultrasonic-based obstacle location and avoidance system which leads the user to avoid obstacles by steering around / away from the detected obstacle by providing tactile feedback through a rigid connecting 'lead'. The UltraCane is based on a traditional white cane, but it uses "echolocation" to emit ultrasonic waves that reflect from objects in its path and echo back to the cane. It feeds that information through to the buttons on the handle, indicating to a user how far away the object is, and whether it is in front or at head height. This gives users more knowledge about their environment, and enables them to make decisions much more quickly than is possible with an ordinary white cane.

GPS Position locator

The global positioning system (GPS) is based upon a series of satellites and was originally developed by the U.S. Department of Defence to provide information about the location, such as the latitude, longitude and altitude or elevation of a military target. GPS technology is certainly suitable for broad scale guidance and orientation in relatively open spaces, and has been integrated into a number of location and orientation devices – both for sighted and vision impaired users. However GPS is not well suited for indoor navigation or for use nearby tall city buildings since it relies on direct access to at least three of the satellites to calculate correct location and orientation. Products developed include: MoBIC Travel Aid and the Drishti system.

Personal Digital Assistant (PDA) & Notetakers

A range of accessibility features such as on-screen text and video magnifiers, full audio prompts, and more recently speech synthesis and speech recognition have become available on laptop computers and their characteristics have developed substantially. Laptop computers and Personal Digital Assistants can now be used to provide audio capture and playback of notes, documents, and a wide range of information.

Technology Area 2:
DYNAMIC SYSTEMS AND TECHNOLOGIES, continued

Selected Examples of Technology in Action, continued:

Talking Digital Map Systems

The Trekker is a package of a GPS receiver, speaker, and additional battery pack combined with an off-the-shelf PDA (HP iPAQ), and a Braille touch screen. As the vision impaired traveller moves about the urban environment, the Trekker utilises a digital map-base of GPS coordinates to find street names, intersections, addresses and major landmarks or features and then uses the speech applications of the PDA to articulate them to the user.

Tactile Map Systems

The Arlene Gordon Research Institute of Lighthouse International is currently undertaking a research project to test the feasibility of commercial development of a computer-controlled, interactive tactile map and way-finding system to enhance the accessibility for vision impaired individuals, of office buildings and other public accommodations. The research is advised as current however little else can be located about the on-going research or results.

Technology in Focus:

Mobile Phones / Communicators

A number of cell/mobile phones may have *potential* as navigation and location aids for vision impaired persons. Two Nokia devices both with added software for speech input/output, and more recently the Audiovox, Toshiba and Samsung have models that included speech systems. Neither of the tested Nokia's had GPS capability, however both Audiovox and Samsung phones have a GPS feature that may be used to help locate users in case of an emergency, but the local emergency system must be equipped to use satellite systems. The GPS feature can also access other location-based services (such as location of restaurants, retail outlets, etc.) that may be offered by network providers in the future

Technology Area 3: INFRASTRUCTURE-BASED SYSTEMS AND TECHNOLOGIES

Description:

Infrastructure based systems and technologies will require the broader community (via public and/or private facilities) to install and maintain permanent or fixed communications and/or network infrastructure which can then interact with vision impaired users, providing them with additional audio and/or tactile feedback. The supporting infrastructure may be installed around a built-up precinct or within a building, and may consist of a series of 'independent' pieces of equipment, or a network of linked appliances, which can provide feedback of some form to vision impaired users should they require it.

Selected Examples of Technology in Action:

Accessible Pedestrian Signals (APS)

Accessible pedestrian signals (APS) are additions to the traffic signal system at crossings to provide signal information in audio, tactile, and/or vibrotactile form to the pedestrian. APS devices available today are of four general types: pushbutton integrated, pedhead-mounted, vibrotactile only, and receiver-based.

Press and Listen Signs

Most often used in an indoor setting, and necessarily working in tandem with other signage systems since the "signs" themselves must be first found to be "pressed", Press and Listen Signs can be used in various applications, such as giving spoken directional instructions, spoken information about displays in exhibitions, conferences and museums, or as a means of passing on messages.

Line-Following Guide

Recently, improved algorithms have been devised that will allow a Guiding Robot to detect, recognize and follow a series of TGSi tiles in order to lead a vision impaired user towards their destination. In terms of Line-tracking Guidance, a sensor system mounted on a wheelchair, which was able to 'follow' a reflective tapeline marked on the floor of buildings, and variations of such line-following options have now been incorporated in many wheelchairs. The user would get an audible sound feedback when the line was being followed correctly, but if the sensors detected the chair was 'straying' from the line, voice feedback advised the user to steer left or right in varying degrees to correct their course.

Directional Sound Evacuation

An innovative audio-based guidance system for evacuation has now been developed in the UK with a view to incorporating it with traditional Exit signage. Although perhaps not a general way-finding system specifically for the vision impaired, it certainly assists the vision impaired with emergency egress, as well as the sighted population.

Remote (Infrared) Audible Signage

There has been a substantial amount of research and development into this area of Remote Infrared Audible Signage systems over the past 15 years – mainly in the US and in the UK. Based upon broadcast or transmission of pre-recorded messages, key locations and corridor intersections are fitted with one or more specialist audible signs or transmitters so that users are 'guided' to the facility that they require simply by following the series of messages as they move throughout the building.

Technology Area 3:
INFRASTRUCTURE-BASED SYSTEMS AND TECHNOLOGIES, continued

Selected Examples of Technology in Action, continued:

Remote Radiofrequency Audible Signage

Products such as RNIB React are similar to the Infrared Signage above in the sense that it electronically provides information to vision impaired persons, this radiofrequency signage however is designed for outdoors applications. When the user walks within range of the sign, a radio signal triggers the sign and it speaks the message through a loudspeaker.

Technology in Focus:

On-line Digital Information and Maps

Most recently, new toolkits allowing software developers to customise World Wide Web pages for vision-impaired users are becoming available, so that users can create machine readable Web pages using the syntax and grammar of extensible mark-up language (XML). This will allow computers (desktop, wearable, handheld,) to 'read' WWW pages automatically and decipher their contents for the vision impaired user. Of particular interest is the potential for 'on-the-fly' spoken interpretations of map-based queries from GIS systems.

6 THE FUTURE

Many systems and technologies which have potential application in the area of way-finding or mobility and location assistance for vision impaired persons are expected to mature over the next few years. One only has to consider the enormous developments made by manufacturers of mobile phone handsets to appreciate the rapid changes in characteristics such as lower power consumption; increased battery life; use of integrated audio for dialing; screen resolution and colour; etc. for handheld devices.

Consider also the introduction of small handheld or palmtop devices like Hewlett Packard's iPAQ or the PalmPilot from Palm Corporation with sufficient computer processing power and on-board storage/memory to undertake many complex tasks such as speech processing and location calculations. On the other hand, improvements in the provision of network infrastructure being installed by the telecommunications companies are much slower in arriving (for instance, actual network upgrades to allow higher bandwidth for delivery of information to handsets; and outright costs of using mobile phones and GPRS to give access to the WWW and Web-based information).

Devices and systems such as data-gloves, smart clothing, and various tactual feedback devices may have been developed for personal Virtual Reality or military and commercial applications, but have enormous potential in providing additional spatial information to vision impaired users who can embrace the technology.

7 CONCLUSIONS

There are no international or Australian examples of specific way-finding legislation, which requires building owners and/or public bodies to build in systems or technology to assist people with a sensory impairment to navigate around buildings and other spaces or to exit to a safe place in the event of a fire or other emergency.

The research has revealed that with current systems and technologies the objective of universal way-finding cannot be achieved immediately. However, there are things that can be done immediately to progress the way-finding objective and to lay the foundation for the future.

Public open spaces within buildings, to which people with a sensory impairment have access, should have inbuilt systems to guide those people along safe paths of travel to and from key entrances and exits. This should also include the paths of travel from the main entrance to the lifts, if any, and to a refuge in the event of fire or other emergency.

The research identified that systems and technologies are presently available to achieve this without building owners incurring unreasonable cost or unjustifiable hardship. Examples of these systems that could be used immediately include:

- Ground surface indicators as well as embossed and Braille signage systems are well developed and available.
- Infrared audible signage (known variously as “speaking signs / audio signs / talking signs” etc.) is advanced sufficiently to assist.
- In the **outdoors** environment, the radio beacon approach based on an external audible signage system would appear the best short-term approach.

Improvements in storage devices, communications protocols, plus integration with specialised sensors and improved location positioning systems, it is expected that in the medium term, information that is ‘tailored to the individual’ could be made available to individual users from inbuilt location-specific transmitters.

Devices such as mobile phones (where small computers, personal digital assistants, and digital cameras are already integrated) but with the potential addition of a digital compass, pitch & roll indicator, accelerometer, as well as GPS-type location features, such mobile tools *could* converge into one (maybe costly) device, or could remain as a series of optional add-on extras - depending on how strong the demand is, and on an impaired individual’s particular needs.

It would still appear quite a long way off before a ‘robotic guide’ of some form or similar of a **sufficiently small, light, powerful yet discreet** nature will be available for the sensory or vision impaired visitor to use with confidence for orientation and navigation within the built environment.

Consequently, way-finding guidance of the preferred *refusable, unaided and discreet* type may well come from feedback supplied individually and directly to the sensory-impaired user. These would include innovative and inconspicuous options such as advanced smart clothing and personal tactile devices – perhaps augmenting or replacing traditional tactual and aural sources like vibrating mechanisms and headsets/earphones.

CLIENTS DRIVING INNOVATION INTERNATIONAL CONFERENCE

Practice Paper/Case Study

CLIENT DECISIONS AND E.S.D. - THE STORY SO FAR

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ABSTRACT

The following is a non-peer reviewed practice paper by a CRC-CI scholar. No new research has been conducted at this point. This paper, divided into two main sections, represents a brief summary of a wealth of available research into the environment in relation to construction and the intellectual side of client decision making. With this in mind it considers the type and benefit of the research to be conducted.

Keywords: residential industry, project homes, environment, ESD, psychology, marketing

1. INTRODUCTION

The author of this paper is a CRC – CI scholarship holder. No new research has yet been completed. This paper is written as a non-peer reviewed “practice paper” based on the literature review conducted thus far. It is set out as a summary of the primary points in the literature and a lead into the research to be conducted.

The research being undertaken considers factors influencing client purchasing decisions in relation to environmentally sustainable development. The actual new research component is likely to be narrowed down to focus on the residential sector of the construction industry and in particular the project home market. The influencing factors in this area are likely to be quite different between the investor-client and the owner occupier-client. It has not been determined at this point whether the research focus will need to be further narrowed to study only one of these two markets. While focussed towards the residential sector there will be numerous points that will have a level of validity for the industrial/commercial sector particularly those related to the investor-client.

2. THE INDUSTRY SIDE

2.1 CONSTRUCTION, THE ENVIRONMENT & ESD

Most people in industry probably have at least a basic awareness of the environment, the issues surrounding it and concepts like environmentally sustainable development (ESD). Even the general public have moved slowly towards an effort for sustainability. Australia has now reached a point where only 2% of households do not recycle or re-use waste in one form or another (Australian Bureau of Statistics ^a). A tiny step overall but a huge move from decades past.

2.1.1 Energy Consumption & Greenhouse Gases

Possibly one of the most widely recognised environmental issues is that of greenhouse gas emissions. In 1997-98 almost half of the total greenhouse gas emissions could be accounted for by the electricity supply industry. While the construction industry accounts for only about 1% of energy consumption by sector, residential energy consumption accounts for over 8% of total energy consumption (Australian Bureau of Statistics ^b). In addition to energy consumption alone, households are the third highest emitter of greenhouse gases with 13% of total emissions (Australian Bureau of Statistics ^c). These are the same households that continue to be designed and built by the construction industry today. Residential energy consumption per capita rose approximately 16% from 16.9GJ in 1973-1974 to 19.6 in 1993-1994 and is anticipated to rise a further 10% to 21.6GJ in 2009-2010. (ABS ^b)

2.1.2 Resource use - Timber in Australia

We have a positive rule in every factory and branch that each crate and box must be opened carefully without breaking the wood... All scrap wood eventually gets back to the wood salvage department. Henry Ford 1926

Driving through any new housing estate shows that the vast majority of new houses have footings and a ground floor of concrete. Nonetheless, the same drive will show that the vast majority of new houses still have timber wall frames, roof frames, floor frames and flooring where there is more than one storey. In 1999, almost 15% of Australian homes still used timber as the external cladding. This was most prevalent in Tasmania (32%) and Queensland (28%) (ABS ^b). While Australia is a net importer of timber and timber products (ABS ^c), all these timber building materials come in one form or another from forestry.

There are 164.4 million hectares of varying types of forest in Australia giving it the sixth largest area of forest in the world. This is made up of 117 million hectares of woodland, 43 million hectares of open forest and 5 million hectares of closed forest. (ABS ^c)

Australia is one of 12 'mega-diverse' countries, with ecosystems of exceptional variety and uniqueness. Clearing of native vegetation remains the single greatest threat to terrestrial biodiversity, particularly for forest ecosystems (ABS ^c). However, there is a restructure occurring in the forestry industry. Timber from native forest ecosystems is gradually being replaced by the expansion of hardwood and softwood plantation resources. At 1.5 million hectares plantations account for less than 1% of the total forest area of Australia, yet they supply in excess of 50% of the nation's timber (ABS ^c).

2.1.3 Environmentally Sustainable Development – ESD

The importance of ESD itself to the future of our nation cannot be underestimated. Based on the U.S. experience, green buildings will and do:

- Save energy. About two thirds of electricity and over one third of total energy used in the U.S. is consumed in buildings. Efficient new buildings are saving 70 to 90% of this traditional energy use and contrary to popular myth often several percent in capital cost. In addition they have the economic benefit of typically selling or leasing faster, better retention of tenants due to superior amenity and comfort and lower operating costs. All of which enhance financial returns.
- Save Water. Saving water through the use of efficient plumbing fixtures also reduces overall energy use while potentially eliminating the need to dam new rivers or increase existing catchment areas and create or increase water and waste water treatment facilities.
- Improve Labour Productivity: On average Americans spent 80 to 90% of their time indoors. Green buildings have superior visual, thermal and acoustic comfort which creates a low stress, high performance environment. Research in the U.S. and Europe shows improved productivity and a reduction of absenteeism for those working in green buildings both in office based work and manufacturing along with improved retail sales in 'green-built' retail buildings (particularly related to provision of naturally lighting). These improvements create a unique competitive advantage and further improve real estate value and market performance.
- Improve Health: The U.S. EPA estimates that building related illnesses in the U.S. account for \$60 billion of annual productivity lost

nationwide. A wider study valued that lost productivity in excess of \$400 billion. Enhanced indoor air quality improves health and productivity and reduces liability risk.

- Provide Pollution Reduction: One unit of electricity saved saves three to four units of fuel (usually coal) at the power plant. In turn there is less emission of the principal greenhouse gas CO₂, along with SO_x and NO_x gases which contribute to acid rain.
- Protect the Environment: Poorly (commonly) designed or situated buildings scar the landscape physically and visually, seize precious agricultural and pastoral lands and afflict or destroy wildlife habitat and native flora. Inversely ESD allows for restoration and enhancement of habitat and considers the long term aspects for essential agriculture and the alteration of existing landscape and natural water paths.
- Enhance Security: In the U.S. the construction of buildings consumes one quarter of all harvested timber; Worldwide construction annually consumes 3 billion (thousand million) tons of raw materials. Green buildings reduce the dependence on precarious resource imports and dwindling world supplies of resources and hence have the potential to improve trade balance and competitiveness, and create a fairer, more resource-abundant world.

(Barnett and Browning, 1998; Hawken, Lovins & Lovins, 1999)

Typical American offices spend about one hundred times the amount per square meter for people (payroll with on-costs and individual equipment) as they do for energy. Yet the above benefits are an untapped source of savings for companies. Well measured case studies in Europe and the United States consistently show gains in labour productivity in the range of 6 to 16% when workers are thermally comfortable, can see better and can hear themselves think. If labour productivity increased just one percent in the typical American office this will produce the same bottom line as entirely eliminating the energy bill (Hawken et. al., 1999). At the bottom end of proven productivity gain (6%), any office working company could allow six times their annual energy bill (averaging \$400,000 for large firms in Australia - typically 4% of total operating cost (ABS^b) to be invested in an ESD retrofit to the building and have it paid back in the first year through productivity gains.

Australian research, limited as it is, shows similar results. Industry experience in the commercial building sector plainly indicates that operating energy improvements between 30 and 70% on current industry practice can be readily achieved. In Australian commercial office buildings the average lighting energy is about 16 W/m². With the use of current technology this could be halved to 8 W/m² and emerging technologies would bring this down to 5 W/m² without reduction in lighting quality (Bell & Fawcett, 2001). This is a direct saving of millions of dollars to building owners and occupiers and remembering that one unit of energy saved at the users end is three to four units saved at the power plant (Barnett, 1998) is an enormous saving to our environment in greenhouse gasses.

2.2. Economics - The Residential Sector in Context

When considering the commercial/industrial sector compared to the residential sector the following habitually come to mind:

- The often large physical size difference in individual projects.
- The often vast size of budget differences in individual projects.
- The often massive difference in annual budgets and turnovers.
- The comparatively limited number of organisations involved in commercial work, and;
- The often enormous size difference of the involved organisations.

There may even be a perceived difference in the professionalism of the individual organisations involved in the two sectors. Given all these factors one could soon be forgiven for thinking just how small the residential sector is compared to its big brother in commercial/industrial construction.

Certainly construction itself is large enough. In Australia, the property and construction industry make up approximately 14% of gross domestic product (Hampton, 2004). This combination makes the largest contribution to national GDP of any industry, even coming in ahead of manufacturing at around 11% (Australian Bureau of Statistics ^d). There are 250,000 businesses employing 750,000 people. 94% of businesses employ less than 5 people (Hampton, 2004). Here in Queensland as at May 2004 the construction industry employed 118,000 people (Australian Bureau of Statistics ^e), over 7% of all people employed in the state.

The key figures of building activity in Australia for the quarter ending March 2004 show that approximately \$12.1 billion (thousand million) worth of building work occurred in that three month period. Of that \$12.1b approximately \$7b was new residential building, \$1.3b was alterations and additions to residential buildings and \$3.8b was non-residential work (Australian Bureau of Statistics ^f). Historical data shows the residential sector to be approximately 60% and upward of all building in Australia (Australian Bureau of Statistics ^g). In the March 2004 quarter the residential industry was approaching 70% of all construction work by value.

2.3 TO WHAT END?

The residential construction industry is a massive component of society and the economy. It has a huge direct influence on our environment and an indirect influence that is incalculable. Those associated with the industry are probably familiar with its environmental affects in things such as: land degradation, loss of agricultural land, the problems of expanding hard surfaces, effluent disposal, waste materials, destruction of native forest and habitat, natural water course degradation, chemical hypersensitivity, greenhouse gas emissions, excessive energy and water consumption, the social ills created through poor suburban design and so on. The individual problems often seem endless. In many cases the industry is acting to find and implement solutions to the individual problems. But how often do we step back and look at the whole issue in context.

Although unsustainable buildings' harm may appear to be localized, it actually ripples outwards, sometimes for thousands of miles. Philippine forests are clear-cut for plywood used to build offices in Japan, where sheets used to form concrete are typically thrown away after one use. Homes in Southern California are framed with old-growth lumber from Washington and powered by

burning coal strip-mined from Navajo sacred lands in Arizona. Ultimately, the costs of poor design are borne not solely by a building's owner and those who work and live there, but by everyone.

(Barnett & Browning, 1998)

The changing nature of Australian society to a greater environmental awareness is statistically shown by huge growth in recycling (ABS ^a) and increased government expenditure on reduction and repair of environmental degradation. It can further be evidenced by the increased number of seats for the Greens in the last Federal election; the number of green issues on the political election agenda compared to past decades (Murray River, Tarcine Forest, Tasmanian timber industry etc.); changes to the BCA, thus legislating for energy efficiency requirements in buildings; the NSW governments legislation of the BASIX concept for reduction of water use and greenhouse gas emissions in housing; etc.

With the continuing swing in attitude the residential building industry will by force of law or force of economics be required to move towards serious implementation of ESD as time goes by. The choice now remains for it to lead or to follow. One of the oft quoted reasons for the failure of industry to move itself towards a large scale implementation of ESD is lack of consumer demand.

1998 research by ABARE (in Australian Bureau of Statistics ^b) showed that for Australian firms economic factors such as insufficient rate of return and overly long payback periods were the most common reason for not implementing energy efficiency changes. Nonetheless, 81% of all energy efficiency recommendations within Australian firms were implemented.

Lack of consumer demand is often put down to the aforementioned economic principles. However, as shown in Section 2 insufficient rate of return and lengthy payback periods are generally a misnomer. In the residential sector it would seem highly unlikely that the client would usually even be aware of such concepts.

The residential sector is a massive element of society at large. The overseas experience and Australian research shows that ESD done properly provides huge economic and social gains with no outstanding downside. Nonetheless, the Australian construction industry has failed or refused to pick up the golden ball and run.

The purpose of this research is to consider this issue from the client-side of the equation. The intent is to identify the factors influencing client decision making in relation to ESD in the residential sector. If these factors can be accurately identified they can then be utilised for the benefit of future clients, the environment, and the Australian construction industry.

The remainder of this paper provides a preliminary, general summary of important points in relation to client decision making taking evidence from the disciplines of psychology, marketing and economics.

3. THE CLIENT SIDE

A seriously in-depth consideration of the literature available considering the relevance of marketing, psychology and economics, all of which are interrelated in this context, can not even be considered given nature of the paper. The following is a summary of a few of the major points in relation to these.

3.1 MARKETING – INDUSTRY AND THE CLIENT

Consider the following:

<i>In Selling</i> <i>Emphasis is on the product</i> <i>Company first makes the product and then figures out how to sell it</i> <i>Management is sales volume-oriented</i> <i>Planning is short-run oriented, in terms of today's products and markets</i> <i>Needs of sellers are stressed</i>	<i>In Marketing</i> <i>Emphasis is on customers wants</i> <i>Company first determines customers' wants and then figures out how to make and deliver a product to satisfy those wants</i> <i>Management is profit-oriented</i> <i>Planning is long-run oriented, in terms of new products, tomorrow's markets and future growth</i> <i>Wants of buyers are stressed</i>

(Miller & Layton, 2000)

The difference between selling and marketing could be considered purely semantic. From a certain perspective it is, however, in context it is both conceptual and material and using Miller's cross referenced definitions above it is plain to see that the Australian project home industry is involved in selling, not in marketing. The project home industry is successfully designing the product first and providing the sales push second with only superficial consideration of customer wants. Management is very much sales volume oriented, the sellers' needs are paramount and apart from turning the house into another disposable product there is no thought given to the longer term future. The residential industry, with minor exceptions, tells the client what they can have and then cleverly gets them excited about having it. What residential investor would not desire to have increased occupancy levels by design? What owner occupier would not want the benefits of vastly reduced life cycle costs that come into effect from day one at potentially no extra capital cost? It is rare to see the industry go beyond the usual, "Would you like fries with that?" approach to residential client needs.

Miller & Layton (2000) also make the following pertinent observations:

"In the 1990's, many Australians are placing a greater emphasis on the quality of life rather than on the quantity of goods consumed. The theme is 'not more, but better'. High on the list of what people consider integral to quality of life is the natural environment. Thus, we hear more concerns expressed about air and water pollution, holes in the ozone layer, acid rain, solid waste

disposal and the destruction of rainforests and other natural resources. These concerns have raised the public's level of environmental consciousness.

The proportion of consumers who are concerned about the environment is growing. In 1994, a study in Australia found that 85 per cent of the sample believed that all individuals had a responsibility to care for the environment. A further 80 per cent indicated that they had modified behaviour including purchasing for environmental reasons. However, it is important for businesses to remember that to satisfy 'green consumers', a product must also be competitive with alternatives on factors such as price."

The famed playwright George Bernard Shaw once commented, "Few people think more than two or three times a year; I have made an international reputation for myself by thinking once or twice a week." Ensuring the competitive nature of green building can take considerably more mental effort in the design stage but other than a level of thought that goes well beyond the accepted practice of project home builders there is nothing to increase the complexity or price of ESD over and above standard thoughtless design.

The marketing industry recognised the shift in consumer sentiment towards environmental concern a decade ago. The building industry has had to have it legislated to make small shifts in a direction the clientele already want to move. In commercial construction it is possible that given the size of individual budgets and the one-off nature of the work (even more so than residential) that industry invests the time with the client to find out what the actual needs are and how they might best be met. However, it is evident that the residential industry is self-serving in nature and fails en-masse to seriously consider or deliver client needs from a true marketing perspective.

3.2 ECONOMIC PSYCHOLOGY

It is essential to understand that psychologically speaking there is a difference between cognition, attitude and behaviour. Cognition covers our ability to understand, to develop knowledge; our thought processes in relation to an object or action. Attitude is, separately, how we feel about an object or action, our mental response to it or our opinion of it. Behaviour, separate again to cognition or attitude, is the actual conduct we take in relation to the object or action. The most important point which differs from traditional psychological theory (from the 1930's through to the 1970's) is that attitude and behaviour are only linked very loosely if at all. A considerable amount of work by the likes of Fishbein and Wicker has proved the attitude-behaviour link is very weak indeed (Foxall, 1997; Eagley & Chaiken, 1993).

The human ability to understand a concept (cognition) does not mean that he or she will actually believe it (creating attitude). "Selective distortion tells us that marketers cannot assume that a message, even if factually correct, will necessarily be accepted as fact by consumers. In designing a message, the distance between the audience's current belief and the position proposed by the message must be considered. If the distance is large, a moderate claim may be more believable than a dramatic claim, and therefore more effective in moving consumers in the desired direction" (Miller, 2000). Everyone at one

point or another has made a statement of fact to someone only to have it dismissed as being false. Religion and science were for some centuries at loggerheads over the difference in belief and cognitive knowledge, the flatness of the world being a prime early example.

The difference between attitude and behaviour is constantly borne out in general society. They are the minor hypocrisies that we all see in others or indulge in ourselves. It is the morally righteous who puts forth certain philosophies to others but fails to consistently live them personally. In the environmental context it is when someone espouses green ideologies or simply bemoans the waste in society and then throws an aluminium can or a newspaper into the standard household waste because the recycling bin is outside. As most people are guilty of both of the above at one point or another it is easy to understand the limited connection between attitude and behaviour.

4. CONCLUSION – THE RESEARCH TO COME

The summaries given have only provided a shallow smattering of a bulk of fascinating research into the viability of ESD and into consumer behaviour and what leads may be drawn on for further research as to what indeed influences client decision making in relation to ESD in the Australian residential construction industry.

The particular importance of the anomaly discussed in Section 3.2 is to the upcoming research. In discerning the factors influencing client decision making the research must endeavour to uncover at what level (cognition, attitude or behaviour) the breakdown occurs. Current evidence (Section 3.1) would suggest that there is some form of breakdown in cognition. How broad and how influential this is remains to be seen. If the breakdown is minimal at this level at which of the other two levels does it occur and once again, how broadly does it occur and how influential is it?

Given that ESD is proven around the world to be environmentally beneficial and economically viable, and; given that some years ago the marketing industry recognised the now statistically proven consumer move towards environmental sensitivity and altered its technique accordingly for many products; what has been the block to change in the project home market? Can we discover it from the consumer end? If so, can we alter this condition? By better understanding the factors affecting client's decisions in relation to ESD we can move toward providing a consistent industry led change for the betterment of our environment and the future security of our residential industry.

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CLIENTS DRIVING INNOVATION

Case Study

SOURCES AND EFFECTS OF UNCERTAINTY IN THE MANAGEMENT OF CONSTRUCTION PROJECTS: FEDERATION SQUARE

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ABSTRACT

Construction projects have an unmatched level of expertise gained through thousands of years and boast an array of planning and controlling techniques. Still, many construction projects are frequently delayed. This research explores the sources and effects of uncertainty in construction projects as the ultimate reason for project delay. The thesis tested by this research was that projects can only be managed to a certain point due to uncertainty. Because of this limit to managing projects, they are frequently delayed in spite of the implementation of best practice in construction time performance and the effort put into projects by its managers and team members.

Keywords: Project Management, Construction, Uncertainty, Federation Square

1. INTRODUCTION

The construction industry represents a sound percentage of the gross domestic product in Australia, 5.5% of all industries (AusStats, 2002), is the oldest project based industry¹ and uses state-of-the-art management and controlling techniques. Still, on-time completion of projects has always been an irritating concern (Hormozi and Dube, 1999).

If construction projects have been done for quite long time and are so relevant for our culture and economy, why have we not yet mastered a flawless technique for completing construction projects on time? The answer may be "*because we cannot*".

As in *figure 1*, projects can be plotted in reference to their success on a line with two opposite points: *complete project failure* and *complete project success*. Whilst the former refers to projects not being able to finish on time, to cost and quality, the latter contains those finishing on time, on budget and quality. While some projects fail, the use of sound project management tools and techniques allow project managers to lead projects closer to the *complete success* end. However, there is a limit to how close they can get to this end.

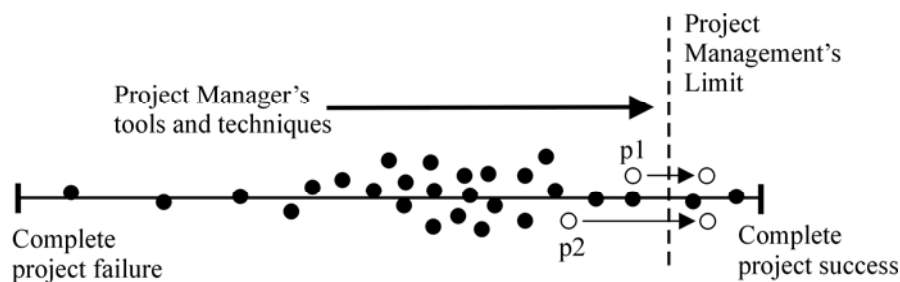


Figure 1: Project Management Limit

All projects between *complete project failure* and *project management's limit* vary only in how well they were managed and planned. However, the reason why some projects cross the *project management's limit* is because it is a possible outcome. That is, whilst a project manager's duty is to take projects as close to the *limit*, the fact that project *p1* crosses it, it is just because of chance. Project managers cannot take credit for that.

If chance is what helps projects to cross the limit; uncertainty is what prevent them from crossing it. This uncertainty is in fact a consequences of the physical characteristics ruling the environment in which projects are undertaken.

¹ Excavations at Terra Amata, France, showed dwellings dating from the Palaeolithic period which were built to specifications, involved planning and use of resources. (Fletcher, 1996)

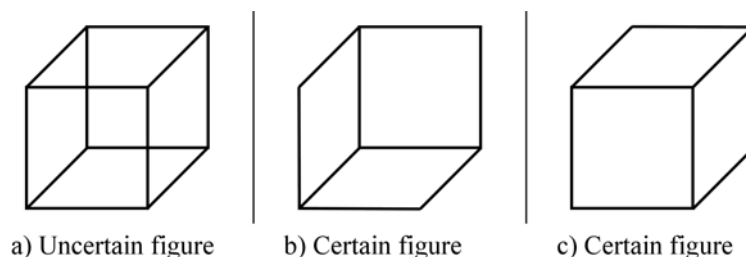
A very common mistake in the management of construction projects is to overlook the uncertain characteristic of the project environment and believe that projects are deterministic.

Determinism is the philosophical belief that every event is the inevitable result of preceding events. Therefore, every event can be completely predicted in advance, or in retrospect. (Coles, 2002) (Hawking, 1989)

For many centuries we believed that we lived in a deterministic world. Newton believed that the universe's behaviour was as regular as a clock work. That is, if the state of the Solar System, at any given time was known, one could predict its state in the future, as well as in the past, with complete accuracy. Nevertheless, in the early twenty century a twist in the scientific knowledge rendered Newton's deterministic model wrong. (Coles, 2002) (Hawkins, 1989)

The lost of a deterministic world not only meant shifting to new formulas or physics theories, it took away the power, or at least the illusion, to accurately predict and therefore manipulate the future. Not to mention the possibility of project managers playing god in their own projects.

Nevertheless, deterministic approaches are the standard on the management of construction projects. (Burke, 1999) It is not easy to leave the comfort of a deterministic world, the project manager dreamed world. However, this might be not only a whim, there are compelling reasons to believe that we have problems understanding, and therefore managing uncertainty. As Gigerenzer (2002) points out, even at unconscious level our perceptual systems automatically transform uncertainty into certainty. The Necker cube, *figure 2*, has ambiguous depth as its two dimensional lines do not indicate which face is in front and which is in back. However, we do not see it as an ambiguous figure, yet we see it one way or the other.



By staring at the cube **a)**, the perceptual impression shifts between **b)** and **c)**.

Figure 2: The Necker cube (Gigerenzer, 2002, p. 9)

If we cannot handle uncertainty, how can we manage projects that are undertaken under an environment that is ruled by it? Physics has proved to us that from the smallest, most elemental particle, the uncertainty principle, to large scale events, chaos theory, our environment is uncertain and produces unpredictable outcomes.

In an attempt to manage uncertainty we rely on probability. Therefore, we can say that a project activity has x% to eventuate. However, accordingly to

Kosko, (1994) probability maths comes from naked assumptions and not from a more general theory. Its axioms can be denied as easily as can be accepted, because mathematicians and scientists have arrive at them by will, by assumption. If you see apples falling from a tree, there is a *probability* that each will fall at a given time in the future. However, if this tree is recorded while its apples are falling and the movie is played backwards, the apple-falling probability never showed up. Where did the randomness go? Whilst probability and randomness is everywhere, we can only find the after-the-fact outcomes of random experiments. We see footprints, we can never catch probability in the act. (Kosko, 1994). In project management terms, once an activity has finished there is no longer uncertainty in its duration. It took as much time as needed and now there is no randomness when explained why it took the time it took.

Probability seems to be a psychological side effect of forward looking creatures. Probability is a physic instinct that help us organise our perceptions and memories and most of all, our expectations. (Kosko, 1994) Only forward looking creatures can conceive a discipline as project management, yet how much is project management possible and how much a created necessity to satisfy our instinct?

2. CASE STUDY: FEDERATION SQUARE



Detail of façade's geometry. Picture taken by Agustin Chevez.

Picture 1: Federation Square

2.1 SELECTION OF CASE STUDY

Whilst any construction project, from a small shed to a gargantuan size project is affected by uncertainty and hence suitable for this research, trying to draw conclusions for a whole group based on a sample demands carefully chosen representative samples, otherwise the information might be misleading. (Becker, 1998) Federation Square was chosen as case study because it is a high profile project, which used best practice for its management which reduced problems produced by poor planning. However, it was submitted to many variables and external pressures that maximised the effects of uncertainty on the project. Federations Square was also selected because research on project delays is difficult due to the fact that delayed projects are companies' well kept secrets. For this reason, information is difficult to access. However, being Federation Square a project under the public eye, its delays were not a secrete. Furthermore, they are well documented on public access information sources.

2.2 PROJECT OVERVIEW

Federation Square is a space that hosts a range of recreational, cultural, commercial, multimedia and entertainment facilities. Federation Square is situated in Melbourne's Central Business District. It is anticipated that 6 million people will visit Federation Square every year. (abc, 2003)

Federation Square is a Victorian Government initiative with support from Melbourne City Council and the Commonwealth Government. It is expected that the total project cost, once finished, can exceed 470 million AUD. (fedsq, 2003)(Misiak, 2003) (Report on Public Sector Agencies, 2003)

In 1988, the Government began the construction of Federation Square, Australia's biggest public project, before the designs were finished. In order to meet the project ambitious timeline, the project needed to be fast-tracked. (fedsq, 2003)

Federation Square was an enormous and challenging project, *"not just because of the scale and cost of the project, but also because of its complexity, its diversity of features, its topical and at times politicised nature as well as the logistics of managing such a large scale project in such a central, visible and contentious location."* (fedsq, 2003)

2.2.1 Timeline

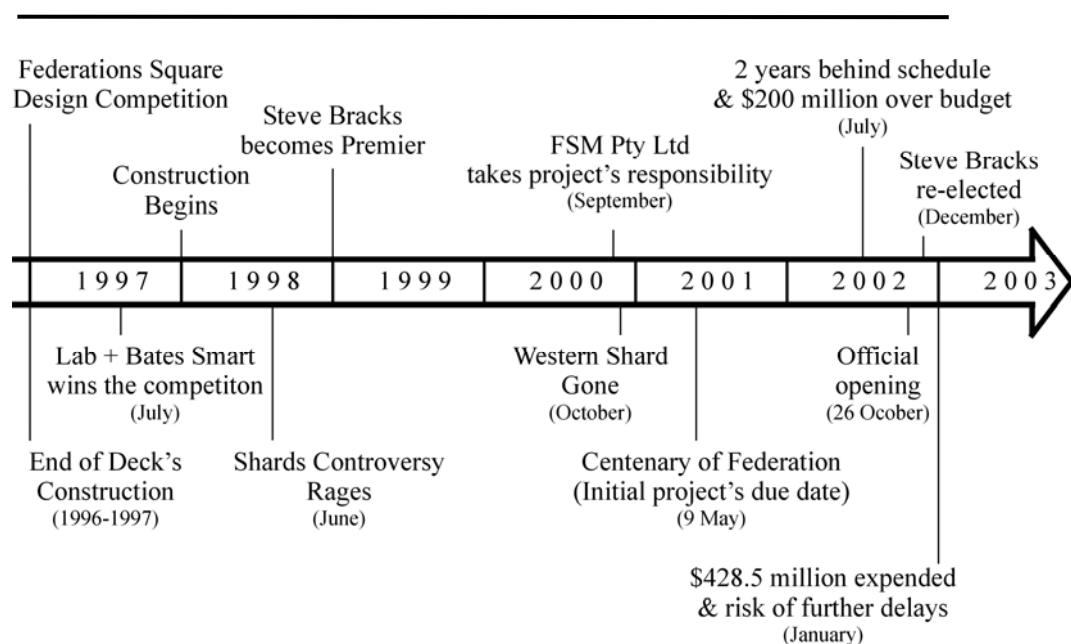


Figure 3: Timeline (abc, 2003)(Fedsq, 2003)(Misiak, 2003)(Report on Public Sector Agencies, 2003)

2.2.2 Political environment

Since its beginnings, Federation Square, was a politically driven project. Things got to the point that the State's Office of Major Project resigned out of

frustration over how the government was handling controversy. (abc, 2003)
(Misiak, 2003)

2.2.3 Financial analysis

The development was expected to cost between \$100 and \$150 million AUD. However, the total cost of the project has reached \$450 millions and is expected to cost \$470 million AUD. Whilst Federation Square is a financial failure, profitability was not the main goal of the project, not even with its initial relatively low cost. (Misiak, 2003)

2.3 QUESTIONNAIRE

A set of carefully designed questions was compose in order to best asses the source and effects of uncertainty in Federation Square. In order to get an holistic perception of how uncertainty was perceived, understood and managed in Federation Square the selection of interviewees included project members from diverse areas. Following are the main 5 areas identified as relevant to the research.(archrecord, 2003)(fedsq, 2003)

1. Civil / Structural (Hyder Consulting, Connell Wagner);
2. Services (AHW Consulting);
3. Architecture (Lab Architecture, Bates Smart);
4. Quantity survey (WTP Melbourne);
5. General Constructor (Multiplex)

Next, are the questions send to 30 project members at different levels from the above companies.

QUESTION I

From the project management point of view, and using the following scale and list, please rank how these listed factors affected the development of Federation Square.

Scale:

- 1 = The factor had no impact in the project.
- 2 = The factor had little impact in the project .
- 3 = The factor had moderate impact in the project.
- 4 = The factor had an important impact in the project.
- 5 = The factor had a decisive impact in the project.

List of factors:

- [] Complexity of the project (Design, construction)

- ☐ Number of stakeholders
- ☐ Political pressures
- ☐ Planning
- ☐ Project duration
- ☐ Unforeseen situations
- ☐ Completion date
- ☐ Other (Please specify): _____
- ☐ Other (Please specify): _____
- ☐ Other (Please specify): _____

QUESTION II

How much do you believe that uncertainty affected the development of Federation Square?

- ☐ It did not affect the development of the project
- ☐ It moderately affected the development of the project
- ☐ It was a major factor that affected the development of the project

QUESTION III

Do you believe that uncertainty in the management of construction projects is:

- ☐ A characteristic of the environment under which projects are undertaken and therefore embedded to all projects.
- ☐ A consequence of poor planning
- ☐ Other (Please specify):

QUESTION IV

Do you believe that projects can be planned to their full extent?

- ☐ Yes,
- ☐ No,

2.3.1 Interviewee response and answers

From 30 questionnaires sent:

- 6 (20%) were answered;

- 15 (50%) were return unanswered because the employee does not longer work in the company. One of the reason for such a high percentage might be that teams could have been dissolved once the project reached certain level.
- 10 (30%) did not reply. The reasons are unknown.

Amongst those who responded were from the areas of:

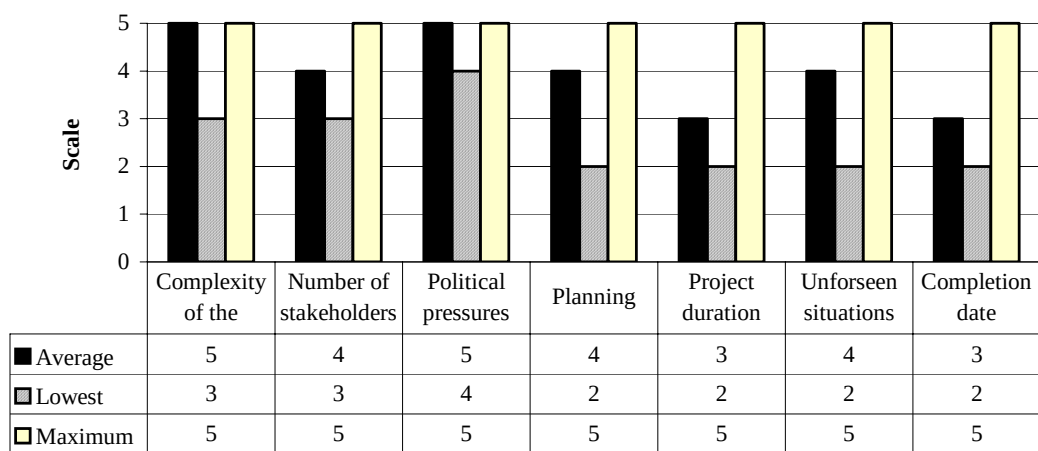
- Civil;
- design; and
- quantity surveyor.

Following is a charted version of the answers to each question.

QUESTION I

Question = "From the project management point of view, and using the following scale and list, please rank how these factors affected the development of Federation's Square."

Table 1: Results Chart 1 - Question I

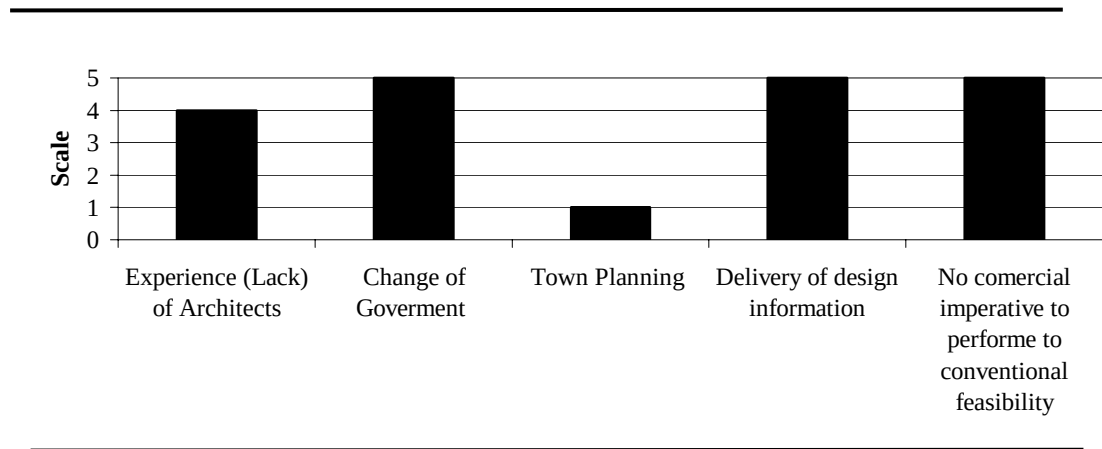


Scale

- 1 = The factor had no impact in the project.
 2 = The factor had little impact in the project .
 3 = The factor had moderate impact in the project.
 4 = The factor had an important impact in the project.
 5 = The factor had a decisive impact in the project.

The following answers were registered in the field "Other (Please specify):" and ranked using same scale as above:

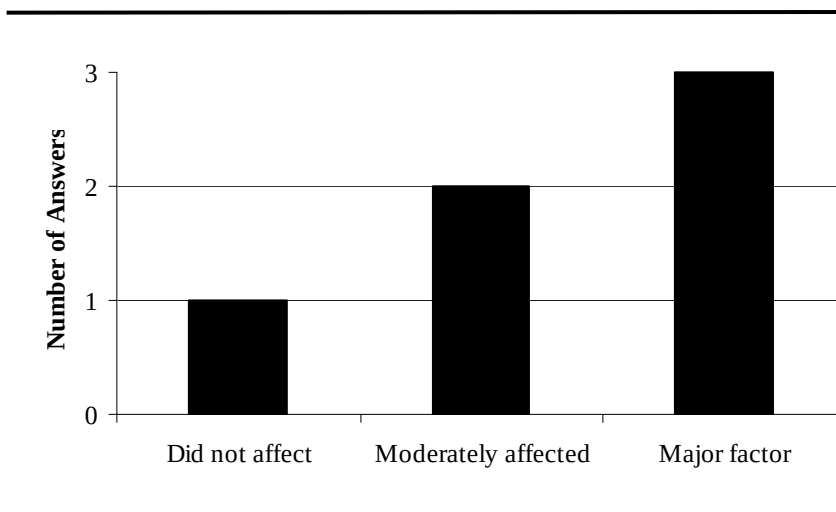
Table 2: Results Chart 2 - *Question I* – Comments to “Other”



QUESTION II

Question = “How much do you believe that uncertainty affected the development of Federation Square?”

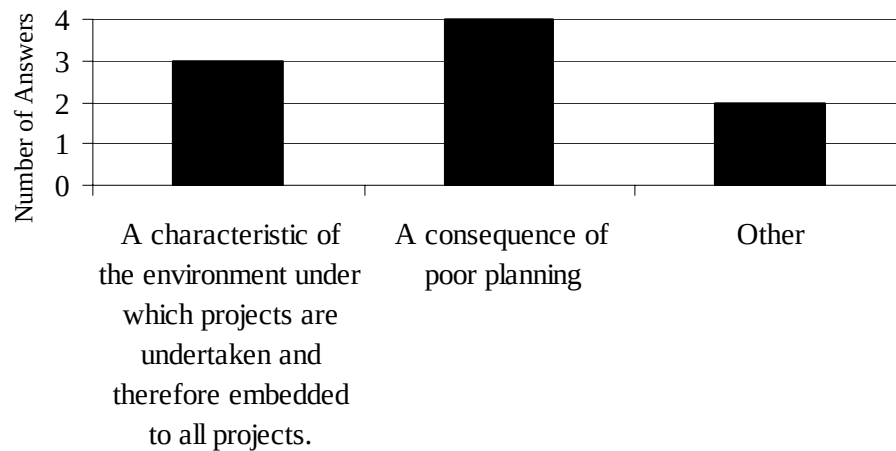
Table 3: Results Chart 3 - *Question II*.



QUESTION III

Question = “Do you believe that uncertainty in the management of construction projects is:”

Table 4: Results Chart 4 - *Question III.*



Some answers registered more than 1 option. Hence the number of answers add up to nine.

Comments on "Other":

- a) *"A characteristic of the nature of the development of large scale projects; however that does not mean it cannot be properly managed, as many projects are delivered without such problems."*
- b) *"Client changes."*

QUESTION IV

Question = *"Do you believe that projects can be planned to their full extent?"*

Table 5: Results Chart 5 - *Question IV.*

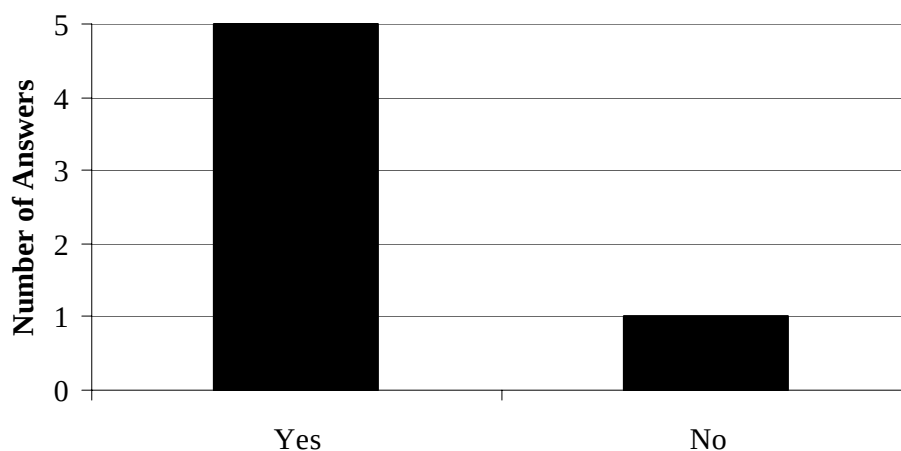


Table 6: Results Chart 6 - Question IV – Comments on “YES” / “NO”.

Comments on “Yes”	Comments on “No”
“With proper briefing, team work, adequate time & cost.”	“Too many external variables. However planning (ongoing!) is important to the success of a project”
“But the management of the planning in practice is more complex than the theoretical planning.”	
“A commitment by the client and all team members to apply appropriate resources and management throughout the project is an essential ingredient for large scale projects.”	

2.3.2 Analysis of results

As previously commented, the political pressures and complexity of the project were two major factors that affected the development of the project. However, in every answered questionnaire, every single option (*Complexity of the project, Number of stake holders, Political pressures*, etc.) was ranked as a factor that had a decisive impact on the project. This denotes that project's threats are perceived differently accordingly not only to the person, but to the role he/she plays in it as different responses were provided accordingly to this latter attribute. Hence, each project member will have a different conception on the uncertain elements of a project.

Uncertainty played an important factor in the development of the project as 50% considered that it was a “Major factor” and 33% that it “Moderately affected” the project. Only 17% (one answer) considered that it did not affect the project. Again, it could be said that, as explained above, the impact that uncertainty has on the project depends on the person and his/her role on it.

The fact that the answer that registered the most responses on *Question III* was “A consequence of poor planning” denotes that there is a feeling that projects are deterministic. The rational behind this idea is that if everything is correctly planned there will be no uncertainty. However, there is a paradox between the results of *Question II* and *Question III*. Whilst *Question II* claims that uncertainty played an important factor in the project, *Question III* assures that if a project is properly planed you avoid uncertainty, yet how can you plan for uncertainty if you believe that projects are deterministic?

On the same question, *Question III*, the answers to the field “Other”: “[Uncertainty is] A characteristic of the nature of the development of large scale projects...”denotes that there is a direct relationship between the size of the project and the level of uncertainty.

With more than 80% of the interviewees believing that projects can be planned to their full extent, *Question IV* confirms the idea that projects are deterministic. However, the comment section explains the complexities of project planning. One particular comment “But the management of the planning in practice is more complex than the theoretical planning” indicates that today's tools are not suitable to manage the complexities of the real environment under which projects are undertaken.

In one way or another, the answers to all questions indicate that projects are affected by uncertainty, yet it is still believed that projects are deterministic. It is also clear that the sources and level of impact that uncertainty has in the project is perceived differently from person to person.

3. CONCLUSIONS

Thinking that we live in a deterministic world whose future we can control is a very comfortable and luxurious point of view. Today's construction industry is paying a high price, millions of dollars in delayed projects, for maintaining this level of comfort and Federation Square was not the exception.

It is obvious that mankind, in one way or another, has found its way to overcome uncertainty and materialise his projects 300,000 years ago, way back before the words "project" and "management" were put together. Further, ironically it can be said that thanks to uncertainty more projects have been constructed. If not, what were the odds of Federation Square ever being built if stakeholders would know beforehand it would take 2 more years and over \$450 million dollars to build it? Uncertainty buffers reality and allows us to undertake projects we would otherwise reject.

Once a project has finished there is no uncertainty in it, but it is also no longer in the project manager's hands. Nevertheless, while it is still in the project manager's domain, uncertainty is constantly shaping the project's future.

Whilst challenging, uncertainty gives the essence of life to the project management practice and the construction industry can dramatically improve its performance by understanding better the environment under which its projects are undertaken.

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CLIENTS DRIVING INNOVATION

Case Study

WEB-BASED COLLABORATION TOOLS FOR THE CONSTRUCTION INDUSTRY: THE JOHN HOLLAND EXPERIENCE

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ABSTRACT

John Holland and other companies in the construction industry are in the early phases of implementing Web-based collaboration tools across their businesses. John Holland has taken the decision, along with a group of 5 other major contractors, to commit to using Optus inCITE. Optus inCITE is a neutral construction industry trading exchange that is available to the construction industry as a whole, and which comprises the three applications that are grouped under a single portal. Those applications are:

- Purchasing – an on-line purchasing system
- Tender Management – e-tendering and subcontract management
- Document Management – on-line management of documents and communication

This paper looks at John Holland's experiences in implementing Optus inCITE applications in its businesses.

Keywords : **Web-based, Collaboration, Documents, Tendering, Purchasing, inCITE**

1. INTRODUCTION

John Holland is committed to develop the appropriate use of Optus inCITE applications throughout its businesses and to promote Optus inCITE in the construction industry as a whole. It is therefore Optus inCITE which has been, and will continue to be, the main focus of our exploration and implementation of Web-based collaboration tools.

All the same, many of the features of Optus inCITE applications and the issues relating to their implementation will be in common with other Web-based collaboration tools.

1.1 BACKGROUND TO OPTUS INCITE

The concept behind Optus inCITE was developed by CITE Australia Pty Ltd (CITE). CITE was formed by a group of seven major contractors who came together with the specific purpose of establishing an on-line trading exchange for the construction industry. The seven contractors were Barclay Mowlem, Baulderstone Hornibrook, John Holland, Leighton Contractors, Thiess, Walter Construction and Transfield (the construction businesses of Transfield were later acquired by John Holland). The concept was for neutral trading exchange which would cater for the construction industry as a whole; accessed through a single Web-based portal. It was intended that the trading exchange would provide services such as on-line applications for communication, document management, procurement, industry publications, discussion forums, project and tender opportunities, and company information; all of which could be customised by the users depending on their requirements.

After a lengthy process of requesting proposals, analysing proposals and negotiating the details, CITE signed an agreement with Optus in October 2002, and Optus inCITE went into development. Under the agreement Optus committed to develop, own and operate the trading exchange; to market it to all sectors and participants in the industry, to provide training and support, and to continue development of the exchange to meet developing industry needs. For their part, the CITE companies agreed to sign off on and test the software, participate in marketing programmes, assist with further development of the exchange, promote internal use of the system, and encourage wider use to other sectors of the construction industry, with the intention that Optus inCITE should become an industry standard.

Optus inCITE came on-line in May 2003 bringing together three initial applications within one portal, and they are available to the Australian construction industry on a pay-for-use basis.

1.2 THE APPLICATIONS

The initial applications selected for incorporation into Optus inCITE were Tender Management, from EU Supply of Sweden; Purchasing, from Conexa of New Zealand; and Document Management, from AEC Communications of Germany. These applications are accessed through a Web portal designed exclusively for Optus by Hothouse of Australia.

1.2.1 The Portal

The Web portal is the single point for access, registration and administration for the trading exchange. Once logged onto the portal, users can see the various applications for which they are registered and can readily move between them.

1.2.2 Purchasing

The purchasing application (Purchasing) is an on-line system for both buyers and suppliers. It provides catalogue-based purchasing, issuing and receiving of requests for quotation, purchase order management and invoice matching.

The application can be customised to reflect the workflows or approval process of each company or business unit. Whilst a single set of catalogues may be used for a particular supplier, each purchasing company can maintain their own price list and terms. This allows each company to negotiate national and regional agreements with suppliers, and to make those agreements automatically available to all the purchasers of that company.

1.2.3 Tender Management

The tender management application (Tender Management) covers both estimating and procurement phases of a project. Drawings and documents, electronic bills, and electronic question and answer forms are distributed to invited responders (contractors, subcontractors and suppliers) through the portal. These responders then indicate their interest to quote, compile their quotations and responses, and submit their quotations directly through the portal. When the quotations are returned, these can be analysed, compared and approved. The packages can then be let on-line or included in a tender. The system can be configured to follow required authorisation processes and it maintains a clear auditable trail of all transactions.

During the estimating phase (or pre-award) of a project, Tender Management is an e-tendering application by which tender documents are distributed to invited tenderers who then submit their tender on-line. It is multi-tiered in that it allows main contractors to receive tender invitations and documents from a client and then to break this information up into packages for quotation by subcontractors or suppliers. This information can be pushed down to further levels in the supply chain. As quotations are received, the main contractor can analyse and evaluate these within the application and include the appropriate prices and details in the final submission to the client, or the subcontract package to be let.

As a procurement (or post-award) application Tender Management generates invitations to subcontractors and suppliers to quote for discrete packages of work which, once returned, are analysed and awarded to successful bidders. Tender Management also incorporates a contract management module with which a commercial team can continue to manage the subcontract or supply agreements through the construction process.

Tender Management provides for tight version control with all parties looking at the same documents or sub-set of documents in the portal. When addenda are issued to the main contractor and the relevant documents are replaced on the system, the system will identify those subcontract packages that included documents which have been amended. Notifications of revised documents (addenda) can then be sent automatically, and acknowledged by the recipient. The entire process can be monitored and traced.

1.2.4 Document Management

The document management application (Document Management) provides on-line management of documents and drawings, and any required types of formal or informal communication. It supports collaboration by managing the workflows between clients, consultants, contractors, subcontractors and any other stakeholders in a project.

The application is fully configurable to suit project management procedures, approval and verification processes, and distribution and access rights (security). It is a fully collaborative system, in which each individual participant has their own identity, responsibilities and access rights in accordance with their role in the project and the company under which they are registered. Users only see documents or document types that are applicable to them as defined by the configuration, in other words, those for which they have been included in the distribution or given access rights.

All the data are stored and secured and in a single, third-party data warehouse which is owned and operated by Optus. This is a Government A1 accredited site.

Document Management provides for full traceability, identifying documents that have been received and opened, and providing a detailed reference of the document process (document history). It also provides strict version control of documents. Given the configurability of the system and its ready accessibility from any location, it is particularly powerful for use in joint ventures, alliances and projects involving a collaborative design and construction.

2. JOHN HOLLAND'S USE OF WEB-BASED COLLABORATION TOOLS

Whilst our initial focus has been on implementation of Document Management, John Holland intends to develop the use of all three Optus inCITE applications.

Figure 1 below illustrates the fit for the three applications and their various uses across the life-cycle of a construction project.

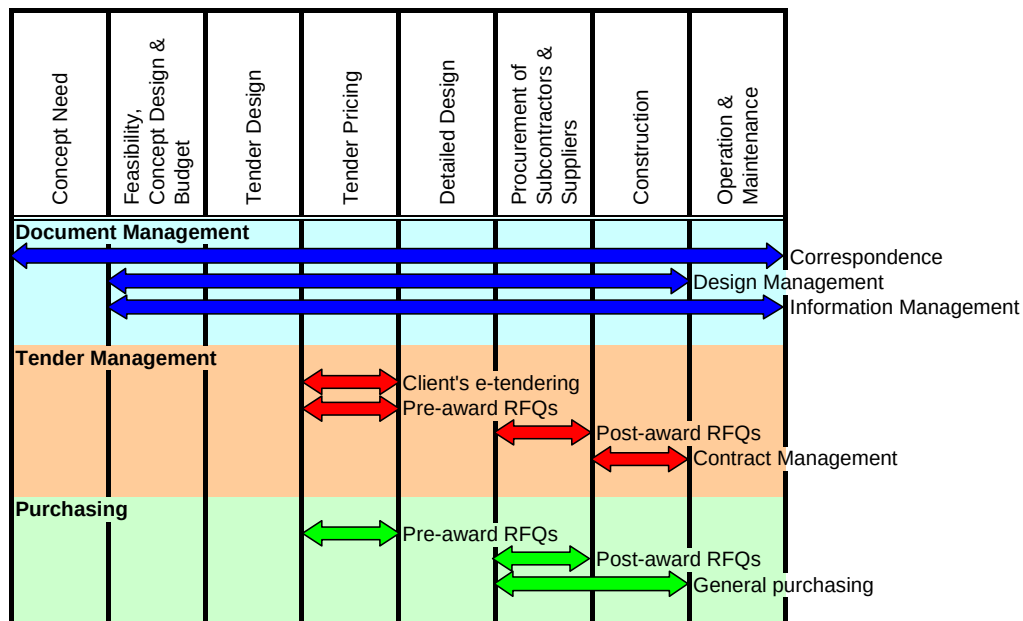


Figure 1 – inCITE Application Fit to Project Life-cycle

2.1 PURCHASING

John Holland's involvement with Purchasing has been limited to date. Supplier adoption meetings have been conducted with major suppliers of John Holland and the other CITE companies, but up-take has been slow. The main reason for this is a "chicken and egg" situation where suppliers are reluctant to come on board until the major contractors are using the system; and major contractors will not commit until the suppliers are trading. However, CITE Australia is committed to developing the use of Purchasing, and the uptake of the system is gaining momentum. Two of the CITE companies have already developed an interface with their back office applications.

There are also cultural barriers that are hindering the implementation of the purchasing system. Potential users perceive that there will be a loss of face-to-face negotiation between supplier and contractor, and that they will have reduced involvement in the selection of preferred suppliers for a project. However, using the application does not affect the way in which deals and agreements are negotiated, and there is no reason why projects should not play a key role in selecting their suppliers, as they do under existing systems.

Some site personnel are not comfortable with using an electronic on-line system for purchasing, or they feel they are too busy to raise orders through the system and would prefer to use the phone or fax. Raising orders through the application at point of purchase saves administration time as well as providing project management with accurate cost commitments. However, the system does not preclude site staff from using the phone or fax to place orders as long as this meets with the approval of project management, and someone is given the task of raising the necessary purchase order number on their behalf.

John Holland is preparing to commence pilot use of the system at selected offices and sites in the near future.

2.1.1 Purchasing: Summary of Findings

Purchasing provides a platform that ensures site staff are placing orders with pre-qualified and approved suppliers, using project or company negotiated prices and terms, adhering to formal approval cycles, controlling receipt of goods and keeping an accurate and up-to-date record of commitments. Purchasing will streamline order and invoice processing across all purchasers and suppliers, and will reduce errors and time spent with administration as the application can be integrated into back office systems.

2.2 TENDER MANAGEMENT

John Holland has started using Tender Management in both pre and post-award phases of a project for issuing tender invitations, asking pre-qualification questions, and distributing documents and addenda. At this stage the system has not been used by a client to issue a tender to main contractors, however, the Roads and Traffic Authority (RTA) of NSW is intending to run a pilot tender in the near future.

2.2.1 Use of Tender Management in the Estimating Phase (Pre-Award)

There is a common belief that many subcontractors and suppliers will not use collaborative Web-based tools because they are not technologically able. Moreover, many estimators believe that during the tender phase we are not in a position to demand responses to requests for quotation on-line, or in a prescribed format – that we need the best offer irrespective of the way in which it is submitted.

There is evidence, however, that subcontractors and suppliers are not as technologically backward as the industry perceives. A research paper by Brad Marriott, from John Holland's Newcastle office, aimed to understand the level of acceptance and utilisation of information and communication technology by subcontractors and suppliers.

Brad Marriott sent out a survey questionnaire to 180 businesses supplying goods or services to the construction industry in the Hunter region of NSW. He received 111 completed responses and discovered that of the respondents:

- 95.5% had access to or used a computers at work;
 - 89.6% used a computer at least once a day;
 - 94.3% had internet access at work; and
 - 89% considered their level of computer experience was at general level or higher
- (Marriot, 2004).

John Holland's NSW/ACT branch has run eight tenders in the estimating phase using Tender Management. They have taken a conservative approach

by focussing on the industries involved in the supply and installation of building services (lifts, fire, hydraulic, electrical and mechanical services). It appears there is a greater acceptance for Web-based collaboration amongst this group.

The experience of using Tender Management in this way has been positive. The building services manager from NSW/ACT branch is very supportive of the application and intends to continue to use it on all suitable tenders. The benefits he has noted include:

- immediate notification when someone agrees to tender;
- fast distribution of documents; and
- quick and reliable management of addenda or changes.

Tender Management enables the tender team to separate the particular documents required to tender from those documents which supply additional information. This has meant that subcontractors are not wading through volumes of paper to find what is required. However, if a subcontractor wants to access more information it is readily available.

We have found that some subcontractors have problems downloading and printing the tender documents from the system, often due to their limited printing capability. There has recently been functionality added to the system that allows the subcontractors to simply choose a print bureau, select the documents they want printed, and produce a print order on-line. They will then receive hardcopy of the documents they want.

Another area where Tender Management has been deployed in the estimating phase is with Defence Maintenance Management (DMM), a joint venture between John Holland and Multiplex. In this instance Tender Management was firstly used to issue prequalification questions to gauge which packages subcontractors were interested in. This prequalification method was used as a way of getting the subcontractors registered and familiar with the system before the invitations to tender were issued. Out of 54 subcontractors 44 answered the prequalification successfully on-line.

Based on the subcontractor's response to the prequalification, packages were then issued in the same manner. Of the 64 subcontractors who accepted packages to tender, 25 used the entire process by submitting an electronic quotation. In the case where the subcontractors chose to submit quotations by other means, they still needed to use the system review documents and bills of quantities. The remaining 37 preferred to stick with the traditional method of submission.

The Tables 1 and 2 below summarise the on-line activity for the DMM tender:

Table 1: Response to Invitation to Prequalify

Description	Number of invitations	Accepted	Declined	Answered Questions On-line
Prequalification Questionnaire	54	47	0	44

Table 2: Response to Requests for Quotation

Description	Number of invitations	Accepted	Declined	Quotation Submitted On-line
Package A	26	18	0	3
Package B	15	11	0	5
Package C	19	13	0	4
Package D	5	1	1	0
Package E	6	4	0	2
Package F	11	4	0	2
Package G	21	13	1	9
TOTAL	103	64	2	25

This tender was in the rural area of the Riverina/Murray Valley in NSW, and indicates that, in this area at least, subcontractors do have the means to use the internet for business. One subcontractor indicated that DMM appeared more professional and organised than the other contractors by using on-line tools; that the information was presented in a clear format and was easy to find. The DMM team saved time by centralising their administration and the system gave them tight control over the process. The system kept them up-to-date with a subcontractor's progress and every transaction was fully traceable.

2.2.2 Use of Tender Management in the Procurement Phase (Post-Award)

DMM has also run a pilot using Tender Management in the procurement phase. All subcontractors used the system to accept the invitation to tender and to collect their documents. The Project Manager recorded his and the subcontractors' experience in a report which was generally positive.

All the subcontractors believed the system was beneficial to them. One subcontractor in particular noted that its team had increased confidence that they were working off controlled documents, that time was saved in not having to prepare multiple hardcopies, and that they could deliver responses back to the Contractor with ease.

(Young, 2003)

2.2.3 Tender Management: Summary of Findings

The immediate strength of this application is for efficient distribution and control of documents and addenda. As the industry becomes more familiar with collaborative tendering, the capabilities of the application can be more fully utilised, and the added benefits will be:

- receipt of quotations in a consistent format;

- efficient analysis and comparison of quotations within the application;
- direct transfer of selected prices and details to the main tender or subcontract documents.

Time is always of the essence to a contractor during a tender, and time saved by more efficient receipt and distribution of tender documents, and analysis of quotations can be utilised for engineering, innovation and other refinement of the tender to the client.

2.3. DOCUMENT MANAGEMENT

As mentioned above, the majority of John Holland's effort to date with the inCITE applications has been directed towards Document Management.

There has been cultural resistance to using a structured, on-line tool such as Document Management. We believe that this is largely due to current proliferation of unstructured e-mail communication, and unfamiliarity with a truly electronic system. Users need to be made aware of the importance of competently capturing and recording project communication, and trained to understand the concept of the system as well as how to operate it.

In General, the collaborative features of the system have been accepted quickly as all stakeholders in a project can readily appreciate the benefit of communicating and sharing documents on the same platform, and being able to access the system in real time from any location.

John Holland has used Document Management in a variety of situations; for tendering, and on active projects in joint ventures, alliances and on our own.

2.3.1 Use of Document Management on Projects

A joint venture of Thiess and John Holland (TJH) is responsible for the design and construction of the Lane Cove Tunnel (LCT) project. That project has employed full use of the Document Management features. It controls all project communication, design, reference materials, procedures, construction documents, human resources and community issues.

An area where the power of on-line collaboration is particularly obvious is in the design review process. The Document Management application has been configured to manage design distribution and approval processes that involve the consultant, the main contractor, the client's reviewers and the independent verifier. All of these parties are registered to use Document Management and complete all their required actions on line.

The collaborative design review process is based on a combination of a document status and a document naming convention. A document's status is similar to an approval cycle in that it determines the documents progress through the process and can only be changed by authorised stakeholders. For example, only the Independent Verifier can change the status of a document to "Verified".

The file naming convention clearly identifies the design document and its version. All Design Consultants on LCT must upload their design lots through inCITE according to this convention. The file name must include codes for document originator, document type, location, design element, document number, revision and version. For example, the file name: PB-SP-TU-DT00-0058-A-1.pdf indicates the originator is "Parsons Brinckerhoff", the document type is "Specification", the location is "Tunnel", the design element is "Driven Tunnel (General)", the document number is "0058", the revision is "A" and the version is "1".

The reason for this combination of naming convention and status is so the system can organise and automatically distribute the documents through the approval cycle, and also populate the key attributes of the document without the need for manual registration.

When the files are uploaded and assigned a status, the system follows preconfigured rules which dictate to who the document should be distributed, and consequently who has access. Design Consultants can only upload files named as indicated above and with a "For TJH Review" status. For example: if the status is "For TJH Review"; if the originator is Parsons Brinckerhoff; if the design element is Driven Tunnel (General); then distribute to the following Thiess John Holland (TJH) personnel. When TJH members have finished reviewing the document, they too change the status to progress the design along for revision or acceptance. Once again the distribution rules take into account the file name and the status to determine the document's route. This predefined workflow continues around to all the stakeholders until the design is verified and hence approved for construction.

Figure 2 below illustrates this flow around the concerned parties:

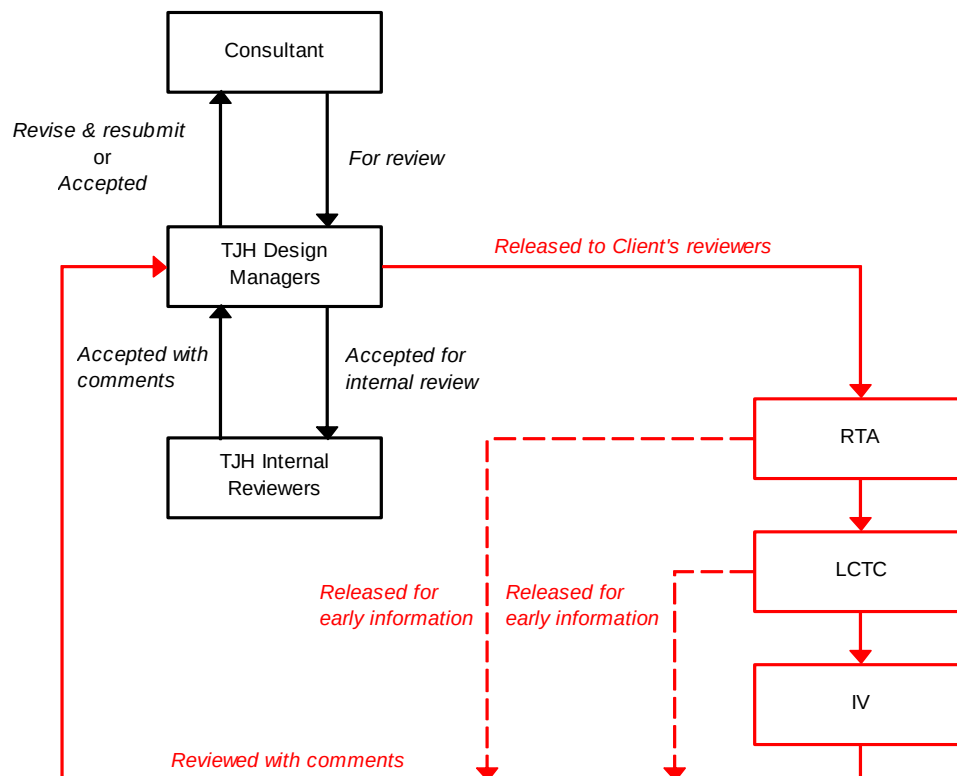


Figure 2: LCT Project Design Review Process

This design process works well in Document Management as people can only see a document when it has achieved a designated status, and they are always viewing the latest version as this only version listed in Document Management (previous versions are maintained in the history). What's more, the system maintains only one copy of each document (or document version) in a central database, so all those who access the system are viewing the same information. This is a very different concept from using e-mail to distribute documents. When a document is e-mailed to ten recipients, ten copies of that file are created, and each recipient must then organise it in such a way as to ensure they always refer to the most recent version.

It is important to note that document in this system can not be altered except if it is uploaded as a new version, in which case it will again enter the distribution and approval process. No document on the system can be deleted and the system maintains a full history and auditable trail of the design process.

We have used similar principles to those described above to configure many other processes on the LCT project so that they are structured, efficient and traceable.

2.3.1 Use of Document Management in Tenders

An example of Document Management for tendering is its use by Gold Coast Water to manage two competitive alliances (a short-listed tender process to select an alliance partner). John Holland was one of the two proponents on each of the competitive alliances, and assisted Gold Coast Water to configure Document Management to meet their rather special requirements. The system had to be set up so that two proponents could communicate with the client, but they could not see each other, and this was subject to close scrutiny by a probity advisor. The benefit for Gold Coast Water was the ability to efficiently control the method and format of document issue, review and endorsement, because the system's set up was identical for each proponent. The benefit for the proponents was the ability to communicate among their own teams in a secure environment and then forward documents directly to client in the prescribed format and manner without any unnecessary reformatting or administration. The benefit overall was that it ensured all were accessing the latest copies of the correct documents, and a complete audit trail was maintained between each proponent and Gold Coast Water.

Once a preferred proponent is selected, the same platform will be used for the project, with the unsuccessful proponent's information being archived off. We believe that Gold Coast Water are intending to use the system for more such tenders and projects in the future.

DMM have also used Document Management during the tender phase to manage correspondence between contributing parties, and the process of drafting reviewing and approving the extensive documents required to be submitted for a Defence maintenance contract tender.

2.3.1 Document Management: Summary of Findings

At the time of writing, John Holland had eight live Document Management projects. Interest in Web-based document management is growing through the company as more hear about the technology and its success, and we surmount the cultural barriers. John Holland's intention is to establish a series of standard configurations that suit various project types and disciplines in John Holland's businesses. Initially our we are targeting projects that have a collaborative element, such as design and construct projects, joint ventures and alliances, as Document Management can most readily add value to these projects. On each project we conduct a briefing and workshop to get buy-in from all the key stakeholders and to agree aspects of the configuration.

3. CONCLUSION

In John Holland we believe that Web-based collaboration tools are the way of the future and we are committed to implementing them across our businesses. These tools can provide efficiency and control in the way we communicate, share information and trade.

There are significant cultural barriers to be overcome, including technical inertia and loyalty to prevailing systems and practices, but there is already a growing momentum, and Web-based collaboration is rapidly gaining industry support.

Ultimately Web-based collaboration will alter the way we do business by changing the way we interface with clients, other stakeholders and the supply chain as a whole. It will provide strategic advantage through improved quality management, greater productivity, cost reduction and better interface with the all the project stakeholders.

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CAPTURING AND MAINTAINING THE CLIENT'S REQUIREMENTS

Case Study

ASSISTING INTERACTIONS IN A DYNAMIC DESIGN PROCESS: A NEW ROLE FOR AN ADAPTIVE DESIGN TOOL

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ABSTRACT

Designing, which is recognized as one of the most complex human endeavours, is critical for the success of any construction project. Design requirements that drive the process are developed inside the design process itself. Designing is an arduous process that requires design expertise and creativity. Designers interact with their design environments in developing the design. They also change the course of developing the design based on these interactions. In order to assist designing in this dynamic process, we need to address the interaction between the tool, the problem it is being used on and the use, in the sense that the tool should be able to learn and construct new concepts from its experiences to facilitate interactions. This paper depicts how a situated agent extends an existing design tool to model interactions, from which the agent learns and constructs its "experiences". Design optimization scenarios will also be discussed to convey the idea proposed.

Keywords: **Designing, Design tool, Situated Agent, Interactions**

1. INTRODUCTION

Designing, the process that produces the structure of an artefact that fulfils the expected function and behaviour, is critical for the success of any construction project. A badly designed facility causes operational failures and incurs high maintenance costs. Design quality is concerned with functionality, which addresses how useful the facility is in achieving its purposes, and build quality, that is the performance of the completed facility (OGC, 2004). Among the critical success factors for achieving design quality, a clear design brief that captures clients' requirements, as well as the related appropriate maintenance during the design stage, have been the focus of many design researches. However, design briefs usually contain abstract terms like "cost effective", "environment concerns", etc., which need to be further re-formalized and developed into detailed design behaviours by the designers. Design requirements that drive the process are built inside the design process itself (Suwa et al., 1999). Designing is a process that requires design expertise and creativity. Designers interact with their design environments in developing the design. They also change the course of developing the design based on these interactions.

In order to assist designing in this dynamic process, we need to be able to address the interaction between the tool, the problem it is being used on and the user, in the sense that the tool should be able to learn and construct new concepts from its experiences to facilitate interactions. However, unlike designers who gain experience while designing, existing design tools keep repeating themselves irrespective of their interactions with the design environment. Such design tools remain unchanged despite their use. Therefore, the work in this paper is motivated by a desire to assist design tasks throughout the dynamic design process with a knowledgeable and personalised design tool. Such a design tool is knowledgeable since it gains experience from its use. It is also personalized because it will change and adapt its behaviour to the interactions in design based on individual use.

This paper depicts how a situated agent extends an existing design tool to model interactions, from which the agent learns and constructs its "experiences" in assisting design.

2. THE NEW ROLE OF THE PROPOSED DESIGN TOOL

Designing can be defined as a means of constructing information in which designers convert clients' functional requirements, regulations and standards, along with their design experiences to design documents. It is a process that is recognized as one of the most complicated of human endeavours. Building design models to understand design process in an attempt to assist this process has long been explored. Recent insights into designing are emerging from the protocol studies of human designers (Gero, 1998). Traditional views of design as static sequential conversion (Figure 1) have been taken over by the notion of "situatedness of designing" that brings forth a situated design model that can be used to develop tools in supporting design. From the findings that have been obtained from protocol studies, designers not only synthesise solutions that satisfy initially given requirements, but also invent design issues or requirements that capture important aspects of the given problem (Suwa et al., 1999). For this reason, design requirements are more interactive and situated, in the sense that

the designer's interpretations of the requirements change according to what we summarize as "where you are when you do what you do matters".

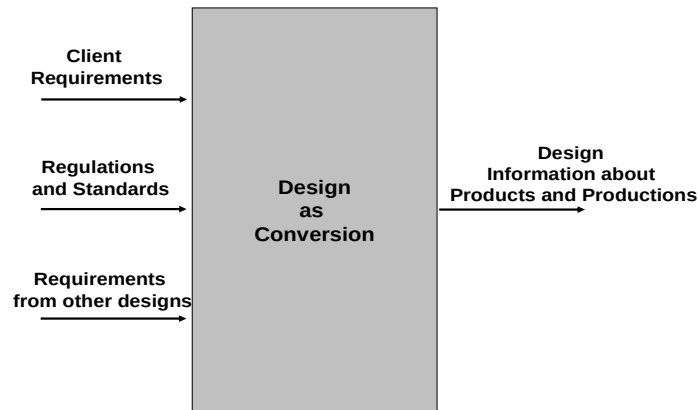


Figure 1. A sequential conversion view of design (adapted from Fabricio et al., (1999)).

Therefore, a new approach is needed to address interactions throughout this dynamic design process, such that the interaction between the designer and the tool can be captured. However, under the traditional paradigm, design tools have been built based on the notion that the tool is unchanged by its use (Gero, 2003). These tools communicate with users through "direct manipulation" in which tools as passive entities merely wait and respond to specific, highly detailed instructions (Green et al., 1997). Using these tools in design cannot meet the changing needs of the designers and the design. Thus, our approach is to develop a situated agent which enables a design tool to learn the interactions during design, and to subsequently use the constructed concepts to facilitate interactions between the designer and the design environment. Figure 2 illustrates this new design tool and demonstrates how this tool learns from events performed by the designer. The incorporation of a situated agent which can sense and affect its environment enables the design tool to learn the ongoing interactions in the design. The agent senses the activities of the designer and then constructs interaction concepts. Learning refers to the concept formation process in which the agent's experiences are reinterpreted, re-structured and reinforced. The process includes perceptual categorizing, conceptualization and reflective reasoning of the current design interactions that is a combination of the interpretations of the external and internal environment within which it is situated.

The suggestions produced by the agent contain information about current design situations that snapshots the sets of entities and relationships involved in designing at a given time stamp. These concepts are formed based on the agent's experiential response to the regularities of the observed design tasks, which can be further served as new suggestions to the designer in guiding their design activities.

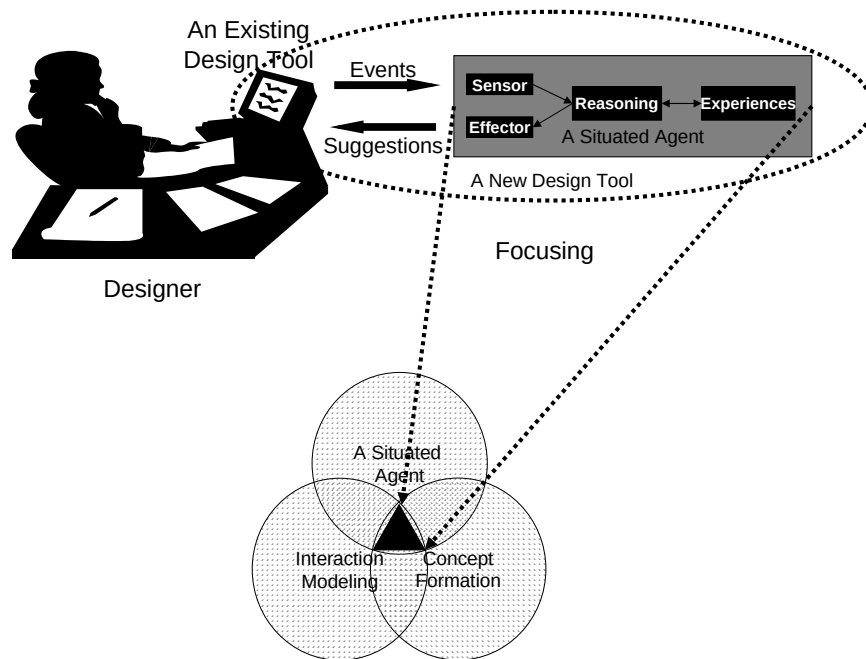


Figure 2. A new design tool and its internal learning mechanisms

3. A FRAMEWORK OF DESIGN TOOLS THAT ADAPT TO THEIR USES

We describe a situated agent that extends an existing design tool to model interactions, from which the agent is able to develop “experiences”. Adaptation, as the agent’s ability to accommodate incremental changes in the environment, enables the design tool to learn from and cope with the interactions in the dynamic design process. As shown in Figure 2, the agent learns from its interaction with the design environment, which includes an existing design tool, the designers, and their activities in forming new concepts which further affect interactions in design. And agent’s experiences bias this concept formation process. The constructive memory model (Gero, 1999), which serves as a meta-level learning mechanism in controlling base level machine learning approaches, also lets the agent learn new situations that will later be grounded in the agent’s experiences by its use.

3.1 A SITUATED AGENT ARCHITECTURE

The agent learns by constructing “experiences” from its interactions with the environments based on its internal representation processes, memory construction and grounding mechanism. The design tool relies on the agent’s situated cognition and changes its behaviours which are embodied as “reflexive”, “reactive” and “reflective” behaviour (Maher and Gero, 2002) to adapt to its use. Here adaptation results from the totality of the coordination of these behaviours within the process of memory construction and grounding.

The internal representation processes consist of sensation, perception, conception, hypothesizing, expectation generation and modification. Each

couples with one another in synthesizing data driven from environment with expectation-driven experiences in order to form constructed memory, Figure 3.

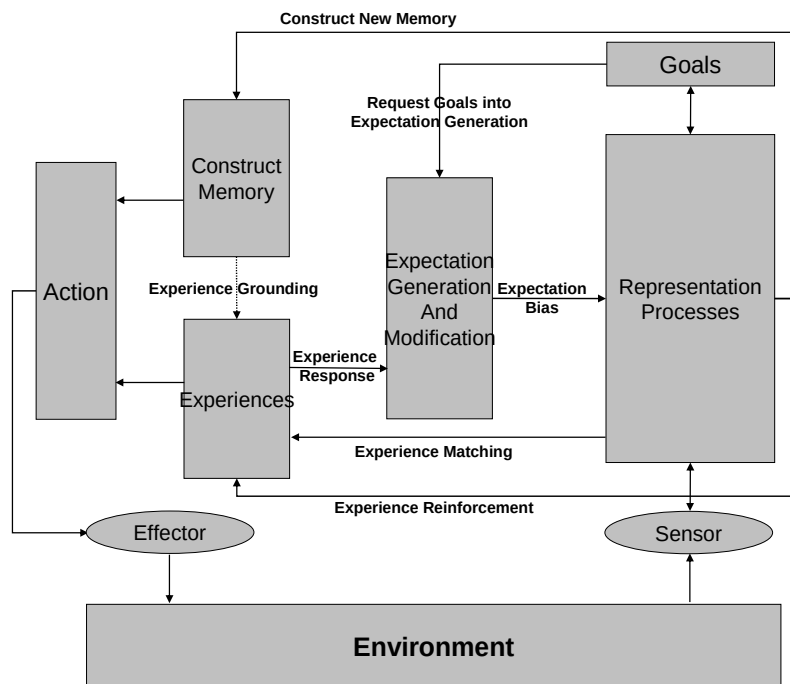


Figure 3. The architecture of a situated agent (adapted from Gero & Peng (2004)).

Sensation is the process of generating sensory data from outside stimuli for further processing. Perception is the process of generating percepts from sequencing and coupling sensory data. Perception also structures these adapted sensory data into sequence or simultaneous chunks (percepts) based on past sequences, coupled categorizations (perceptual experiences) and activated abstractions of percepts (concepts). Conception is the process of categorizing perceptual sequences and chunks in order to form concepts. Concepts are abstractions of experience that confer a predictive ability for new situations (Rosenstein and Cohen 1998; Smith and Gero, 2000).

Expectation generation and modification processes play a crucial role in constructing memory which matches past experiences. Expectation, which is related to agent's view about possible consequences of certain actions, affects its decision making. The hypothesizing process analyses the possible causality of expectation failures and hypothesizes possible solutions. A situated agent reinterprets the design environment based on expectations which are regenerated from matching refocused concepts with current situation.

Agent's actions are embodied as design tool's behaviours which result from coordination of internal representation processes. It is through action that the agent's constructed memory is connected with the environment such that feedback from the environment can serve as cues for the modification of agent's behaviours.

The sensor is the unit by which an agent receives and gathers stimuli from environments. An agent obtains access to the environment through sensors and affects the environment via effectors. An effector is the means by which the agent brings changes to the environment through its actions.

3.2 THE DESIGN TOOL'S ADAPTIVE BEHAVIOUR

A design tool's adaptive behaviours are embodied as reflexive, reactive and reflective behaviour in response to changing situations occurring in the interactions. We discuss adaptive behaviour, in which the design tool manifests as agent's ability to change tool's behaviours to achieve goals based on the concepts formed from the agent's situated representation mechanisms and a constructive memory system.

An agent responds reflexively to environment stimuli based solely on its experiences without reasoning when its experiential response to current sensed data is sufficiently strong to affect action directly. Agent reacts to environment stimuli, when the experiential response to currently sensed and perceived data is sufficiently strong, such that the perceptual experiences in terms of habitual sequences or coupled information can directly affect actions. In its reflective behaviour, the agent coordinates all the representation processes in providing an ongoing awareness about the situation. It is the agent's reflective behaviour that enables design concepts to be constructed. These concepts represent the agent's belief about the possible incoming events and the consequences of the resulting actions.

4. A DESIGN SCENARIO

In this section, a simplified spatial layout problem, treated as a design optimization scenario is discussed to show how this adaptive design tool can be used to improve the designer's interaction. The design objective is to find an optimal layout within certain design constraints. The clients' requirements in this problem are described as "minimize construction cost" and "maximize usage area". The floor layout is described in Figure 4.

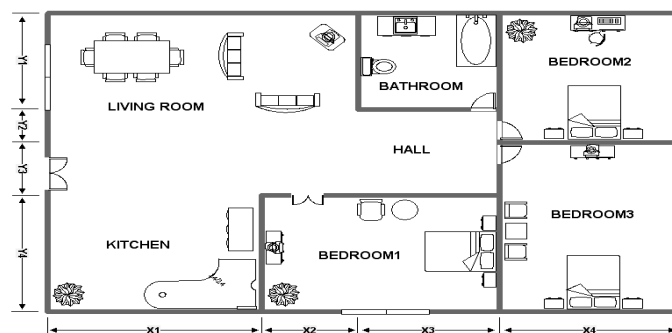


Figure 4. The floor plan of an apartment used for design optimization.

A scenario is illustrated in Figure 5, designers formulate the clients' requirements into objective functions and then apply a suitable optimization algorithm to the design problem. They not only choose optimizers based on their own experience, but also explore new approaches in a trial and error manner. In this way, they will eventually reach a solution during the interactions with the design environment.

The solution is only satisfactory to the designer but may not be optimal. How can a design tool improve its behaviour based on its use by the designer?

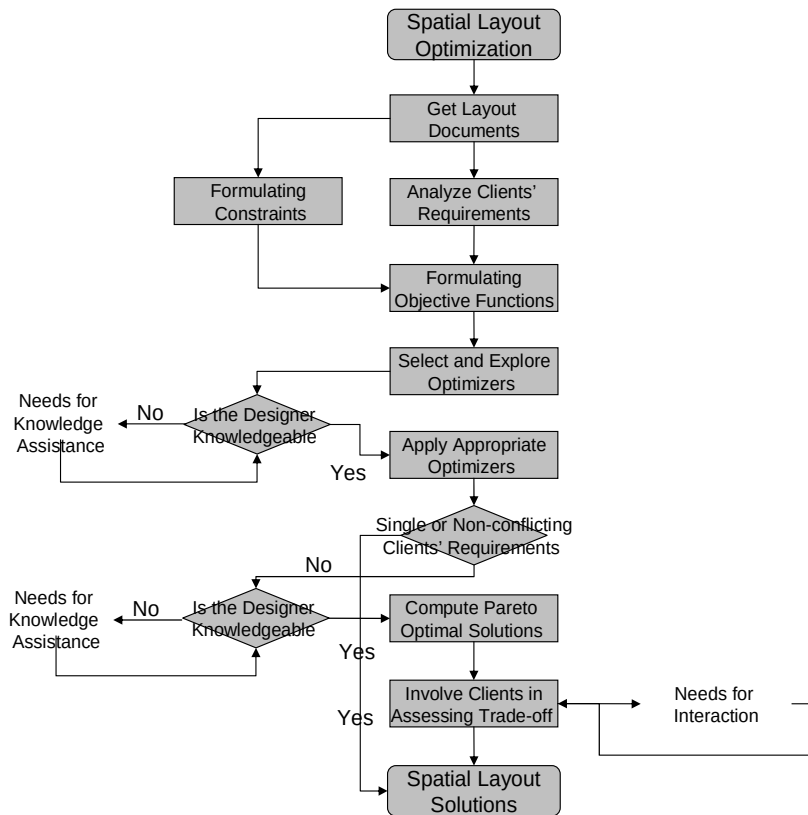


Figure 5. Needs for design knowledge supports and interactions for a typical design optimization problem.

A situated agent can be involved in constructing concepts resulting from the interactions between the agent and its environment that include the designer and the design. Sequences of events performed by the designer are further sensed and perceived by the agent. These environmental variables then activate the agent's associated sensory experiences which are structured as a portion of an Interactive Activation and Competition (IAC) neural network (McClelland 1981; 1995). An IAC neural network applies an activation and competition mechanism to a set of instance nodes which are further linked to groups of property nodes. The agent's sensory, perceptual and conceptual experiences can be represented as different layers of an IAC network. In constructing a concept for the current situation, environment variables undergo different levels of processing (Liew & Gero, 2002) through the agent's internal representation processes and experiences.

Thus, an environment variable at time stamp "Ev(t+n) = {... "click on objective function text field", "K", "X", "^", "2", "+" ... "submit objective function" ... "select optimization algorithms", "click on QP algorithm", "K", "X", "^", "2", "+" ... "submit" ... "Algorithm" ... "DP" ... "K", "X", "^", "2", "+" ... "submit" ... "Algorithm" ... "GE"...}" can be constructed as a concept that can be used as suggestions for the designer to select suitable optimizers, Figure 6.

Another problem arises when the clients' requirements conflict with each other. Then it is necessary to involve the clients in the design process to negotiate a

trade-off solution. The objectives of “lowest construction cost” and “maximum usage area” conflict with each other in this design scenario. With the Pareto optimal set generated, the agent can construct a design concept in terms of a two-dimensional plot which represents each solution in clients’ requirements space, Figure 7. Some heuristic rules can also be developed to give a trade-off suggestion to the designer and the clients involved.

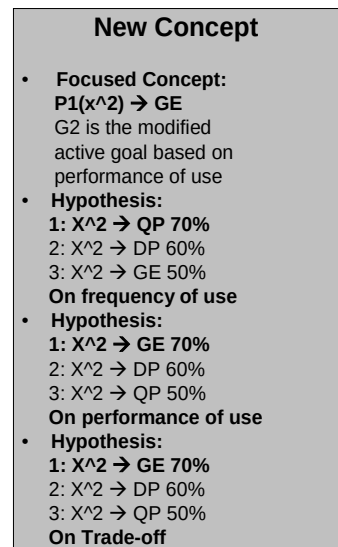


Figure 6. An example of possible concepts constructed by the agent.

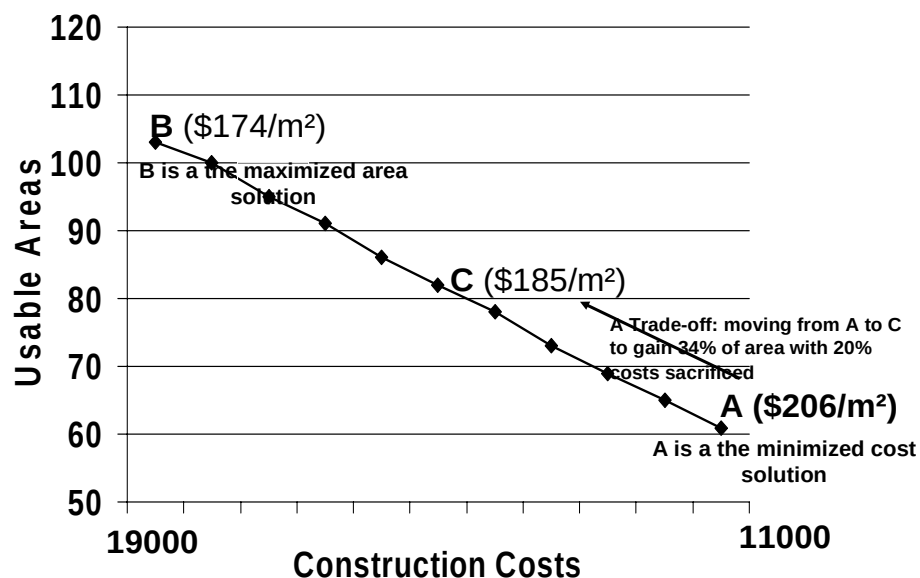


Figure 7. An example of design concepts for solving conflicting clients’ requirements (created from the data adapted from Balachandran (1988)).

5. DISCUSSION

This paper describes a new role for a design tool to assist the interactions during which the client's requirements can be further developed by designers in a dynamic design process. These client's requirements are formulated into design goals. A situated agent learns and constructs concepts that represent designer interactions with the tools in which the tools used in the design process are augmented to account for the experiences that have been gained in using them.

Within this knowledge demanding design process, the proposed design tool also plays an important role in supporting the design with the knowledge it learnt from the agent's interaction with the design environment. The knowledge constructed during designing is further grounded as experience which subsequently biases the agent's concept formation in a later time frame. Designers are connected to the agent's knowledge which can guide the interactions in design. However, this is not to suggest that the tool will be developed into a knowledge database that is widely regarded as not dynamic in addressing the interactions in the design. Even a tool that learns about a particular problem may not be applicable in another domain because the problems lack similarities (Gero, 1996). To solve this challenging problem, an important notion is that the tool is being reused instead of the knowledge which is constructed during the usage of the tool. We may need to build specialised agent for particular tasks or functions of design tools.

As a common ground that can be shared by the design teams even the clients, this adaptive design tool is able to be personalised so that different user groups have their own interactions. This will be one of the future milestones yet to be delivered.

6. ACKNOWLEDGEMENT

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CASE STUDIES IN INNOVATION

DEMONSTRATING EXCELLENCE THROUGH CLIENT ENGAGEMENT

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ABSTRACT

It has been acknowledged that the construction client has a crucial role to play both at the project and industry level. The argument however, is made that because construction represents only a small percentage of total costs of a business enterprise, traditionally the constructed facility is rarely regarded as integral to a profit making enterprise. The client is often reluctant to invest in new construction processes and technologies as the business case for doing so is not yet fully proven to them.

However, the counter argument is made that rather than being reluctant to invest in new techniques and technologies, the informed or intelligent client plays a key role in promoting innovation and idea generation in the design and construction phase, particularly where that construction would eventually house the client's core operation or would impact upon the success of future business activities (Lenard 1997).

Evidence has emerged that higher levels of innovation and productivity are achieved on projects where there is open communication between the client and the main contractor and their working relationship goes beyond traditional contractual boundaries (CII 1996b, Knott 1996). The argument is subsequently made that there is a link between the input of the client and the relationship between the client and the main contractor.

Structural change in the support of research and innovation to all industries from the UK Government (DTI Innovation Report 2003) is also regarded as a driver for improving innovation. The UK DTI in line with other European countries has changed from providing specific sector support to a themed approach across the piece, therefore being able to support larger projects. Construction research in the UK averages £60m per annum, less than 1% of construction output. The main fund

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holders for construction research are the Department of Trade and Industry, ESPRC, ERSC. However, Business expenditure in construction research and innovation figures accord to the Office of National Statistics is typically £40M for the sector. "on the job innovation in design and engineering on problem solving is not recorded. However the UK demonstration programme suggests that since 1998 some £8 billion GBP of construction projects have recorded the business case for change and innovative business practices.

Therefore this paper discusses the role of client driven innovation, the business benefits of this process, and how the conditions are created for delivering innovation on projects in the UK construction industry. The study is based on research collected from 445 demonstration projects totalling £8 billion GBP and is based on the Constructing Excellence 2003 and 2004 reports (Constructing Excellence, 2003) .

INTRODUCTION

In 1998 the report "Rethinking Construction" (Construction Task Force chaired by Sir John Egan, HMSO, DETR 1998) made 72 recommendations to make the UK construction industry world class. The emphasis in the report was the performance of other industries and how these lessons could be translated into the construction sector. The way forward for the sector was five proposals that set out the conditions for Government, Clients and the Industry to interact in many differing ways. These were:

Demonstration projects; projects that demonstrated the business case for change and innovation in the UK construction industry

Movement for Change; [Innovation]; a non institutionalised group that facilitated the demonstration projects and the UK change agenda, set up in 1998 by DETR (Department of Environment Transport and Regions - dissolved in 2002, Construction transferred to Department of Trade and Industry DTI)

Knowledge Centre; The DETR was developing the Construction Best Practice Programme and this group fulfilled the role of providing a knowledge centre for the UK construction industry. Both The Movement for Innovation, the Housing Forum, Local Government Task Force and Construction Best Practice have merged under the umbrella of Constructing Excellence (Constructing Excellence, 2003).

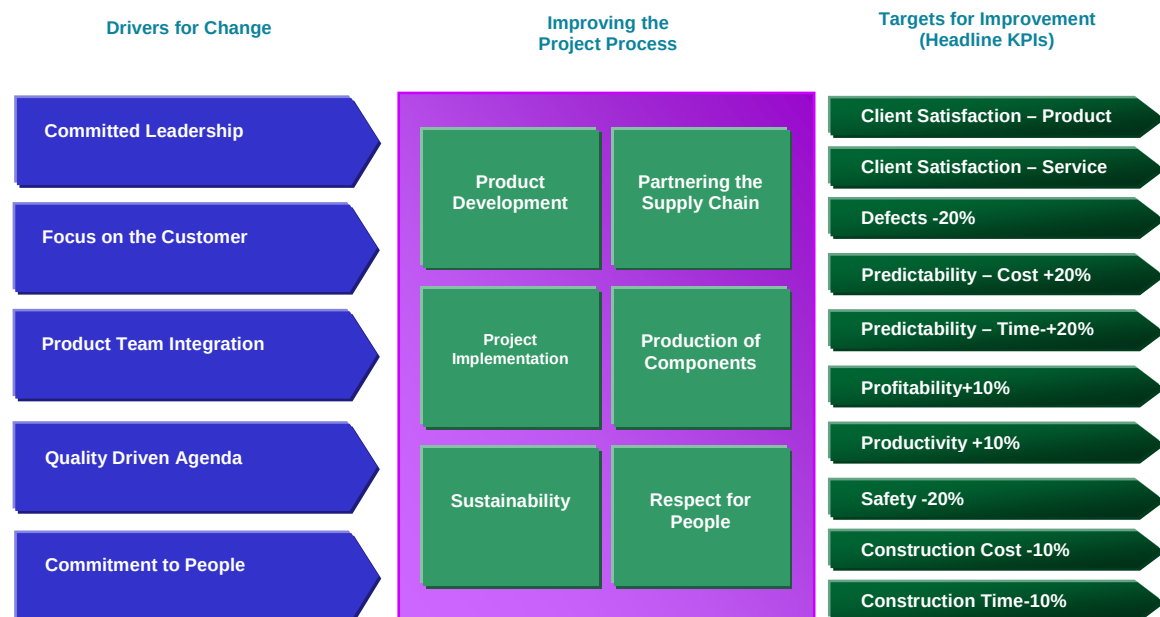
Public Sector Clients; As the Public sector is the largest client of the construction sector, the government delivered both the Government Clients Construction Panel, and Local Government Task Force to take leadership and promote innovation in the procurement and delivery of construction in the UK. The majority of innovative output is recorded in the demonstration project programme.

Occasional Clients; A programme for the occasional clients many of whom procure major projects; it was of concern to the task force that this level of activity would be excluded from the change agenda. A charter was created under the auspices of the Construction Clients Group (http://www.clientsuccess.org/home_1.asp)

Branded Products; The Task Group felt that the industry must grasp the opportunity of improvement through specialisations and the creation of supply chains to deliver products for major clients i.e. the experience of getting well, rather than the hospital project as a driver for performance improvement.

The model for the UK construction industry is simply to create an industrial movement for change. Initially the target was for £500m, so that businesses, individuals and corporations could come together to share and learn best practice, and aggregate ideas on innovation based on evidence for bottom line improvement. All this was achieved through a Demonstration Project Programme now comprising 445 projects. The programme demonstrated innovation around the drivers for change, the key process and the targets as set out below

Figure 1 Constructing Excellence Model for Change in the UK Construction Industry



All UK based demonstration projects have delivered tangible improvements by implementing innovation in the above project processes, they have used cultural drivers for change with respect for people issues. All measured their improvements in relation to the above targets.

In a market where there is (at least in terms of perception) little competition, incentive to innovate or no risk of being globally challenged, it was largely the conditions placed on the sector by clients that led to such significant results. There are two distinct models, one based on cost predominately in the private sector, whereby lowest outturn cost is a key operating measure. However changes in the way the public sector was funded looking at value rather than cost and looking at whole life and the removal of the requirement of Compulsory Competitive Tendering allowed the public sector to look at tested and tangible ways of obtaining a value driven sustainable approach to design and construction. The primary measure for the public sector still remains return on capital efficiency, but with incorporation of a better understanding of value in achieving this efficiency. It is here that Constructing Excellence has helped to improve the competitiveness of the UK by:

- enhancing corporate competitiveness through business innovation
- improving service and product quality by measuring industry performance
- providing a business to business network

The May 2004 Report from the Demonstrating Excellence Programme continues to indicate that demonstration projects outperform the general construction industry in all but one of the key performance indicators. This has been a trend since the programme started in 1998. These projects have shown that they are safer, deliver better environmental performance and also are more productive and offer better services and products to clients. Generally these improvements are in line with the targets set up in the report Rethinking Construction (1998), with the result that demonstration is a vital driver for innovation, competitiveness and productivity improvement for the sector at large.

Some of the key findings are:

- **demonstration projects are more than twice as safe as the industry average**
- **demonstration projects are scoring more than twice the industry average in employee satisfaction**
- **productivity on demonstration projects is 65 % more than the industry average**
- **environmental performance is 40% more than the industry average**

The results show that the best are getting better, but most encouraging is the fact that the whole industry performance is also rising. Whilst there are many variances in projects and procurement routes, the common factor in the demonstration projects is direct client engagement and leadership and facilitation of innovation.

The Demonstration Programme has created the conditions in the UK whereby the construction industry, clients and government can come together to collectively improve performance through the sharing, learning of best practice and innovation.

A good gauge of industry improvement is client satisfaction and over the last five years the results show a steady increase in product and service satisfaction.

There has been a welcome increase in the number of firms reporting zero accidents.

RESEARCH METHODOLOGY

The demonstration project process comprises the requirement to codify innovation through peer review. Each project has to prepare a case history and produce a set of Key Performance Indicators. The data from the demonstration project Key Performance Indicators and case histories is then compared to the broader construction industry.

The case histories investigate the following areas:

- the codification of the innovation
- the specific tangible benefits of the innovation
- the lessons learnt and recommendations for the future
- the performance of the project benchmarked against industry norms.

The data is collected and presented at peer review meetings where the knowledge is shared across the industry. The peer review meetings are cross-sectoral. The submitted innovations are scored by a peer group and in most cases by an executive board to provide a level of consistency. At this meeting we also record the peer comment and learning points for each attendee. Case studies are then derived from the data. This is how the knowledge is transferred across the sector, raising the performance of the participants.

The UK demonstration project process and Key Performance Indicator system is now being used to facilitate the sharing of knowledge across the world and compare relative progress. Constructing Excellence Key Performance Indicators are being used as the standard on which to base benchmarks internationally.

RESULT OF CLIENT DRIVEN INNOVATION:

The business benefit for an ongoing Demonstration Programme is clearly shown in the table below:

Demonstration Projects' performance 4 year average	Rethinking Construction Demonstration Projects (£7bn)	Construction Industry, as a whole (£70bn)
Client Construction Cost Demonstration project costs are 6.0% lower than industry average	Reduced client construction costs from Demonstration Projects = £420m	Reduced client costs if one-third of industry take up = £1.4bn
Safety Demonstration project accident rates are 61% lower than industry average. Estimates put accident costs across the industry at 8.5% of turnover*	Reduced costs of accidents from Demonstration Projects = £363m	Reduced costs if one-third of industry take up = £1.2bn
Profitability Rethinking Construction projects achieve 2 per cent more profit than the industry average	Increased profit from Demonstration Projects = £140m	Increased profit if one-third of industry take up = £466m

Source "Rethinking Construction Report 2003 (www.constructingexcellence.org.uk/publications)"

THE STUDY

The aim of the overall study (part only is presented here) was to explore the role of the client and the contractor in promoting innovation and learning in the project and procurement process.

The projects described in the case studies reflect the clients' success. they describe how they did this by taking a team approach and by working with people they trusted and who shared their values rather than with people who offered the lowest tenders. This approach released value from the supply chain, and project costs were held without prejudicing success. Discussions were open and frank, with everyone realising that changes were to be expected and would require managing.

A set of common attributes was identified in the majority of projects. The attributes also delivered benefits in both positive and negative outcomes of a project demonstration.

These were:

DRIVERS IN THE PROCUREMENT PROCESS

This attribute encompassed the relationship between the client and the main contractor, subcontractors and suppliers in terms of the client's expectations of the contracted parties and the forms of contract that were in place (i.e. lump sum, design

and construct and any partnering arrangements). However in the majority of projects an overriding set of working principles was created by a statement of shared vision and values, this focussed the proactive attitude needed to make such improvements.

Typically the scope of the project allowed the team's role to explore any incentives to be put in place to encourage the supply side to make innovative contributions to the design, procurement and construction process. The incentive for the team to deliver improved performance was facilitated by two major factors, appropriate allocation of risk and often the concept of target costs and risk/reward mechanisms for project management

PLANNING AND COMMUNICATION

Attributes included the significant extent to which the main contractor, suppliers and subcontractors were involved in decision making, project development and project delivery processes. A process of conflict/dispute resolution was installed on many of the projects to allow decision making to be made at the lowest level.

This finding was part of the examination of the systems and procedures put in place to facilitate communication between the client and the contracted parties. This examination also aimed to identify how improvements were incorporated into the procurement process; more specifically, whether such improvements came from the client, or whether there was scope for suppliers and subcontractors to provide input.

IMPARTING KNOWLEDGE TO THE PROJECT TEAM

Particular emphasis was placed on the role of the client, in terms of creating a learning environment, applying knowledge to the site and the implementation of best practices. The transfer of knowledge from the contracted parties to the client was also examined in terms of how such transfer is facilitated and encouraged.

SUMMARY

In summary we have investigated a number of projects, and to increase the likelihood of success we have identified a number of key attributes.

These are:

- quality based selection of the team
- target cost contracts/partnering contracts
- fair allocation of risk
- shared values
- dispute and conflict resolution
- effective planning and communication in the value chain
- the right people leading the project at the right time
- quality driven approach to information and material streams
- value engineering and value management
- stakeholder participation
- key performance indicators
- review and improvement processes

Case Study #1

Blackpool Borough Council- St Stephens Avenue Coastal Protection Scheme

When Blackpool Borough Council decided to adopt the principles of Rethinking Construction, they realised that they had to ensure that their construction work provided the best quality and value for money for the residents of Blackpool. Their long journey began in 1998 when they set up a working party to evaluate the Report "Rethinking Construction with the eventual conclusion that the Council should "embrace the Report's findings".

This then lead the Council on an awareness raising programme that took in meetings, seminars and conferences involving the likes of Rethinking Construction, the Movement for Innovation and the Construction Best Practice Programme. In order to put the principles they had learnt into practice, the Council decided to adopt one of their projects as an M4I demonstration project and, in August 2000, the St Stephens Avenue Coastal Protection Scheme - a project for the reconstruction of time-expired concrete coastal defences - was chosen.

The Council, through Technical Services, was determined that any new systems and methods that were to be adopted would be "robust and transferable" to all future work done by all Blackpool Borough Council departments - "A Better Way" - and some of the key lessons learnt are as follows:-

A new procurement strategy with selection on the basis of quality.

The first stage for Blackpool Borough Council and Technical Services was the development of a procurement strategy that made selection on the basis of quality and not on lowest cost. In the case of the St Stephens Avenue contract, price negotiations were to take place after the selection of a successful partner. As funding for the project was coming from both the Council and DEFRA - both of which organisations have rigorous audit systems - any new way of procurement had to have clear selection criteria in order to demonstrate that best value had been achieved.

Nine contractors were initially invited to make early submissions giving details on:-

- recent work (for references)
- financial information (on the contractor)
- recent experience and capability
- health & safety
- quality management
- staff
- subcontractors and suppliers
- environmental policy

As a result of the above, three contractors were then invited to make separate, scheme specific, formal presentations that covered the following:-

- Quality
- design & construction planning
- health & safety
- resourcing & partnerships
- risk & value management
- quantification & pricing
- conditions of contract
- environmental measures
- benchmarking & performance indicators

- financial controls

The presentations were assessed by Technical Services using a matrix scoring system with Birse Construction achieving the highest score and, subsequently being recommended as the Council's "Construction Partner" for the St Stephens Avenue scheme.

Blackpool Borough Council considered that it was important to have a clearly defined contract that all potential contractors agreed to and bought in to - the main criteria being that the contract used would work on all future projects as well.

After considering various standard contracts already available, Technical Services eventually decided upon the NEC Option C X12 Partnering Agreement (June 2001) as being the most suitable as it enabled true partnering and provided incentivisation for the contractor, the supply chain and the client whilst providing a ceiling of certainty to the contract in the form of a maximum lump sum price.

Having selected the main contractor there was still a lot of hard work to do before construction work could begin on the project. Perhaps the most significant difference in the way that Blackpool Borough Council developed this method of procurement was in the open and frank discussions that took place at this early stage which enabled problems to be resolved amicably prior to commencement of the work.

Past experience had shown that such early resolution of problems ensured that "entrenched positions" were not likely to be adopted during the construction phase. Additionally, integrating the team early enabled value to be maximised through a combination of buildability, value engineering, design enhancements and risk management using the experience of the whole supply chain.

Contract value

The next stage for Technical Services was to agree the value of the contract. Value for money was guaranteed by analysing previous similar contracts and extrapolating the tender costs of the competing contractors to obtain a benchmark cost for the St Stephens Avenue project.

After a period of negotiation, a guaranteed maximum price was agreed upon by Technical Services and Birse and, as part of this procedure, a "gainshare" agreement was also struck whereby any costs above the guaranteed maximum price would be met by Birse and that any savings made below the maximum would be shared by Blackpool Borough Council and Birse on a percentage formula. After agreeing the value of the contract a Value Engineering workshop was held involving project staff from Blackpool Borough Council and Birse, where the whole scheme was reviewed. After an assessment of cost, time, practicality and whole-life issues, several items were considered and built into the project.

Measurement and Key Performance Indicators

Measurement and benchmarking were a key part of the St Stephens Avenue scheme – not only were they a method for driving continuous improvement throughout the supply chain, but also satisfactory KPI achievement was used as a measure for the amount of any earned saving share-out between the client and the main contractor.

The lessons learnt (so far)

Now that the St Stephens Avenue Coastal Protection Scheme has reached the construction stage, it is worthwhile considering the lessons learnt so far. The change by the Council to this new style of working has not been a short one. It needed considerable planning and the involvement of all relevant stakeholders within the Council. A clear auditable procurement policy was necessary to show that best value was obtained without recourse to lowest cost.

The NEC OptionC XI2Partnering Agreement (June 2001) provides for partnering and gainshare through-out the supply chain. It is wrong to think that the selection of the contractor is the end of the hard work. The selection of the contractor was followed by a period of tough but open negotiations before the commencement of work. This enabled problems and issues to be aired at a point when changes were far easier to implement. It also meant that the quality of the construction could be maintained at an appropriate standard, with cost efficiencies also being maintained. A process of value engineering is an integral part of the procedure so that all members of the supply chain benefit.

Benchmarking is an important tool that can be used for continuous improvement and as a performance indicator upon which gainshare can be made dependent. Finally it is worthwhile adding that the project teams have found working in this way a more rewarding experience which they feel will continue to benefit all parties in the future.

Case Studies#2

Project Aquarius

Project Aquarius is a series of civil engineering infrastructure projects carried out by Water Service Northern Ireland. The projects entail pipeline laying, water treatment works and various reservoirs and infrastructure modifications. The driver for the project is the European Waste Water Directive, along with the need for strategic upgrading of the water, waste treatment and distribution in the province.

The client in this case is a central government department who has been a traditionally conservative procurer. We use the term conservative due to the recent past of the province whereby project procurement needed to assure adequate equality, and whereby rules and regulation tended to preclude much innovative client practice. However as a result of a secondment to the UKs, the Government Clients Construction Panel (GCCP). The GCCP is a panel of central government clients who met and devised a series of policies and guidance notes on new methods of public sector procurement. It was noted by the client of the project that aspects of traditional procurement practices could be changed to encourage innovation and collaboration whilst retaining the need to ensure equality. (Due to the troubles in NI, equality in the selection of personnel had to comply with local byelaws, section 76)

The Tendering Process

To facilitate innovation, the client started with standard target cost contracts based on the NEC option C form of contract. After several contracts the client needed to ensure that transaction costs were kept to a minimum and that the time to “dig” from tender was also shortened to meet with the client's many programmes of work. Typically the process to get to tender stage took many years so a procedure to speed up the delivery of projects was needed. This approach was facilitated by a framework agreement. The framework is essentially an umbrella agreement and protocol document that allows a series of construction projects to be delivered without

unnecessary bureaucracy. The frame-work is a quality based procurement and selection tool, its primary purpose is to short list supply chains for project delivery. The tendering basis was 85% quality 15% cost. The client uses the quality based selection methodology after deciding, in each case the necessary requirements and objectives of the project. The supplier is then given the opportunity to bid in a process which is designed to align competencies and values in the prospective supply chain. Project execution, in this scenario is based on an ongoing continuous improvement programme ensuring best value for money is derived, and that financial probity is adhered to without the need for subsequent tendering processes.

Client Innovation

Through the process of selection the client identified a number of key traits required from the supply chain. The client investigated key statements from the suppliers and scored them on their ability to innovate in terms of business and technical matters.

Most significant of the many improvement techniques is the use of **value management & value engineering**. This activity was delivered in a series of workshops. Also some areas of integration & synergistic partnerships were resultant as part of this process.

Stake-holder buy-in at the time of the individual project value engineering exercise is crucial to ensure perceptions and expectations are clearly obvious and considered. However, the improvement processes plateau after several iterations of the project process.

The client needed a new focus for the delivery of the projects which improved performance of a sustainable basis.

The uses of the tools from the other sectors were transferred into the client organisation and principle contractor. The primary tools were:

1. creating the conditions for innovation
2. tools for developing systematic innovation
3. tools for development of the supply chain.

1. Creating the conditions for innovation

“Project Aquarius” is a brand that builds together the values of the team. This allows most teams to be able to focus on the delivery of the projects. Appropriate risk allocation in most instances now lies with the client who in most circumstances, is best placed to manage risk.

A values workshop for each project was held and looks at key policy deployment issues. This delivered targets for financial benefits, productivity and heads of agreement.

An empowered team able to deliver innovation within the parameters set out within the scope and Heads of Agreement.

A contractual frame work providing for the setting of a fixed scope and cost to ensure quality and predictability. Overheads and profits are dealt with under the auspices of this frame work. Costs and scopes are then engineered to deliver full functionality at the best costs using a must, should, could and would selection process. The client

leads the stake-holders in these exercises and all agree as to the way forward thereby facilitating an environment of innovation.

A series of interdependent delivery teams were set up to focus and co-ordinate costs, information and interfaces in order to help the delivery of innovation and cross functional working.

The team applied new tools from other industries by the client as a result of Constructing Excellence's innovation and business development clusters;

These were:

- workplace organisation (Masaaki Imai, Gemba Kaizan 1997)
- value stream analysis (Seeing the whole, Dan Jones and Jim Womack)
- triz – theory of inventive problem solving (G Altschuller, and suddenly the inventor appeared 1996)
- production control (Last Planner, Lean Construction Institute, Glen Ballard, Greg Howe) (Critical Chain Scheduling, Dr Eli Goldratt)

Tackling people issues such as team effectiveness, process improvements and the way the teams are organised. The client codified this into a route map for success.

Aligning vision and values across the value chain and policy deployment, getting the message across in terms of targets and improvement teams were foundation stones of creating the conditions for innovation. Policy deployment gave the compelling need to deliver change in process thinking.

2. Tools for developing Systematic Innovation

The client implemented training in the use of value stream analysis, in particular the Toyota based tool of process activity mapping.

The client mapped the time value is added [value add] in relation to the total time spent by objects flowing through a process. Records show that use of this tool has helped others make sustainable improvement decisions for over several decades.

By continually measuring the value add in objects, information and people flowing through processes, a factual base line about performance is established and from this continuous improvement targets could be achieved. Typically doubling of production could be achieved from the result of this process.

The client measured value add in the concrete, rebar process, the notion is that both processes were thought to be quite productive, however using process activity mapping they found that efficacy was as low as 4%. By improving the layout and innovating in the tying of rebar they managed to make a 75% increase in the pours that could be achieved in a day.

The tool used, quantifies and visualises waste in process in a graphical format thereby allowing easier diagnosis of where areas for improvement lie.

Supplementary tools were used such as Workplace Organisation Techniques such as 5S to ensure standards were maintained and improved.

Production control was the next area where big losses were identified. Up to 50% of time is typically added as safety in general construction timeline. The use of Critical Chain Scheduling and Buffer Management, aided in the control of interfaces and communication and reduction in the programme through waste minimisation.

Currently the programme is 10% ahead of time with zero losses for quality and 20% under budget, saving several millions of pounds.

3. Tools for development of the supply chain.

The team, once grounded in the concepts and the use of the above mentioned tools, looked at supplier development as an opportunity for further savings on the project.

The contractual arrangement for the supplier [Steelwork fabricator] was in essence a mirror of the target cost arrangement. The problems facing the site were predictability issues regarding delivery and satisfactory cost management. Cost issues internally were due to increased costs due to overtime, this was factored into the price to the main contractor.

The team carried out a process activity map and work place organisation survey and delivered a £30,000 saving to the contract and increased the capacity of the factory so that overtime was reduced to zero.

Delivery was improved due to much more predictable process based on understanding work flow through the factory.

Commentary

Much of the paper addresses the way relationships have changed and how the suppliers are satisfying clients demands for change. This final commentary addresses the future and the need for technological innovation, indeed this was a feature of the longer term improvements in case history #2

Many construction contractors agree that there is a significant need for improvement, particularly in the areas of efficiency, flexibility and management practices. Certainly, over the past ten years, the construction industry has been forced to address a variety of issues as they have acquired greater industrial, organisational, legal and commercial importance. The construction market in general is becoming more competitive as firms are required to exhibit a level of organisational, technical and commercial sophistication not previously envisaged. Construction facilities are becoming increasingly complex, demanding greater technological sophistication to build them. The ongoing change requires extensive supply reorganisation and (Office of the Deputy Prime Minister, MMC, Modern Methods of Construction) MC just to deliver the required volume of dwellings and infrastructure requirements for the UK. To get a scale on this viz. 30,000 new homes per annum in London alone up to 2016. Clients are demanding 'more construction for their money' in a number of spheres, from the purely financial to the environmental. These factors necessitate change and place a new emphasis on the need to increase the industry's capacity for innovation. This can only be done if the client demands improvement, measurement and improvement in the value add component of process performance.

However, while improvements have been made in some areas, there is a general concern that if systematic change is not being achieved that the aforementioned small gains will be lost once industry activity continues to increase. The next wave of industrial development will necessarily incorporate the adoption and utilisation of

innovative technological processes and developments, and see the emergence of highly responsive organisations capable of exploiting transient and niche markets. This polarised environment (Rethinking Construction 7th Target “improve turnover and profits by 10% on the preface of industry reorganisation) demands a responsive and dynamic construction industry with the diversity to cope with and initiate change, that is capable of employing a range of approaches to the procurement and delivery of construction. This will necessitate a much stronger emphasis on innovation than ever before.

The question as to why the construction sector (demand) has not taken up such technologies needs to be addressed. Quite simply it may be down to lack of competition in the UK marketplace. For a construction organisation to commit itself to the use of advanced technology over an established practice it must be seen to benefit the construction process in at least four areas, ie the project objectives, expected benefits, risk and liability (insurances), and cost. The project objectives and technical requirements set basic criteria for acceptance of the final product and selection of a method to produce it. The expected benefits include competitive advantage in winning the job and performance advantage in decreasing costs and schedules, with resulting improvements to profitability. Further, the new technology must be proven to out-perform existing technology.

Unfortunately, new technology rarely satisfies such exacting criteria immediately. Often, it has to be tailored to meet specific needs or environmental conditions, and staff must be educated as to its use (processes which may take considerable time and resources). These factors, combined with the absence of reliable templates against which to cost new technology, have meant that the construction industry has been slow to invest in this area and as a result, has not reaped the benefits such technology has furnished in other industry sectors. However the West's drive for innovation through technology needs to be accepted cautiously, simply the business model for the sector needs to be reviewed and passed before technology takes hold.

There are several structural problems that exist within the construction industry due to lack of competition. The construction industry's inability to measure and improve “value add” when compared to world-class organisations. If this simple process was driven by clients the improvement potential would last for upwards of 40 years, viz Toyota cars and most likely reduce the perceived skills deficit to oversupply in less than 3 years.

If the industry is to adopt a more innovative stance, then it is imperative that it explores the use of advanced technology and incorporates the need for such exploration into the planning process. Construction plans and budgets must recognize the start-up costs of new technologies. This includes the cost of hardware, parts, technical support and training for the new operation and the possible lower production and productivity of the new method during the start-up period. In other words we need to set projects up as a business and balance the capital investment to labour ratio.

Innovation

Through the programme of demonstrations, Constructing Excellence is proving that construction projects procured and carried out through integrated techniques achieve:

- better quality
- fewer accidents

- increased productivity
- a staff turnover that is three times better than the industry
- A more qualified and highly satisfied work force.
- Completion in less time than the rest of the industry that is still dominated by those using traditional techniques.

In spite of this evidence many construction clients continue to favour the traditional method of segregated teams. This is an inefficient way of working, typically less than 1%.

Although profitability on demonstrations has remained consistent, there still remains a challenge to the industry to turn competitive advantage into improved profitability. However it is clear from the figures that many organizations are investing in the long-term and also many are involved in the early stages of frame-work agreements, which requires upfront investment.

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CAPTURING AND MAINTAINING THE CLIENT'S REQUIREMENTS

SYSTEMATIC PERFORMANCE REQUIREMENTS MANAGEMENT OF BUILT FACILITIES

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ABSTRACT

The successful 'project definition' phase is the corner stone in realising satisfying end products. In the building and construction domain, this phase is particularly important, yet it is often rushed and poorly conducted. Jumping straight into technical solutions is the *modus operandi*. Typically, the architect's first proposal for a building layout acts as the baseline for the decision-making throughout the entire project. Inclusion of the end user objectives usually happens (unsatisfactorily) by simply asking for comments on the proposed technical solutions. This can easily lead to a loss of value and can cause problems during the use of the building, and lead to disputes during the construction. It is widely recognised that human and organisational questions need more attention than technical solutions in the early phases of the process. The performance approach has been presented as one potential catalyst for positive change in this area. The performance approach is concerned with what the building is required to do, not with describing the technical solutions i.e. how it is constructed.

A key driver for the performance approach implementation in Finland has been a software tool called EcoProP. Its next generation version, PRISM, stands for 'Intelligent Systematic Performance Requirements Management' and is currently being translated and revised for application in Australia and other countries.

In this paper, current problems in the project definition phase are presented. The requirements management and performance approach are introduced, and the barriers to implementation are discussed. The use of EcoProP on projects in Finland is presented, and in conclusion, the use of PRISM for performance requirements management in various countries is discussed.

1. INTRODUCTION

The importance of fulfilling customer expectations to attain a satisfactory end product is clearly documented (Lindkvist, 1996; Smith, 1998). In a construction project, this can only be achieved by considering the different stakeholders' needs and aspirations during the earliest possible stages of the project, however there are many difficulties in capturing these requirements in practice (Huovila, 1998; Kumaraswamy, 1997). The problems of project briefing are mainly the same as they were thirty years ago, and the current practice has many deficiencies (Barrett, 1996; Ohrn, 1998; Kähkönen, 1999; Lahdenpera, 1988; Huovila, 1999; Koskela, 2000); the brief consists of unclear or conflicting objectives, original requirements are not documented in the brief, transformation lacks creativeness and flexibility, selection of the contractor is based on price, and the construction phase is full of communication problems and 'corner-cutting' causing the loss of essential requirements. The process is mainly production-driven instead of being customer-driven. (Kamara, 1999) states four deficiencies of the briefing process:

1. often no formal or structured procedure in the evaluation of the brief is applied.
2. horizontal integration among stakeholders is inadequate (communication problem).
3. lack of information technology support causes problems when chances to requirements occur.
4. traceability of design decisions to client requirements is inadequate.

The decisions in the building construction process are based on the investment costs. When the life-cycle costs of an office space are calculated, it can easily be concluded that the investment cost is not that important when considering the bigger picture (Hattis, 1971; Romm, 1994). Salaries of the workers are a vastly bigger issue than the investment cost. Increasing worker satisfaction and productivity by providing a well performing space is much more important than saving money in the design and construction phase. It is evident that a more thorough analysis of users' needs and ultimately, behaviour and increased productivity, is potentially where the maximum benefits can be achieved (Hattis, 1971). This philosophy has been around for more than thirty years, yet still, the majority of decisions are made, based purely on the investment cost.

Research shows that during the project definition phase, the human and organisational questions are more important and need more attention than technical aspects, and that the analysis of the client's needs is the most important during the earliest stages of the process (Lindkvist, 1996). To reach the best result it is vital that project parties have a means to communicate their requirements to the design team (Smith, 1998).

2. REQUIREMENTS MANAGEMENT AND PERFORMANCE APPROACH

2.1 REQUIREMENTS MANAGEMENT APPROACH

The requirements management process ensures that we know what the customer wants and that the solution also efficiently meets these requirements. There are also other terms to represent the same procedure, like requirements engineering. Requirements management represents straightforward work, which benefits are realized at a later date (Stevens, 1999). The goal is to understand, model and analyse the needs of users and stakeholders' task for validating whether the vision is correct (Sampaio, 2000; Robertson, 2000; Haumer, 2000). The purpose is to establish a complete, consistent and unambiguous requirements specification (Haumer, 2000). Furthermore, it is emphasised that requirements management process is a continuous and concurrently developing procedure during the whole life time of the building.

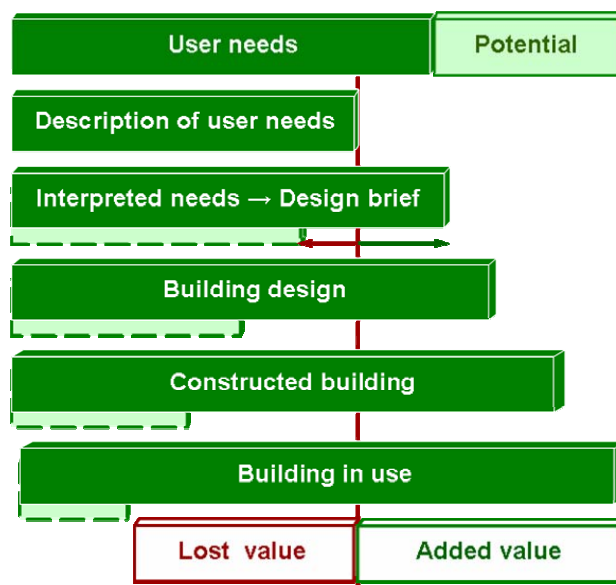


Figure 1 – The value can be added or lost in the process.

The end product of the building construction, the building itself, should fulfil the needs of all stakeholders in a comprehensive manner. In order to attain this, the user requirements need to be captured. As shown in Figure 1, capturing the user needs is critical for maximising the value of the end product. This is the ultimate target of requirements management. Since it is impossible to satisfy all the needs of relevant stakeholders the practical objective of requirements engineering is to merge various user requirements to a realistic but holistic solution. Effective decision support tools to facilitate this are needed.

2.2 PERFORMANCE APPROACH IN THEORY

The performance approach is the practice of thinking and working in terms of ends rather than means (CIB, 1982). It is about describing what the building is expected to do, and not prescribing how it is to be realized (CIB, 1982). Performance specification should include statements about (International Standard, 1984):

1. Performance requirements (expressed as ranges of values and grades) for buildings or their parts under specified conditions and referring to:

- a. related user requirements;
 - b. agents relevant to building performance, such as climate, site conditions, occupancy characteristics or design consequences;
2. Methods of assessing each performance characteristics, including performance over time referring to the requirements and agents, as in 1.

The first step of the performance requirements management is to recognize the users. By user, in this context, we mean relevant stakeholders of the project, such as occupants, owners, managers and financiers of the building (CIB, 1982). It is also vital to know the activities taking place in the building (use of building). The user requirements are often qualitative statements (Gross, 1996). Based on user requirements and the surrounding conditions (climate, existing buildings etc.), the quantitative performance requirements are set (Bjorneboe, 1982). The technical solutions proposed during the design phase are verified against the set performance requirements. If they match, then the proposed technical solution may be approved. In addition to verification during design phase it is also important to verify that the desired performance is reached also during operation (Sneck, 1988). In many cases project definition phase doesn't proceed straightforward and possibility of changes is more than probable. Therefore, change management is carried out simultaneously with verification process. This summary of performance requirements management is outlined in Figure 2.

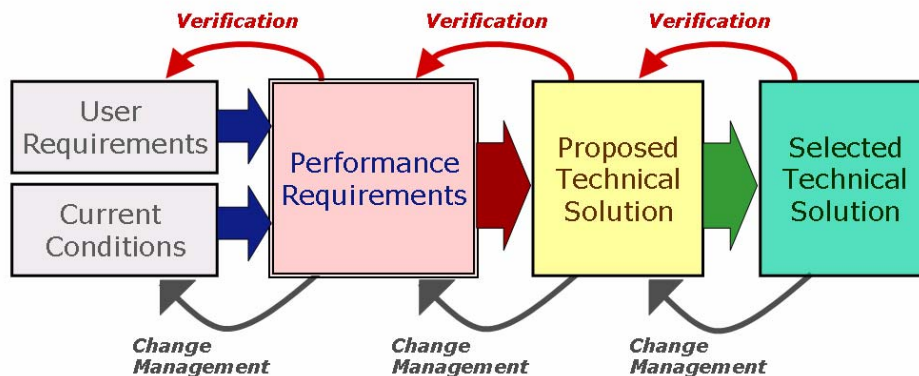


Figure 2 - Performance requirements management process.

In addition to the essential aspects described above, there is also other important information which can help implementing the performance approach in building construction project (Gross, 1996):

1. Commentary - Background and rationale behind the performance requirement.
2. Deemed to satisfy documents - Examples of technical solutions that fulfil the requirement.
3. Quality control manuals - Documents that describe the quality procedures during project.
4. Post-occupancy evaluation - Evaluation of the actual performance of the building providing feedback for future work.

2.3 IMPLEMENTATION BARRIERS

Based on Hens (Hens Hugo, 1996), there are also inherent barriers in implementing the performance concept:

1. Disintegration of design, engineering and construction.
2. The fragmentation of the design and the construction side.
3. The guilds mentality.
4. Too strict market approach of the manufacturing industry.
5. The low level of R&D investments in the construction industry.

With the new performance based procurement practice we are able at least partly remove the first two and possibly third barriers. It is assumed that when: i) architects and engineers exploit their core knowledge to create the overall technical solutions that fulfil the set performance requirements; and ii) construction companies have the opportunity to take long-term responsibility for building parts developed together with architects, engineers and product suppliers; the quality of the end product improves. Based on the authors' experience there are also other major problems of implementing performance approach:

1. The client does not trust the construction companies to provide the quality that is expected unless the technical solutions are described in detail.
2. There are no tools in wide use that would support the implementation of the performance approach.
3. There is not enough knowledge (or understanding) of the performance approach in the construction industry.
4. There is a common concern among practitioners that performance approach requires a lot of effort, uses a lot of time and generates information that is not precise.
5. A lack of agreed quantitative performance criteria for key requirements

2.4 SYSTEMATIC REQUIREMENTS MANAGEMENT IN PERFORMANCE APPROACH PRACTICE

CSIRO Manufacturing and Infrastructure Technology (Australia) and VTT Building and Transport (Finland) are currently developing a software tool called PRISM, for systematic performance requirements management. The PRISM software helps to fulfil customer requirements and expectations by describing the properties of the final product using a hierarchy of performance requirements and different performance 'levels'. The technical solutions can then be designed based on the specified performance requirements. PRISM can also be used to estimate life-cycle costs associated with different scenarios, based on the environmental 'costs' which result from the construction and operation of the building. A screenshot from the PRISM software is shown in Figure 3.

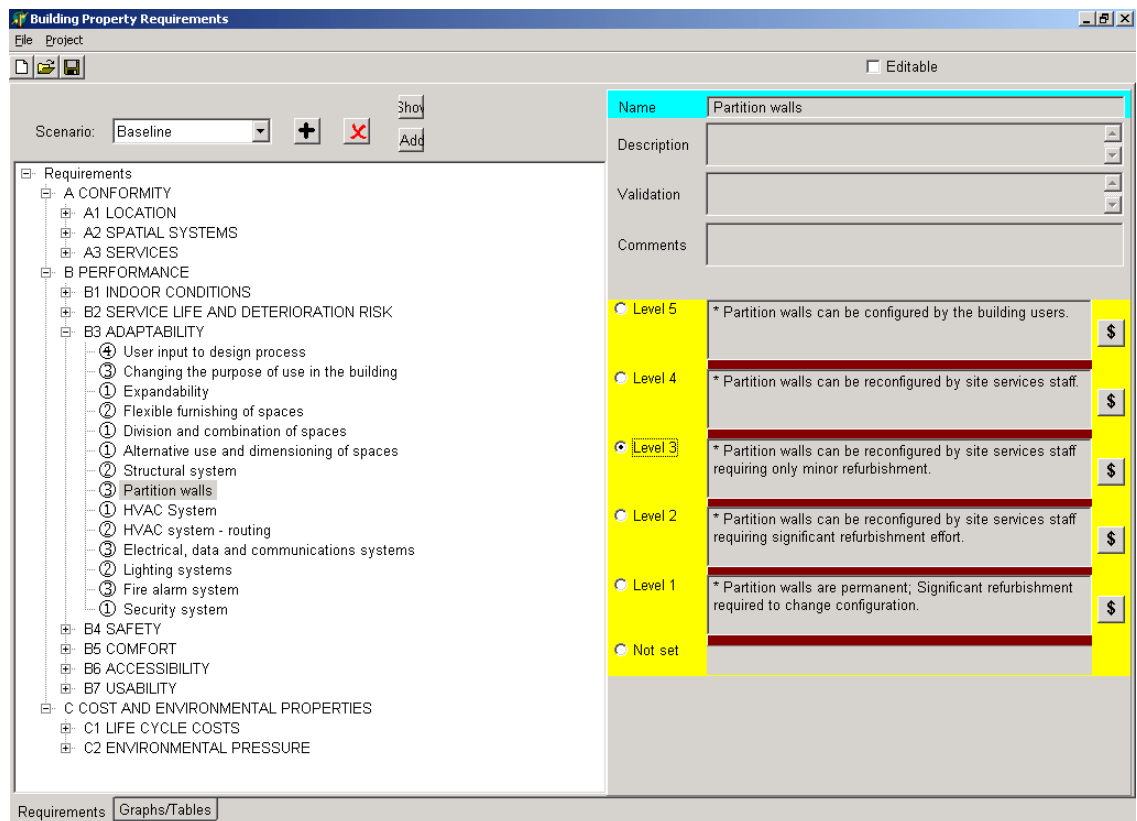


Figure 3 – PRISM software screenshot

Although the English language version of PRISM is still under development, a Finnish language version of the software (EcoProP) has been used in various projects in Finland including office buildings, schools, nurseries, residential developments and shopping centres. One of the companies which has used the tool, is the owner and operator of the vocational education facilities of the Jyväskylä region (JKKK). The other is a consultant company (Controlteam) that provides project management services for JKKK. They have worked together for several years successfully using the traditional practice: JKKK collects the user requirements for a new building from the educational unit that will use the building. Based on this information, Controlteam manages the design phase and arranges the request for tenders with near-final versions of the design and drawings. Since JKKK is a publicly owned company, the cheapest offer is selected. JKKK people have recognized that this does not lead to the best possible performance and life-cycle cost of the facilities. They feel that the buildings they operate should have a long, well performing life cycle and small operating costs. At the beginning of the project, the JKKK people assisted by Controlteam will set the performance and environmental requirements together with the users. Also the cost effects of the requirements are analysed. Final document containing set performance requirements acts as an enclosure to design brief.

The investment cost analysis is not originally supported by the performance approach. It is not the performance requirement that drives the investment costs but the corresponding technical solution. In this sense the process is iterative. The effect on investment costs for particular technical solutions have to be analysed and if necessary, changes must be made to the performance

requirement. The goal of tool is to give a rough level estimate of the annual cost based on the current performance and environmental requirements and expected life cycle with certain interest rate. Hence it is possible for JKKK to show to the company decision makers that it pays back to select an alternative that might be a bit more expensive at the construction phase. Furthermore, EcoProP has proven to be a valuable aid in implementing the performance approach in Finland because the users are 'forced' to think their objectives through, before jumping into the technical solutions.

PRISM can be used in a team session or one user can set requirements. The use of PRISM in a team session improves the quality of the selected targets and goals of the project since participants challenge each other's ideas and selections. Also the commitment of the project team members increases. The scope of controlling and managing the requirements has to be seen in a broader context, where customers can link all relevant information from their point of view to software managing performance requirements. This means that decisions can for example lean on to company's business plan and relevant other information gathered. This leads to more transparent decisions and combine varied approaches which for example owner, user, designer and architect have.

3. DISCUSSION

PRISM was originally developed, and has been successfully used, in Finland. In development of PRISM, the potential influence of national culture has been explored. In particular, it can affect what attributes of PRISM would be considered most important by its users. Research suggests that national culture can have a strong influence in certain circumstances. Two leading researchers in cross-cultural study both categorize nations in terms of cultural clusters. Fons Trompenaars has suggested that there are four categories of corporate culture that arise from national values (Trompenaars, 1993). He has called these: Family, Guided Missile, Incubator and Eiffel Tower (no prizes for guessing which category he put French companies into – yes that's right: Family). Within these categories he identifies common characteristics, or more specifically, ways of thinking. For example, German corporate culture is said to value logical, analytical and rationally efficient thinking. This attribution of characteristics is broadly consistent with the findings of Geert Hofstede (Hofstede, 1994). Also, it is similar to the anecdotal evidence put forward by requirements management experts in the United States (Hooks, 2001).

Clearly, the systematic approach offered by PRISM is highly compatible with analytical thinking. However, in other national cultures other types of thinking are more valued. For example, it has been suggested that Russians have excellent analysis skills and little tolerance for mistakes. On the other hand, it has also been argued that they do not have such a ready inclination to interact with customers. In this type of cultural setting, the structured approach in which PRISM provides for improved customer interaction can be highly valuable. Japan perhaps offers the perfect implementation environment for PRISM. This is because the Japanese are familiar with advanced methods for analysing customer priorities. As a result, they understand the iterative nature of requirements management. Nevertheless, when Japanese companies work overseas they can find themselves dealing with one-off

clients with less knowledge of the construction process than their Japanese counterparts. In this type of situation, PRISM provides a robust tool which offers a universal and standardised set of procedures. It goes a long way towards filling gaps that can be caused by expert contractors assuming that customers are as familiar with requirements as they are.

Other benefits of PRISM may be valued more in the “Anglo” cultures of Australia, Britain and the United States. It has been reported that this type of culture is characterized by impatience with delays, acceptance of mistakes, the urge to improvise and bias towards assumptions (Hammond, 1998). Clearly, these types of situations make a structured requirements management system all the more important. Yet, they can make implementation quite challenging. Hence, counter actions may be required. For example, users could develop simulations to validate high risk requirements. The requirements engineering phase could be occasionally turned into an improvisation exercise by anticipating the potential future problems (Trompenaars, 1993). Overall, national culture can have an influence on what users value most (or not) about a tool such as PRISM.

4. CONCLUSIONS

Incorporation of different stakeholders needs and aspirations, and setting of clear performance requirements at the earliest possible stage in a construction project leads to a vastly improved end product. The authors' experience has shown that through intelligent performance requirements management, this can be achieved with less effort, in less time, and with improved precision, than through more traditional approaches.

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PROCUREMENT AND RISK SHARING

Case Study

DECLINING STANDARDS OF PROJECT DOCUMENTATION QUALITY IN THE BUILDING & CONSTRUCTION INDUSTRY **A MAJOR CHALLENGE FOR ALL STAKEHOLDERS**

Alan McLennan

Trevor Parminter

ABSTRACT

Evidence of a continuing decline in the quality of project documentation in the building and construction industry has been documented by a number of authors over the past 10 years.

The scale of the problem is so significant that poor quality design and documentation is contributing at least 12% to project costs. This equates to some \$7b that is lost on unproductive activities in Australia's building and construction industry each year.

The authors have concluded that the causes of the problem lie in all phases of project delivery from concept and project initiation, through development, design and documentation stages, to tendering and construction activities. All stakeholders in the industry contribute in one way or another to the problem (by their attitudes and/or direct actions) and all of them have much to gain if the problem is overcome.

A number of attempts have been made to address the problem and some proposals have been developed.

This paper outlines the initiative being undertaken by Engineers Australia (Queensland Division) to address the problem collaboratively with a number of industry stakeholders. The methodology being employed and expected outcomes are outlined.

The paper demonstrates that resolution of the problem can only be achieved through development of an industry-wide strategy and generation of commitment by all industry stakeholders to implement the strategy in a spirit of cooperation.

INTRODUCTION

Designers provide the graphic and written representations that allow construction and trade contractors to transform concepts and ideas into physical reality. How effectively and efficiently this transformation occurs depends largely on the quality of the design and documentation provided. Whilst good design needs to be “effective” and ensure fitness for purpose, it also needs to be communicated effectively through the contract documentation including drawings, specifications and project controls.

Engineers Australia members have been concerned about the problem of poor project documentation quality for more than ten years. Some of them have been directly associated with initiatives aimed at overcoming the problem (eg CIDA, 1993).

Subsequently, some members developed an association with the research being undertaken by CSIRO (Tiley et al., 2002 & 2000). Engineers Australia was one of a number of organisations that actively assisted CSIRO by promoting to its members the desirability of their responding to questionnaires and other approaches for collection of research data relevant to the problem.

During 2001, progress findings of this CSIRO research was discussed at two seminars sponsored by Engineers Australia (Queensland Division). In this context the authors concluded it was essential that the problem be addressed in a manner which ensures that the various issues, adverse impacts and consequences would be turned around, and that there was an urgent need to do this in the interests of efficiency and productivity of the building and construction industry.

Subsequently, the authors and a number of their industry colleagues prepared a proposal whereby the Queensland Division of Engineers Australia would assume a leadership role in the resolution of the matter by involving their members and all other industry stakeholders (Gallo et al., 2002).

Engineers Australia (Queensland Division) adopted this proposal and has established a Task Group to address the problem. Some 12 stakeholder bodies are represented as well as a number of members of Engineers Australia (Queensland Division).

The aim of this paper is to demonstrate that resolution of the problem can only be achieved through :

- development of an industry-wide strategy on the part of industry stakeholders,
 - generation of commitment by all of them to implement the strategy in a spirit of cooperation, and
 - their active participation in a managed plan for implementation of that strategy.
- It is also hoped to foster support for and participation in the work of the Task Group.

THE PROBLEM

OVERVIEW

The Australian construction industry has been portrayed by industry analysts as being uncompetitive and inefficient (BCA, 1993; CIDA, 1993; Crow, 1997; Ireland, 1988 & 1994; Koskela & Sharpe, 1994; Love et al., 1996; Mohamed & Yates, 1995;

Walker, 1994. Crow (1997) in particular is highly critical of the Australian construction industry, claiming that:

“...up to 40% of effort in developing and operating capital works facilities is wasted and adds no value to the end user/customer whilst depleting profitability of the client, designers and contractors.”

Concerns have been expressed in the building and construction industry that a declining standard of documentation quality has contributed significantly to a similar decline in construction efficiency.

These concerns have been confirmed by research undertaken by CSIRO (Tilley et al, 2000, 2002), the Construction Industry Development Agency (CIDA, 1993), and Construction Queensland (eg Construction Queensland 2001).

RESEARCH FINDINGS

Since 1995, Paul Tilley and others in the CSIRO Manufacturing and Infrastructure Technology Division have been investigating issues affecting design and documentation quality and their impact on the efficiency of the construction process. During his research Tilley has undertaken a number of surveys among client organizations, designers, main contractors and trade contractors. His research findings include specific data on the nature of the impacts of poor documentation quality (for all stakeholders), their causes, and perceptions of the various stakeholders. These are published in a number of papers, some of which are included in the list of references in this paper.

Key research conclusions based on data collected and analysed are:

- design and documentation quality have worsened over time apparently in direct relationship with reductions in design fees; and
- at the same time there have been increases in project time, costs and non-desirable elements of construction including (inter alia) disputation, project delays, and cost overruns.

SCALE OF THE PROBLEM

Size of the Industry

In the 2000-2001 financial year, the building and construction industry accounted for approximately 12% of Australia's Gross National Product, ie an annual expenditure of \$58b. (Smithies, 2001) There are also approximately 210,000 firms operating within the industry employing around 670,000 people, which represents about 7.4% of the workforce. (McCarthy, 2001, Smithies, 2001)

However, as large as the industry is, the effect that the industry has on the rest of the national economy is sometimes overlooked. For every extra \$1m of construction undertaken, an additional \$1.87m is generated elsewhere in the economy and provides an additional 1.73 full-time, non-construction jobs. (McCarthy, 2001)

Scale of Inefficiency

It has been determined that up to 40% of the cost of non-manufactured components of built-assets (eg certain management processes, rework by designers, documentation clarification, resolving RFIs) adds no value to the end-user and thus

reduces the investment value of the assets to clients. (Construction Queensland, 2001)

In an environment where inadequate time is allocated for design and analysis of alternatives, it is inevitable that conservative designs which are not necessarily the best-for-purpose are produced; for example manufactured components are often over-sized for functionality by up to 15%, or do not achieve fitness-for-purpose criteria.

Clearly there is significant scope for improvement with consequent benefit to all stakeholders and to Australia as a whole.

Research has indicated that poor quality design and documentation can conservatively contribute up to 12% of project costs at tender time (due to allowances for project uncertainty) (Tilley, 2000) and is a major contributor to project variations and rework (Love et al, 2000). When the costs of project delays, disputation and additional project administration by all project participants are included, the overall costs of poor design and documentation are very significant indeed.

Assuming that improvements in design and documentation can reduce overall project costs by just 1%, based on the figures above this alone has the potential to save the Australian construction industry around \$600M each year. Clearly there is significant scope for improvement with benefits for all stakeholders and for Australia as a whole.

CAUSES

Overview across project phases

The authors have recognised in the available research as well in their professional experience that there are many causes that contribute to the problem – some are consequential on others, some involve more than one stakeholder.

Gallo et al., (2002) listed under stakeholder groupings a number of causes that have been identified by a range of stakeholder representatives and professionals working in the building and construction industry. These same causes are represented below in lists of causes attributable to project phases.

Project initiation phase

- Inadequate recognition of whole-of-life implications at briefing and design phases.
- Lowest price mentality in engagement of planners and designers.
- Unrealistic expectations about time and cost constraints.
- Client reluctance to bear design and construction phase risks.
- Failure to appoint an overall project manager.
- Inadequate client knowledge of the implications of their expectations, demands and directions.

Design phase

- Optimum design solution not adequately researched.
- Inadequate consideration of whole-of-life cycle and constructability issues including poor coordination between services and suboptimal sequencing of project activities.
- Focus on risk shedding rather than on targeting quality of documentation.

- Reluctance to allocate experienced staff to projects because of their high cost in an environment of inadequate fees.
- Short-cut design times result in inadequate checking of details and insufficient reviews with relevant parties.
- Inadequate design coordination between engineering, architectural and mechanical design disciplines.
- Inadequate coordination across design components developed by various parties.
- “Cut and paste” syndrome due to quest for economy of design time - lack of integration results in ambiguities in documentation.
- Erosion of expertise – eg design draftsmen being replaced with CAD operators.
- Fewer “green field” and more retrofit projects lead to tighter tolerances and more interfaces – increased costs without corresponding recompense in fees.
- An apparent “design by crisis” operating mentality - leaving design issues to be sorted out in the construction process.
- Emphasis on minimum effort rather than on doing the right job the first time – driven by commercial pressures and failure to maintain professional standards.
- Incomplete documentation including inadequate detail - issued with known deficiencies.

Tendering phase

- Multiple “notices to tenderers” and question/answer steps erode document accuracy due to short time for amendments.
- Reluctance by tenderers to ask questions that might reveal competitive edge.
- Extended and unduly complicated award processes.
- Reduced tender times.

Construction phase

- Adversarial attitudes (all parties) and seeking to re-apportion risks to other stakeholders.
- Defensive approach to variations and claims for additional costs or time.
- Cumbersome and defensive approach to RFIs.
- Introduction of legal and insurance advice in order to cover perceived risks.
- Lowest price mentality in engagement of subcontractors.
- Difficulties in maintaining skill levels.

Consequences for Stakeholders

Overall Environment

Overall, these causes work together to create an unsatisfactory environment for the building and construction industry characterised by :

- disruption to programmed activities and delays including fabrication of components and completion of stages of projects;
- acceptance of rework and additional expense;
- additional time in analysis of problems and determination of remedial actions;
- an unnecessarily conservative approach including over design and other attempts to ensure inter alia adequate factors of safety and margins;
- overly complex and voluminous contract documentation through over prescription of control mechanisms in traditional forms of contract (which in turn lead to adversarial approach to problem solving);
- a culture of blame rather than one focused on effective team work;

- adversarial consideration of the costs and impacts of time delays and additional work;
- inequitable sharing of risks and costs;
- diminution of respect between parties – deterioration of relationships and breakdown in cooperation;
- focus on immediate or short term activities at the expense of whole-of-life asset considerations.

Consequences

The following lists are not exhaustive; they are presented here to illustrate the range, scale and severity of the problem – as recognised by a range of stakeholder representatives. A picture of inequitable project delivery is also evident.

1. Contractors

Contractors are expected to price their tenders in a competitive environment often with inadequate time to research all details of site conditions. Poor project documentation results in adverse consequences during a number of project stages -

- a) during the tender stage as a result of inadequate tender documentation
 - multiple notices to tenderers, amended documents issued during the tender period resulting in wasted effort by all tenderers;
 - uncertainty following “rounds of questioning” causing increased costs of tendering and higher tender prices;
 - increased costs (to all tenderers) in attempting to respond to notices and answers to questions;
- b) during the contract award stage
 - extended and/or complicated award processes causing increased costs;
- c) during the construction stage
 - ambiguities, errors and oversights leading to RFIs with consequent direct costs due to rescheduling and delays; indirect costs due to reallocation of resources and secondary effects;
 - resolution of documentation deficiencies often occur at inopportune times, leading to deterioration in contract relationships;
- d) during the post-construction stage
 - delays in reaching agreement on final quantities, variations, extensions, delay and disruption effects leading to further costs and deterioration in relationships.
- e) throughout
 - additional managerial and administration costs;
 - perception of inequitable sharing of project risks generates adversarial behaviour.

2. Subcontractors

Subcontractors are often remote from the direct superintendent/contractor dealings; hence subcontractor generated RFIs generally involve significant time delays, complex dealings and increased costs -

- additional drafting time spent on shop drawings;
- delays and rescheduling of activities;
- relocation costs for men, equipment and materials;
- secondary effects on other trades – rescheduling;
- interfaces between trades work areas not aligned;
- frequent changes and reissue of drawings generate quality concerns;

- solutions offered for correction of design errors and ambiguities without the benefit of insight to the overall design;
- tight time frame when RFIs are resolved often requires “high pressure” work, overtime and even sharing of work with various subcontractors leading to consequent loss of work volume to individual subcontractors who then are not able to recoup overheads and set up costs.

3. Clients

Clients take the lead in project initiation and indeed in setting the framework within which the project is to be delivered. The following are some consequences of the problem that indicate that client objectives are often frustrated -

- higher tender prices;
- extended and/or more complex award processes;
- time and cost over runs;
- disputation and relationship issues;
- sub-optimal outputs for the overall project.

4. Designers

Designers are relied upon to apply their professional expertise and to ensure that appropriate standards are followed. However, undue emphasis on cost and time factors often leads to the following consequences -

- loss of professional reputation;
- loss of expertise of design draftsman resulting from cutting fees and not being able to afford to use the best people for the job and having good people filter out to other parties;
- loss of profitability and perhaps business viability;
- increased stress levels for design staff by having to revisit old jobs to fix problems;
- current job programs being put constantly under pressure by having to revisit completed jobs;
- inadequate opportunity for analysis of alternative options - the chance of defining the optimum design solution is consequently limited;
- restricted review processes with all interested parties – implications include constructability deficiencies, poor coordination between services, project activities suboptimal, whole-of-life cycle issues not adequately considered, inadequate detail in documentation;
- designers are required to place undue emphasis on commercial aspects to maintain viability – often at the expense of truly professional performance.

Summary of Consequences – Broader Issues

The overall problem and the environment it has created generate impacts on all stakeholders, particularly in the aspects summarised below; this leads to inequitable outcomes from the project delivery:

- delayed completion of projects;
- increased costs;
- reduced margins; and
- reduced quality of built infrastructure and/or level of service.

Consideration of the problem and its consequences is complex due to the wide ranging issues, their causes and implications. Some of these are of a broad strategic nature whilst others are quite detailed and operational in nature.

To overcome this problem it is essential that a thoroughly planned and prioritised approach be taken and which will be defined, implemented and managed with a strategic focus.

PREFERRED PROJECT ENVIRONMENT

The authors consider that a transformation is needed to create a preferred project environment that would include the dimensions summarised below. This list is indicative only, and needs to be examined further in order to develop a comprehensive vision for the future.

Dimensions

Dimensions of the preferred project environment :

- sustainable and efficient construction industry which contributes to wealth creation;
- end users satisfied;
- viability of projects established in the business case before initiation of project design;
- reasonable profits for all stakeholders – through equitable project delivery;
- built infrastructure of a good standard in both the physical and whole-of-life senses;
- thorough assessment of the risks and their equitable allocation to the various stakeholders;
- industry supported by research and development leading to future improvements in productivity;
- proper balance between commercial and professional imperatives.

Preferred behaviours and operational strategies

These dimensions would be characterised by behaviours and operational strategies that encompass the following:

- cooperative relationships between all parties – client/designer, client/contractor, etc;
- allocation of appropriate people, time and budgets to each phase of all projects;
- sufficient project planning undertaken prior to commencement of design;
- competent processes for design coordination and design review on all projects integration of project documentation essential;
- adequate assessment of constructability of designs;
- documented processes for progressive client acceptance and sign-off of the design during previously identified phases of the design process;
- effective communication and collaboration processes involving clients, designers, contractors and other stakeholders;
- adoption of appropriate and more effective project delivery processes – more equitable forms of contract;
- less allocation of blame and taking of positions – more professional integrity and accountability.

Vision

The authors have concluded that the above characteristics can be summarised in the following vision for the industry :

- Emphasis on best-for-project and end-user outcomes – so as to ensure best value for investment and costs of operation.
- Elimination of unnecessary costs of argument, arbitration and litigation.
- Encouragement of innovation and “clever” designs – fit for purpose, yet encompassing new ideas and “new ways”.
- All stakeholders have ownership of and pride in the outcomes.
- Improved satisfaction levels and co-operative working environment will encourage capable people to join and remain in the industry.

WHY PREVIOUS ATTEMPTS HAVE NOT CHANGED THINGS

A number of well founded and well intentioned initiatives have been undertaken by various parties over the past 10 – 15 years with a view to overcoming the problem (of declining quality of project documentation), eg

- Strategies for the Reduction of Claims in the Construction Industry – a research report (Nov 1988)
- “No dispute” – Strategies for Improvement in the Australian Building & Construction Industry (May 1990)
- Construction Industry Development Agency (CIDA) – established to *(to be expanded when details obtained from DPW library)*.
- Construction Queensland – established to *(similar wording as for CIDA above yet to be “researched”)*.
- “Design Documentation Guidelines for Architectural and Structural Designers” - Construction Liaison Group, NZ (draft 2002)
- Improving Project Documentation – a Guide to Improve Current Practice – Australian Procurement and Construction Council with the Australian Construction Industry Forum, Canberra, Australia (2003)

It is recognised that in certain situations considerable improvement and benefit have been achieved :

- Project Initiation Guide for project sponsors, clients and owners – published by the Construction Industry Development Agency, 1993
- Model projects (success stories) highlighted in “Wealth Creation through Equitable Asset Delivery” – report & implementation guide published by Construction Queensland, 2001
- Advances in equitable project delivery, including relationship contracting alliance agreements.

Nevertheless, the overall picture continues to be one of declining quality in project documentation as evidenced by most recent research findings and reports on industry experiences.

The authors have concluded that there are a number of factors preventing the desired improvement; these include :

- The building and construction industry is very complex with many specialist components and many stakeholders with competing and sometimes conflicting objectives.
- The identified problems involve more than one stakeholder – resolution requires communication skill and co-operation without allocating blame.
- Lack of appreciation that feasibility analysis (including consideration of options), planning and design all form part of overall project delivery – small increases in effort during these phases give potential for significant savings in construction

costs (ie better designs with fewer errors and less ambiguity result in less re-work, less unproductive time in resolution of disputes, etc).

- Political and commercial pressures for “instant” results – pressure on project initiation and project planning phases and which also flow on to the construction phase.
- Lack of appreciation of the distinction between project initiation and project planning phases on the one hand and design processes on the other.
- Preparation and publication of technical guides does not of itself lead to their implementation and improved performance and productivity – other initiatives are essential (eg build awareness of relevance and need for the improvements, training, feedback on use, etc) in order to embed the improved practices in the culture of the industry.
- Industry culture and attitudes – including erroneous views that engagement of professional and specialist services can be made in the same way as purchase of commodities.
- Government policies which may not be best suited for the realities of the building and construction industry (eg purchasing policies that pursue unbridled competition).

“DIMENSIONS” OF REAL SOLUTIONS

Whole-of-industry (involvement & commitment)

Widespread acknowledgement of the problem, and of its causes in all stakeholder areas is needed so as to ensure commitment by all stakeholders to collaboratively develop solutions and to implement them.

Without such understanding and commitment by all stakeholders to work together, part-solutions only can be defined and implemented. Such initiatives have only limited impact on the problem and may not be sustainable (as has been found with a number of previous attempts to overcome the problem).

Strategic approach in definition of package of solutions

The authors contend that the only way to define a comprehensive package of solutions is through application of strategic thinking about the overall problem (and its dimensions).

In this way all components of the necessary solutions can be identified, including measures that :

- Can be implemented in the short term.
- Need longer periods to fully research and define.
- Address industry attitudes and the need for culture change.

Relevance & need for managed change program (including cultural change)

Changes are inevitable and are continuously affecting the industry (eg in materials, equipment and technology) –of themselves these are the cause of some dimensions of the problem.

It is essential that an organised approach be defined and implemented for management of change in the industry (by all stakeholders and the industry at large) so that :

- The benefits of the improvements available can be achieved.
- The necessary attitudinal and cultural changes can be put in place.

Management plan & arrangements for implementation

The magnitude and complexity of the challenge in implementing the necessary solutions to the problem are significant. The industry needs to apply the same techniques for ensuring successful delivery of the package of solutions that all of its stakeholders apply to their business endeavours, viz define and implement a management plan for the program of activities, including definition of :

- Management arrangements and responsibilities.
- Priorities and time targets.
- Processes for review of progress and reporting of results.
- Means for highlighting and rewarding success.
- Procedures for identification of impediments and shortcomings, and for their resolution.

ENGINEERS AUSTRALIA, QUEENSLAND DIVISION INITIATIVES

Following consideration of the paper “Project Documentation Quality and its Impact on Efficiency in the Building & Construction Industry” Gallo et al., 2002 the Queensland Division of Engineers Australia decided to establish an industry wide Task Group to address the problem of declining project documentation quality that is evident throughout the building and construction industry. The charter of this Task Group is defined in the following terms.

Mission

To avoid waste and to raise effectiveness and profitability in the building and construction industry by achieving a high standard of project documentation.

Objectives

- a. To understand the wide impacts of poor quality of documentation on the national economy, and on the well being and profitability of all industry players along the supply chain.
- b. To articulate the problem in a way that allows identification of the full range of critical issues and their primary causes.
- c. To develop sustainable and implementable solutions that address the critical issues.
- d. To influence industry at all points along the supply chain to avoid the pitfalls and to consistently adopt best practice in project documentation quality.

Scope

Definition of practical solutions to the problem and a plan for their implementation.

Stakeholder bodies

The following stakeholder bodies have confirmed their commitment to the charter of the Task Group and are represented by experienced and senior professionals :

- Air Conditioning & Mechanical Contractors Association of Queensland Limited

- Association of Consulting Engineers, Australia (Queensland Division)
- Australian Institute of Building (Queensland Chapter)
- Australian Institute of Quantity Surveyors (Queensland Chapter)
- Australian Steel Institute (Queensland/Northern Territory Division)
- City Design – Brisbane City Council
- Civil Contractors Federation (Queensland Division)
- Department of Main Roads, Queensland
- Department of Public Works, Queensland
- Queensland Major Contractors Association
- Queensland Master Builders Association
- Royal Australian Institute of Architects (Queensland Chapter)

Construction Industry Forum

The Task Group convened a Forum in May 2004 at which 120 representatives of all stakeholders in the industry discussed the problem. Small group workshops were conducted to identify causes of the problem and possible solutions to them; each workshop was followed by group feedback and plenary discussion.

The findings of the Forum are documented in a report that has been widely published “The declining standard of documentation in the building and construction industry – report on possible causes and solutions – outputs from Construction Industry Forum” May 2004. These are summarised as follows :

- The dimensions of the problem, the issues behind them and the list of causes being developed by the Task Group were confirmed.
- The Task Group can proceed with confidence with more detailed analysis of causes and development of solutions – for consideration by the industry.

Management framework

The Task Group has adopted a project management framework with specific goals, target dates and desired outcomes. Specific sub-groups of volunteer professionals from the various stakeholder bodies represented on the Task Group have been established, each with nominated roles and objectives – progress reports from each sub-group are considered at each Task Group meeting :

- Project Plan – definition and monitoring of progress, methodology, communications strategy, and stakeholder involvement.
- Review research – identification of relevant research papers, development of data base with convenient electronic access.
- Root Causes – define the root causes of the problem, including identification of priorities for resolution and practical constraints.
- Develop Solutions – identify those root causes amenable to short term solution and those with longer term constraints, develop practical solutions with any implications and/or constraints to be addressed.
- Define Implementation Strategy – a package of achievable implementable activities, including proposals for management and monitoring of an implementation plan, and for identification of costs and benefits.

The Task Group was established in January 2004 and proposes to document its findings in a report by the end of 2004.

The report is to be published throughout the industry and the wider community with a view to ensuring support for the implementation strategy that it will propose, for

adoption of it and agreement to proceed with its implementation in a collaborative manner.

SUMMARY

There is widespread acknowledgement in the building and construction industry that the problem of declining standards in the quality of project documentation must be overcome. This paper outlines a wide range of causes and consequences of declining standards and provides an indication of the direction that must be pursued in order to overcome the problem.

Significant commitment, support and effort is being devoted to that endeavour by the primary industry stakeholders, including acceptance of the importance of the lead role being taken by Engineers Australia (Queensland Division).

The authors (and the Task Group) are confident that these joint endeavours will enable the problem to be turned around and that significant benefits will result for the industry and the community at large.

Support and assistance from organisations and individuals associated with the industry, or affected by it, are welcome at any time.

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CAPTURING AND MAINTAINING THE CLIENTS REQUIREMENTS

Case Study

RE-ENGINEERING SCOPE MANAGEMENT

Harry Carrick
CEO Rawlinsons Group

INTRODUCTION

This paper addresses the management of scope in construction projects and proposes a change to scope management processes to reduce cost over-runs caused by scope 'creep' and deliver a completed construction project to clients' quality expectations.

Our industry faces a significant problem with the management of scope and the containment of budgeted costs in both public and private sector projects.

This has led to client dissatisfaction with project outcomes in terms of quality and scope, and cost over-runs which impact on budgeting and project profitability.

In the public sector, governments have less to spend on infrastructure and in the private sector clients are disinclined to invest in construction projects when their returns are uncertain.

BACKGROUND

Scope 'creep' – *a progressive growth of project quantum and quality over that provided in the project cost budget* – is a major cause of cost-overruns and client dissatisfaction with project outcomes. The project cost budget arrived at by applying analysed historical cost data to a building function, quantum and quality, is a finite number.

Changes to the function, quantum or quality of the building have a direct impact on the project cost budget. To effectively control the project budget, scope must be clearly defined at the outset and managed throughout the design and delivery stages.

Over the past 15 to 20 years, the way we design and deliver projects has changed significantly but there has not been a corresponding change in scope management practices. Projects are now designed using CAD. Cost risk is transferred from Client to Contractor at an earlier stage, when the definition of scope is open to a much wider interpretation by both parties. This has resulted

in increased conflict of both cost and quality expectations as the project progresses.

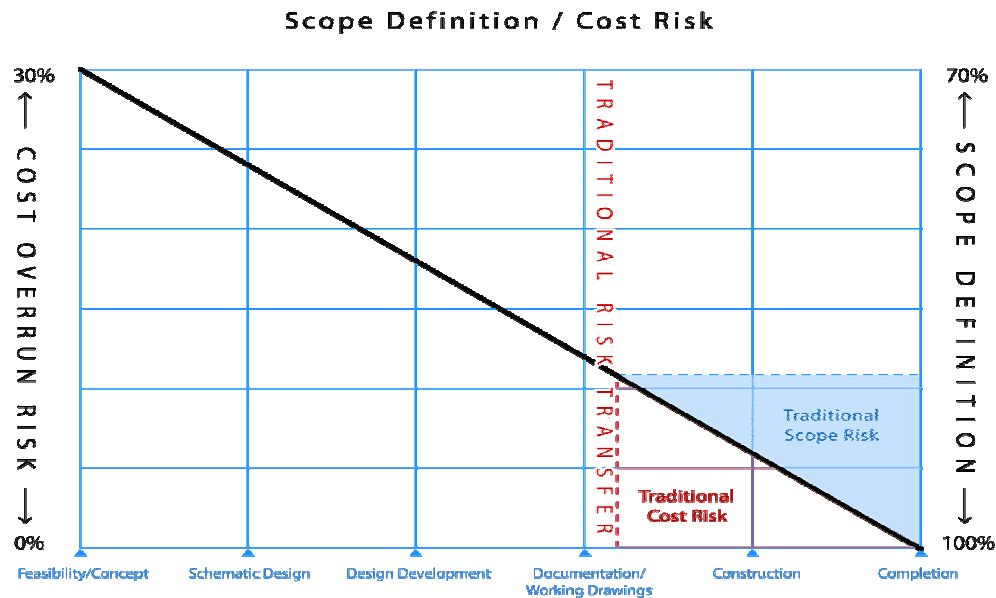


Figure 1 – Cost Risk Transfer - Traditional

Under traditional contract systems the cost risk was transferred through a tender process. This process comprehensively defined project scope in a priceable market form. Bills of quantities were prepared using a standardised measurement format, from detailed design drawings and comprehensive specifications. Effective management and interpretation of clients' requirements and scope definition was required to arrive at this level of documentation. The documents issued to tenderers, while not 'for construction' drawings, allowed a comprehensive commercial statement of the project requirements to be tendered.

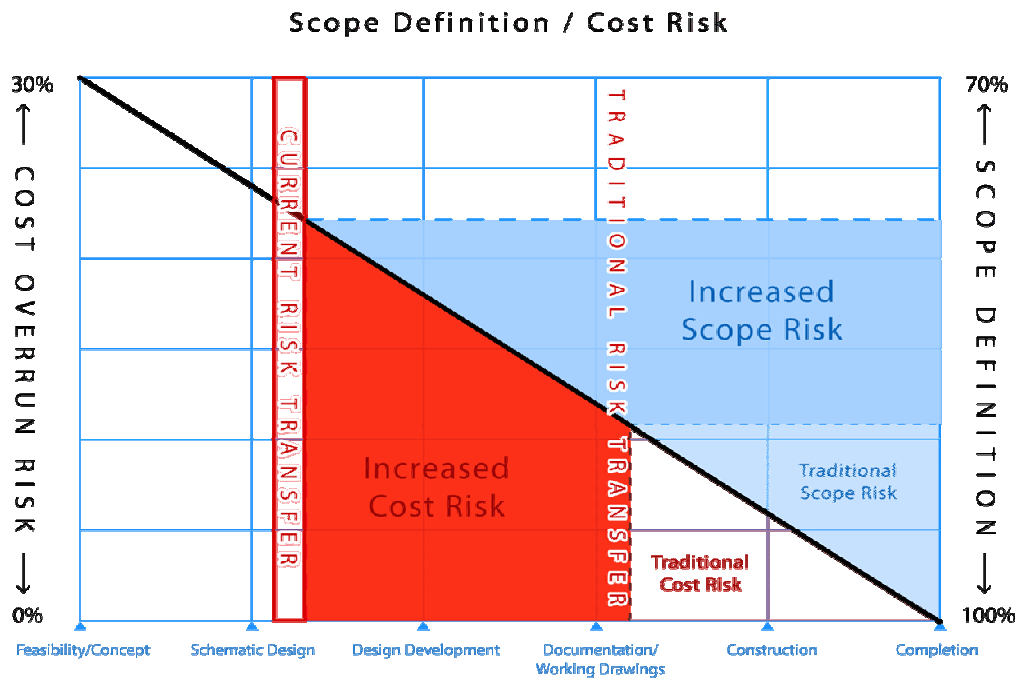


Figure 1 – Cost Risk Transfer – Current

Budgets are increasingly being set on limited scope information to meet program demands with the doubtful assurance that the cost risk is being effectively transferred.

With cost risk transferred Client to Contractor at an earlier design stage, when scope is less defined, conflicts in expectation on quantum, quality and cost are inevitable.

At this early stage the Clients' fixed cost expectations as expressed in the budget figure are too often in conflict with the contractors' costing and interpretation of the scope and quality required.

Accepting that the industry is unlikely to rapidly change its tendering and commercial management practices, a new approach to managing scope is needed to achieve better outcomes.

THE SCALE OF THE PROBLEM FOR CLIENTS

There is widely reported evidence of substantial cost overruns in construction projects in both the public and private sectors. Scope 'creep' is a major contributing factor to cost overruns.

There is also widespread concern and dissatisfaction among stakeholders with the ineffectiveness of current practices and failures in scope management practices.

While the scale of the problem is difficult to accurately assess – as many are reluctant to admit to it and others can't keep track - there are abundant examples in parliamentary and media reports of projects sustaining cost overruns of from 20 to 50% and more. Ineffective scope management is a major contributing factor to cost overruns. The problem is serious and one which the whole industry must confront and overcome.

A recent construction industry forum on *The Declining Standard of Documentation in the Construction Industry*, hosted by Engineers Australia, was presented with evidence of 12% cost overruns across a series of public sector capital projects in Queensland. The projected impact was \$1billion per annum on public capital expenditure in Queensland alone.

This 12% cost overrun figure related only to the impact of scope changes/variations from working drawings to completion. Assuming a similar pattern of cost overruns exist in other states, the total impact of cost overruns attributable to scope creep could be in the order of \$4+ billion per annum nationally.

The problem of scope management and resultant cost overruns also has a negative commercial impact on private sector clients. Poor scope management weakens confidence in the construction industry's ability to deliver on budget and reduces the attractiveness of investing in property developments because of the uncertainty of cost outcome.

IMPACT ON THE WHOLE INDUSTRY

Clients

Problems with scope creep usually start with poor project definition by the client and/or inadequate project budgeting processes. Definition of project scope and cost is fundamental to project success and is the cornerstone of the business case for the project whether social or commercial.

If the brief definition and the cost budget are inadequate, function is compromised. Issues such as ecological sustainability and energy rating become esoteric if the basic foundation of the project is unsound.

Clients need a transparent process that locks in function, quality and cost, allowing them to see what they are getting for their money as the project proceeds. With this security of functional and cost outcome, decisions on ecological sustainability energy ratings and whole-of-life impacts can be made with greater confidence.

The problems of scope creep and the resultant cost blow-outs must be addressed if the forward vision of the industry is to stand a chance of being translated into building reality.

On top of the direct impact on Clients and the security of their investment, scope 'creep' has a flow-on effect on the whole construction industry.

Contractors

With earlier risk transfer, Contractors are entering into contracts based on concept design drawings with only an outline specification. The translation and interpretation

of the concept/schematic design information into working drawings for construction usually results in the addition of significant volume of items which have not been allowed for in arriving at the tender price. Anecdotal evidence from a range of senior estimators from major contracting companies judges the impact of this 'scope creep' to be in the order of 2.5% to 4% between early tender stage and package lettings.

Taking account of contractors' margins, a 'scope creep' of this magnitude can significantly erode or wipe out profitability. In the past, contractors have sought to recover the 2.5%-4% from the sub-contractor's price to recover the margin. In the current buoyant market their only recourse is to seek recovery from clients.

Sub-contractors

Sub-contractors pricing on concept or early schematic designs are faced with even greater difficulties. As trade contractors, their pricing capabilities are based on receiving a detailed trade definition of quantum and specification. It is now almost common practice for them to be faced with taking risks on quantity and specification because the design information is not sufficiently articulated to allow them to price in detail.

In recessionary times, subcontractors may be prepared to wear the risk. But in boom times they will load their prices or decline to tender on inadequate documentation, leading to sharp increases in sub-contract prices. In the current boom in the Queensland market, substantial rises in sub-contract prices are in part a reaction to the losses suffered in leaner years from these crude tendering processes.

Architects and designers

The cost of re-design work necessitated by cost overruns resulting from scope creep has a major impact on design resources and prejudices good design outcomes. Design resources are being wasted re-designing buildings back to budget because 'scope creep' has not been adequately managed.

There is no doubt that much of the criticism levelled at the declining standard of documentation arises from the early use of the documentation for purposes for which it was never intended. Schematic and concept design drawings are being issued to secure fixed trade prices and design development drawings are being issued for construction.

The time needed to adequately define scope to the project stakeholders, including sub-contractors and specialists, is often not made available because of the pressure to commence and proceed with construction. It is inevitable that if design is playing catch-up with the construction process, without the necessary co-ordination, research and checking, then additional scope will creep in with its resultant cost overrun.

Costing Techniques

As cost overruns appear to be the most measurable result of poor management of scope, it is appropriate to examine the cost techniques currently in use.

Costing techniques and processes have not met the challenge of the changing industry and have fallen far behind in responding to design.

Traditional costing techniques depended on a quantifiable basis of defining work capable of being priced at trade level by the market after working drawings and bills of quantities had been prepared. Thanks to earlier cost risk transfer, shorter program times, and a decline in documentation standards, traditional costing techniques have become ineffective in controlling cost outcomes.

This is largely because the foundation for cost planning and high-level estimating is a detailed, priced Bill of Quantities. It provided the basis for analysing market costs on a trade, elemental and whole of building basis. Few projects are being let on a detailed Bill of Quantities basis so analysed cost data is hard to come by.

The other main failing of current estimating and cost planning practices is that they do not relate to the current design medium of the industry – CAD – and still rely on manually applying scale rules to printed drawings with manual input to spreadsheet or database estimating packages.

A number of software packages allow digitising or on-screen polylining/tracing over CAD drawings, but provide no direct link between the CAD design and the cost. The process of quantification, which must be carried out prior to costing, is overly time-consuming and severely limits the ability to quickly respond to design changes and developments, allowing scope to creep unchecked.

If cost exercises reveal a cost overrun due to scope creep, the process of redesigning back to budget has a major impact on time, design direction and team morale. This is further complicated as design has continued to progress during the time the cost exercise was being undertaken.

Because of the impact of these 'after the event' costings on program time, there has been an increasing tendency, particularly in the private sector, to limit the number of cost exercises, thereby eliminating one of the best available scope management tools.

A change in costing processes and techniques, which integrates costing with CAD, is needed to service the needs of a faster moving industry.

Improving the Process

Some of the root causes of scope management problems - declining standards of documentation in the industry, constantly decreasing time programs, letting contracts early on limited information, a shortage of skilled and experienced people to manage and design projects - are deeply embedded in the industry and are not going to be easily solved in the short or medium term.

However, the scale of the scope creep problem is so large - more than \$4 billion per annum - that action is needed now. The challenge is to accept the current weaknesses of the industry and selectively re-engineer those processes that are

likely to have the biggest short-term impact to improve scope management practices and reduce cost overruns.

Costing processes and techniques offer the best opportunity for improvement and re-engineering through the adoption of new technology directly linking cost to CAD design.

Techniques have changed little in the past 50 years apart from automation in calculation and data sorting through the application of spreadsheet and database programs.

In considering the change in costing processes we need to look at the relationship of cost to scope.

Scope Management Objective

The Scope Management objective is:

To start with a defined scope and approved budget and deliver that scope on budget.

Although at outset project scope is only expressed in outline terms, the capital cost budget is expressed in a finite \$ number arrived at by a process of definition and calculation. As the budget is finite so is affordable scope.

This capital cost budget figure is a cornerstone of the business case for the project, whether social or commercial. It is the starting point for managing scope and cost. It is also the point against which the success of the design and delivery process will be measured.

With the price fixed, there is a direct relationship between quantum and specification as follows:

The Scope Management Equation

Scope = Quantum X Quality/Specification

Scope X Market Price = \$ Project Cost

Improved Scope Definition Conventions

Traditional scope management practices defined scope progressively through development of the design, confirmation with owners and users, detailed documentation and translation through quantification to priceable items before commitment.

Current scope definition terminology is loose and open to too wide an interpretation by all parties involved. There is a sufficient body of knowledge available across a full

range of building types to allow scope to be better defined even at early design stages. Building efficiencies and cost geometry (*Quantum*) can be established at concept stage with typical specifications (*Quality*) used to express quality expectations and set benchmarks for affordability. (*Price*)

By combining CAD and cost technologies scope definition practices can be developed to standardise the process of defining scope through each risk transfer point. To ensure adherence to budget, it is important to maintain the transparency of scope definition to all project stakeholders.

An industry agreed standard on extent and quality of information to be provided at the various design stages would assist in aligning expectations of all stakeholders. A common set of basic CAD protocols would also allow better understanding and more effective use of the information provided.

Improved transparency between cost and scope will allow contractors and sub-contractors to compete on market prices and management/time factors and not a 'guess the scope' basis.

Alliance Contracting has shown that scope is better managed with affordable budgets when scope definition is a more open process.

Quantum

For a particular building type there are inherent relationships in the geometry of its design that directly impact on its cost –its “cost geometry”. These relationships are defined at the earliest design stages and are the framework upon which the project scope is built.

For example – gross floor areas, building envelope ratios, internal wall ratios, footprints, functional areas, units, treated areas. From this prime cost geometry flow the related elemental items e.g. floor tiling, number of entry doors, air-conditioning volumes, number of WCs.

Project budget cost is set using analysed historical cost data (rate/m² of GFA, cost per unit) for a similar facility having similar cost geometry and relationships.

So by starting with the basic \$/m² or cost/unit a cost model for the building type can be generated in an elemental format, reflecting the typical cost geometry for a building of its type and a similar quality standard.

Using industry first software called CostX, developed by Exactal Pty Ltd www.exactal.com.au detailed cost geometry can be extracted from the earliest CAD designs and quickly applied to the cost model for the building type. The software can generate a project specific cost model which defines project scope at an elemental level. The Exactal website includes a demonstration of the CostX software.

QUALITY/SPECIFICATION

While the detailed specification is not available at concept or schematic stage, the expectation of quality is firmly set in the minds of clients and users. Their perception

of quality is derived from their knowledge of comparable constructed buildings of defined specification. By incorporating these specifications into the scope definition a benchmark for affordability can be easily set and be understood by all parties.

PRICE

By drawing down cost data from an external cost library of typical elemental specifications for similar building types, a detailed affordable scope definition to element unit level can be generated. By using an elemental cost library, which derives elemental cost from market trade prices across a range of material specifications, the cost model becomes a usable cost plan to manage and control project scope, thereby reducing the risk of cost overrun.

Because the building quantum is directly linked to the CAD drawings and the specification quality is articulated in the cost plan based on market prices, affordable scope is defined.

CAD-BASED COST PLANNING

Having defined the scope initially and fixed a budget/tender price it is critical that the link between scope and price be maintained and managed. As the design develops in CAD and the specification selected, the cost plan can be quickly regenerated using CAD based cost planning software and the cost implications of changes immediately identified and acted on as necessary to keep the project within budget.

Because the link between design and cost becomes transparent, accountability for decisions affecting scope and/or cost is made easy.

The new process quickly and accurately defines affordable scope at market prices.

The benefits of the new approach include:

- Reduction in cost overruns
- Greater certainty of scope outcome for clients
- Definition of scope and cost is transparent to all project stakeholders
- Reduced price risks for contractors, sub-contractors and suppliers
- Continuous real-time updating of costs with design
- Reduction in redesign work for architects, engineers
- More creative use of design resources
- Savings in program time for design, client approvals, package lettings
- Transparency of scope and cost decisions

Greater accountability in management of projects

DESIGN INFORMATION QUALITY STANDARDS

Critical to establishing and managing the scope cost link is the quality of design information. There has been debate and general agreement on the declining standards of documentation in the industry (Engineers Australia Conference – May 2004).

Arguably though, this appears to be a timing issue as there is general agreement that the quality of the final documentation is higher than 10 years ago. In the absence of a standard for information quality and a re-engineering of current processes to match design information quality with intended use, the perception of declining documentation is likely to worsen.

An independent assessment of the design information against an agreed standard would help curtail inappropriate use of design information (e.g. detailed fixed prices being sought using schematic design information; design development information being issued for construction.) Much of the criticism of the poor quality of design relates to the frustration of the parties trying to use the information for pricing purposes.

A defined standard for scope and design information with an independent assessment would provide a solid foundation for the management of scope. It would also provide an audit trail for accounting for scope changes.

Such an auditable process would provide a powerful tool in managing project scope.

CONCLUSION

By harnessing new technology and setting common standards for scope definition and design information quality, scope management practices can be effectively re-engineered to reduce cost overruns and increase client satisfaction with project outcomes.

With greater transparency, clients will be able to see what they are getting for their money and pay a fair price and contractors and sub-contractors can compete on price and management skill and expect a fair return.

The proposed process change is not re-inventing the wheel. It is about creating better transparency in commercial relationships and making the cost wheel spin at the same speed as the design wheel.

STAKEHOLDERS

Case Study

ORGANISATIONAL STRUCTURE, CULTURE AND COMMITMENT: AN AUSTRALIA PUBLIC SECTOR CASE STUDY

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ABSTRACT

This paper reports the findings of a survey undertaken with a government department in Queensland Australia. It focuses on the perceptions of professional personnel and mismatches are found in both organisational structuring and organisational culture developed in the department. The level of commitment was also found to be low on all three dimensions – normative, continuous and affective. The findings in the survey are discussed and explored with reference to Hofstede's culture concepts. Emerging lessons which come from the survey and subsequent interviews that are backed up by the case studies undertaken are also presented.

Keywords: Organisational culture, organisational structure, commitment, cultural values

BACKGROUND

The implicit link between organisational culture and organisational performance has long been recognised in both mainstream management literature (Handy, 1985; Hofstede, 1980) as well as in the construction management literature (Liu and Fellows, 2001; Rowlinson, 2001). Within the construction research domain, the impact of culture and organisation on project performance is becoming an increasingly important topic for the establishment of a sound partnering or alliancing approach to projects. However, the efficacy of alliancing has so far produced mixed results and this research aims to shed light on the practice and pre-requisites for alliancing to be successful: see Bresnen and Marshall (2000a,b,c) for example. A number of characteristics have been identified in recent studies e.g. Rowlinson (2001), Winch *et al.* (2000; 1997). These studies addressed innovation and change in the context of the working relations in project organisations. The main parameters identified as being significant in shaping how an organisation performed and the spirit within the organisation were: Organisational culture; Organisational structuring; Commitment and Culture.

Despite initial scepticism by the project participants concerning the measurement instruments it was found that the research results, as explained in the questionnaire responses, provided a good picture of the problems and issues facing the department. By using independently collected data it was possible to verify the thinking of key individuals in the department as to the strengths and weaknesses of the systems currently in place. As a consequence, the department has been able to move forward confidently in the expectation that the changes and solutions it is putting in place are soundly based in fact, and not just opinion.

The objective of this research is to investigate the impact of the various cultural variables on project performance, which then allows patterns, in which alliancing contracts work and other patterns where traditional contracts work, to be defined. The research was carried out by investigating the organisational structure, culture and commitment in a large public sector organisation in Queensland Australia and to identify the key issues affecting project performance. In order to do so, an audit was carried out to find out where the organisation currently stands, along with questionnaires, interviews and case studies which were conducted in order to validate the results. Hence, the study was triangulated and the results presented here distil the key research issues and findings that came from this particular piece of research.

ORGANISATIONAL CULTURE

The results of the organisation culture survey are shown in Table 1. It is clear that a task culture is preferred by those in the organisation. Handy (1985) describes task culture as being best suited to groups, project teams or task forces which are formed for a specific purpose, which very much describes the job nature in the public sector organisation. Individuals in the department belong to his/her own project team for each project and are highly likely to work with a different team of people in each new project.

Organisational Culture	Preferred Culture	Perceived Culture
Power	0	0.5*
Role	0	4
Task	6	1.5*
Person	0	0

*Same score for Power and Task Culture was calculated from one of the returned questionnaires.

Table 1 Results of Survey of Organisational Culture

Task culture can be found where the market is competitive, the product life is short, speed of reaction is important. In this instance this fits well with the organisation as the participants generally work as a team, a project team. The participants form as a team for a specific purpose, the project. Also, achievement is judged by results, success of the project. Lastly, the work relationships within the team are emphasised. However, when the results were analysed further it was found that the culture that was perceived to exist within the organisation was a role culture.

Role culture is often found where economies of scale are more important than flexibility or where technical expertise and depth of specialisation are more important than product innovation or product cost. In this context it is apparent in bureaucracy; heavy reliance on procedures and formal authority; and long product life i.e. the department still exists when projects (e.g. roads, bridges, schools, residential blocks, hospitals) have finished. Professionals in the department would not expect to be abandoned after each project completion and see their future as being tied into the continued existence of the parent organisation rather than individual projects. Hence, the existing structuring, necessary for a large government department to work effectively is fundamentally at odds with the needs of short term project organisations. This paradox is not new but is one that many organisations find difficult to cope with in terms of their organisation and employee satisfaction and needs to be recognised as an important issue that must be addressed, even if it cannot be optimally resolved.

The mismatch identified here can be seen to have an effect on issues such as commitment and structuring. Such mismatches are not uncommon in organisation which have the conflicting objectives of long term employment, service and systems but which also need to be involved in relatively short term projects.

COMMITMENT

The same group of professionals was questioned at the same time on the concept of commitment, using Meyer and Allen's (1997) affective, continuance and normative commitment scales. Both affective commitment (emotional attachment to the organisation) and normative commitment (acceptance of the organisation's set of values) were found to be a little stronger than continuance commitment (costs of leaving the organisation outweigh the opportunity costs of staying). However, all scores are rather "middling", indicating a "non-committal" level of commitment. It is interesting to note that these scores are still substantially higher than those reported by Rowlinson (2001) in his study of Architectural Services Department (a public sector organisation) in Hong Kong.

A relational contracting approach cannot succeed if the collaborating organisations do not accept its ethos. Hence, commitment to the goals and objectives of the organisation is crucial in implementing new approaches to contract strategy.

ORGANISATIONAL STRUCTURE

The type of the structuring prevalent in the organisation was explored using Van de Ven and Ferry's (1980) organisational assessment. This is to relate to the nature of the tasks being undertaken by the organisation, with a view to identifying mismatches. Again, the same group of professionals was questioned, together with further questioning, by means of a sub-questionnaire, sent out to another group of professionals (here-in-after called Other Units), who had work relationships with the respondent in the past six months, as identified in the main questionnaire. The aim of this was to explore the quality of relationships and depth of communication within the project team.

Van de Ven and Ferry (1980) suggested that organisational units that undertake work at high levels of difficulty and variability adopt what they termed a developmental group mode. Table 2 presents the hypothesised patterns of their three design modes in complex organisations. A developmental group mode is aimed at creating a programme for handling tasks, problems or issues that have not been encountered before, and/or are sufficiently difficult or complex, which require further work for solutions. It is also suggested that a developmental programme consists of (1) general goals or ends to be achieved in a specified amount of time, leaving unspecified the precise means to achieve them, and (2) a set of norms and expectations regarding the nature of behaviour and interactions among group members. The characteristics mentioned above seem to fit in with the organisation's mission very well. One of the major roles of the organisation is to be part of the project team in a construction project, including being able to react to unforeseeable events which occur during the project, whether these events have natural or man-made causes. It is also common not to have the project thoroughly strategically planned and specified at the outset, particularly when dealing with complex "multi-clients", as often happens with this government department. Based on the facts and characteristics described above, a developmental group mode is seen as being the most appropriate design mode for the organisation.

Difficulty & Variability of Tasks, Problems, Issues Encountered by subsystem –	Systematized Impersonal Mode	Discretionary Personal Mode	Developmental Group Mode
	Low	Medium	High
Salient Dimensions of Managerial Subsystem			
1. Organizational Referent	Central information systems	Hierarchy & staff	Coordination committees
2. Coordination and Control by:	Rules, plans, schedules	Exceptions to hierarchy	Mutual group adjustments
3. Resource & Information Flows among Organizational Levels, Units, & Positions:			
a. Direction	Diffuse	Vertical	Horizontal
b. Amount	High	Medium	Low
c. Standardization & Codification	High	Medium	Low
4. Perceived Interdependence among Components	Low	Medium	High
5. Frequency of conflict among Components	Low	Medium	High

Table 2 Hypothesised Patterns of Systematized, Discretionary and Developmental Modes in Complex Organisations (extracted from Van de Ven and Ferry, 1980, p. 368-369)

Using the results generated from the survey, Table 3 is developed to test the hypothesised patterns suggested by Van de Ven and Ferry. It is noticed that although the organisation was initially expected to follow the logic of developmental group mode, in reality, the logic of systematised mode is more closely followed (although it is apparent from Table 3 that the mode displayed is to some extent a hybrid). This again reflects the results emanating from Handy's instrument but, as Van de Ven has written extensively on organisational change, he does provide us with a useful set of tried and tested methods (tools) to bring about an appropriate organisational change and to measure the degree of change over time.

The average frequency of conflict for both government organisation and Other Units is found to be low. There is no correlation between degree of personal acquaintance and frequency of conflict; the nature of the construction industry is such that it allows conflicts or disagreements to appear during work due to uncertainties, and misunderstanding or misinterpretation.

	Systematized Impersonal Mode	Discretionary Personal Mode	Developmental Group Mode
Salient Dimensions of Managerial Subsystem			
1. Organizational Referent	Central information systems?	Hierarchy & Staff?	
2. Coordination and Control by:	Rules, plans, schedules		
3. Resource & Information Flows among Organizational Levels, Units, & Positions:	Diffuse?		
a. Direction			
b. Amount			
c. Standardization & Codification	High	Medium	Low
4. Perceived Interdependence among Components			High
5. Frequency of conflict among Components	Low		

Table 3 Hypothesised Patterns of Design Mode in the Government Organisation

An explanatory conclusion can be drawn from the findings above. The professionals, in theory, should be following a developmental group mode and do prefer working in a task culture but are actually in a role culture and follow the systematised mode. Hence, the results support one another. It would appear that there is a mismatch between how the organisation in general operates, the role model, and what those working in the project side of the organisation actually want to be and to achieve – the task model.

When disagreements arise, the most frequently used resolution method was by an open exchange of information about the conflict or problem and a working through of differences to reach a mutually agreeable solution. A significant correlation is found between effectiveness of working relationship and frequency of conflict from the government organisation, suggesting the lower the effectiveness of working relationship, the higher frequency of conflict. However, there is found no significant correlation with Other Units on the tested variables. The resolution of disagreements reflects an intra-organisational partnering/alliancing approach within the department. This suggests that a social infrastructure already exists within the department which is in harmony with relational contracting approaches and this should be further nurtured and documented as a learning and skills issue.

Face-to-face talks were found to have a high correlation with the effectiveness of the government organisation's working relationship with other parties. One common behaviour observed from successful alliancing projects or projects using relationship management is frequent, frank, face-to-face talks between parties. Issues or foreseeable problems are often resolved before conflicts arise, allowing relationships between parties to be nurtured and sustained. This is the essence of relationship management. One interviewee pointed out face-to-face talks or meetings as being an issue for project teams due to distance between parties, physical meetings are not feasible and telephone conferences are used instead. With today's technology, one suggestion to achieve some of the benefits of face-to-face talks is to carry out video

conferencing or use *netmeeting*® or similar via the internet. Although physical presence does not exist, these technologies do allow behaviour or body language of the other party to be observed. Of particular importance is the role of external consultants in this process and attention should be applied to bringing them into this loop.

A very strong correlation is found between consensus and quality of communication, indicating there is a higher degree of agreement in situations when it is easier to get ideas across, whereas a positive correlation is found between difficulty getting in touch and hindered performance in Other Units. This is purely a consequence of the nature of construction in that all works are inter-related. For example, there being a problem on the quality of concrete, consent is required from the person-in-charge from the department. Should the person not able to be reached in a day, work will then be delayed for one day and so on. Quality of information flow has always been crucial in the project team. Such is again confirmed by the positive correlation between difficulty in getting ideas across and frequency of dispute, suggesting a poor quality of communication often leads to a higher frequency of dispute. All of these issues have surfaced as anecdotal evidence in case studies and reinforce the issue of face-to-face meetings.

Significant correlations are found between variability of resource flow and standardisation of relationship. This suggests that a higher degree of official communication channels and standard operating procedures, rules and policies, a higher uniformity of resource flows may well in fact lead to a higher frequency of interruptions and problems encountered in transferring work objects and materials between parties. A more formal and standardised relationship does not necessarily lead to more uniform resource flows. More problems or interruptions might well be encountered (the view was expressed that not everything can be “solved” or “clarified” or “problems reduced” by having everything down in black and white, in fact the opposite attitude pertains. The number of rules and procedures does not run in parallel with improved relationships). Thus, these findings back up the observations on organisational culture and organisation mode – a task culture and developmental group mode fit the needs of a project based organisation, albeit a temporary multi-intra-organisation, rather than the role culture and systematised mode which appear to be evident as the predominant cultures in the organisation. A theme that has emerged in this survey research and in the case studies is that the organisation’s management of its own clients, the temporary multi-intra-organisation that is imposed on it during projects, is a key issue in the whole project delivery process.

A positive correlation is found between the extent of commitment by the organisation and Other Units, suggesting that there is the potential to increase the extent of commitment by other parties if more evidence of commitment is made apparent by either the government organisation or Other Units.

The power of informal relations, intra-organisational alliancing even, is apparent from the survey results which show that the level of standardised relationship has a negative correlation with the equality of transactions, meaning the more formalised the relationship is, i.e. the more the agreement between parties is written down or contracted, the less acceptable are informal and collaborative problem solving with the other party which actually move the project forward. This is further evidence that simple stated, but well run, relationship management contracts can be successful.

CULTURE

A number of questions were asked which related to individual participants' cultural values. Professionals in the organisation rate personal time, challenges at work and freedom to adopt own approach at work as very important for their ideal job. However, working in a successful company and the size of the organisation is considered to be not so important or desirable. It is agreed by the respondents that it is very important to have a good relationship with their direct superior. Being consulted by their superiors is important, yet it is found less important than the immediate work place relationships. It is suggested that although respondents work together in the organisation, each of them is engaged in various project teams. One of the main philosophies in relational contracting is to have a good working relationship with the project team.

Respondents find they do not often feel stress at work. Also, the majority disagree that a large corporation is a more desirable place to work than a small company, and theory X is strongly rejected – these all match nicely with what Hofstede suggested to be found in an organisation with a low masculinity index. It is shown in the survey results that relationship and cooperation with co-workers are rated of high importance, yet the importance of having sufficient time left for one's personal life is rated the highest, suggesting work is less central in people's lives, which again coheres with an organisation with a low masculinity index as suggested by Hofstede. It is also agreed by the majority that formal procedures should be retained in order to ensure both personal and firm's objectives are met. The high uncertainty avoidance found in the organisation is again verified.

From the survey results and the data collected in the interviews with the respondents, the majority agree very much that personal relationships are an important aspect in managing projects. One common statement obtained from the interviewees is they all find having a good personal relationship with their project team members helps to minimise the chance of conflicts during work. Such observation is reinforced by the disagreement to the statement on "one must be will to sacrifice personal relationships with members of the project team to ensure one's personal objectives are met". However, as noted earlier in this paper, the degree of personal acquaintance is found to be low. Also, the majority agree that personal relationships need to be sacrificed to ensure a successful project completion and to meet the firm's objectives. Suggesting after all, work is work, and with reference to earlier survey results (please refer to Table 1), task culture is preferred by those in the organisation.

CONCLUSION

The most obvious issue raised in this study is the mismatch between expectations of professionals in terms of organisational culture and structuring and how it is actually perceived in practice. It would appear that there is a mismatch between how the organisation in general operates, Handy's role model, and what those working in the project side of the organisation actually want to be and to achieve – the task model. Although the organisation was initially expected to follow the logic of Van de Ven and Ferry's developmental group mode, in reality, the logic of systematised mode is more closely followed. This situation is not uncommon in large organisations which have ongoing, long term goals but which are also involved in many, short term projects.

However, as Van de Ven has written extensively on organisational change, he does provide a useful set of tools to bring about organisational change and to measure the degree of change over time. However, the issue of commitment needs to be addressed; levels of commitment are, at best, average in this survey.

That said, generally the results are found to be very promising. The level of awareness between the organisation and Other Units increases as the frequency of communication increases, a lesson to be re-learned in those projects when communications fail. It is also noted that when there is a high domain similarity, the lower the amount of conflict that exists between parties. However, it is interesting to see that high productive relationships actually occur despite lower quality of communication. As mentioned previously, quality of communication here refers to difficulty in getting in touch and getting ideas across. It is often the case for a person to be involved in more than one project at the same time. One common issue pointed out by the participants from the government organisation in this survey is more face-to-face and continuing open communication is needed. To find time to get around the table and discuss is often a challenge, and this inability leads to problems such as late provisions or approvals, late response to queries, poor quality of response, cost and programme problems, opinions on design elements, etc these mostly relate to information flow issues. "Finding time" for communication seems to be a major issue in the organisation.

It was expected that there would be a correlation between resource dependence and frequency of communication. However, no significant correlation was found. It may well be that the frequency of communication remains at a high level, not necessarily high quality, due to the nature of the construction industry. No matter what the circumstances, site inspections will be carried out whether work is carried out by in-house personnel or contracted out; project meetings will still be held periodically e.g. partnering meetings and regular site meetings. A significant issue is that site meetings and project meetings are held separately from partnering meetings/workshops, suggesting project teams in relationship management projects have more set meetings (higher frequency of communication) than traditional types of contract, allowing each party to become more familiar with other parties' goals and services and, perhaps significantly, for the communication to take place at all levels within the organisation. The organisational cross-sectional nature of the participants taking part in meetings in relationship management projects appears to have a positive impact on the quality of communication and information flow and is a stimulus to timely and appropriate action.

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VISUALISATION AND INFORMATIONS

Case Study

IMPLEMENTATION ISSUES FOR BUILDING PRODUCT MODELS (BPM) IN AUSTRALIA: A FRAMEWORK FOR INVESTIGATION

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ABSTRACT

Although much research has been undertaken into the development of Building Product Models, little has been done to investigate their apparent failure to be implemented within the Australian Construction Industry. Currently their implementation has been limited to a small number of demonstration projects and architectural firms using 3D CAD-based systems.

The aim of this paper is to establish a framework for the investigation of issues affecting the widespread implementation of Building Product Models within the Australian Construction Industry.

The issues contained within this framework have been identified from the relevant literature, with this paper discussing how these issues can be grouped into three main categories: Awareness, Organisational and Project related. In grouping the issues in this way, a holistic understanding of the potential concerns affecting such implementation can be gained.

Through the development of such a model we may now begin to grasp the complexity of issues affecting the widespread implementation of Building Product Models within the Australian Construction Industry and start to understand the connections that exist between such issues.

Keywords : Building Product Model (BPM), Implementation Issues, Australian Construction Industry

1. INTRODUCTION

Technologies are increasingly becoming part of our daily lives, with the speed of their uptake rapidly growing (Gleick, 1999).

This rapid development in technologies has allowed many industries, such as aerospace, automotive, manufacturing and electronics, to undertake major transformations of their business activities and create new and more effective business processes. Although industries such as these have been able to embrace technologies to transform existing business processes, and to create new ones, the Construction Industry (CI) has resisted implementing technological changes to its procedures. Many of the construction industry's current practices are based around those developed as the result of decades of incremental change.

Although a number of technologies, such as Computer Aided Design (CAD) and other specialist softwares, have been adopted by the construction industry, these technologies have had the tendency to automate existing procedures in an effort to improve task efficiency, rather than readdressing the procedure as a whole.

The result of such task-based implementation has been a focus on technology's ability to automate existing tasks, rather than on improving the overall process effectiveness (Aouad et al., 1999)

Since 1967 the vision for such a process improvement has existed within the construction industry. This vision involved the modelling of a building as an object, rather than a series of lines (Eastman, 1999). This concept directly questions the industry's current procedure and involves the implementation of new technologies.

Since the initial creation of this vision, the technology to achieve it has been developed and the benefits of such changes documented. However, widespread implementation has yet to be seen.

2. BUILDING PRODUCT MODELS (BPM)

2.1 DEFINING THE BUILDING PRODUCT MODEL (BPM)

The concept of modelling a building as a series of objects has taken on a number of terms over the years. One such term that has gained acceptance is that of "Building Product Model" or BPM. Eastman (1999) defines a Building Product Model as "a digital information structure of the objects making up a building, capturing the form, behaviour and relations of the parts and assemblies within the building". This definition broadly covers the large number of technologies that currently exist, while still adequately defining the procedure.

2.2 THE BENEFITS OF BPMS

It is suggested by Eastman that the concept of a building product model offers a potentially richer representation of project information than any set of drawings, with a model being able to be implemented in a number of ways (Eastman, 1999).

Through the use of a model, a building can be 'constructed' electronically, therefore allowing the project's participants to identify possible problems with the design before physical construction takes place. In this way scheduling, material and other issues can be dealt with before starting physical construction.

The concept of a Building Product Model (BPM) also allows for the creation of a unifying technology for the industry (Best et al., 1996).

Use of a Building Product Model in this manner also helps to reduce the fragmentation of the industry through the creation of a unifying framework by which to store and access information. Overall the benefits relating to the implementation of Building Product Models within the construction industry include time savings for projects, better information exchange and cost savings (Aouad et al., 1999)

2.3 BPM'S CURRENT USAGE

While there have been many prototypes of building product models developed since 1967, there are now only a few building product models in existence (Eastman, 1999).

Those models that have been developed thus far, have been done so by a specified consortia of users and vendors (Eastman, 1999), and as such have not achieved widespread implementation.

The result of this has been that Building Product Models thus far have typically been restricted to use on 'demonstration' projects, where external groups have assisted with their implementation.

Although building product models are still to be fully developed, they currently offer a large number of capabilities that are yet to be utilised by the industry.

2.4 BPM'S POTENTIAL FUTURE USAGE

Weisberg (2000) argues that the next few years will see significant changes in the way developers, designers, consultants and contractors manage the entire building process due to the implementation of technologies such as Building Product Models.

While industries such as aerospace, automotive, manufacturing and electronics have been able to use modelling to improve their industries, the construction industry has currently avoided such a transition. However their eventual implementation is seen as almost inevitable due to the fact that the construction industry is "currently the only major industry that produces 3D products that is not using some form of product model." (Eastman, 1999)

While these other industries may offer insights into the problems associated with their implementation, the construction industry differs in a number of ways and is seen as having its own unique issues that need to be addressed.

Therefore it is the aim of this paper to identify the issues that are affecting the potential benefits achievable through the implementation of Building Product Models.

3. ESTABLISHING A FRAMEWORK FOR ANALYSIS

3.1 IDENTIFYING THE ISSUES

A detailed literature review has been undertaken to identify the issues affecting the implementation of Building Product Models within the Australian Construction Industry.

While previous research has identified a large number of technical issues, a review of current literature has also revealed a number of non-technical issues.

Looking holistically, fourteen separate issues have been identified from the literature, and these have been grouped under the three broad headings of 'Awareness', 'Organisation' and 'Project'.

A brief analysis of each of these fourteen key areas follows.

3.2 AWARENESS

Awareness is crucial to the implementation of Building Product Models. If one is unaware of a technology, then there is little chance that they will implement it.

It is for this reason that awareness has been identified as a starting point for the identification of issues affecting the implementation of Building Product Models.

It is only once a level of awareness has been achieved that the other issues identified in the literature will come into play.

3.3 ORGANISATION

Organisational issues, for the purpose of this framework, have been identified as those factors that relate to the implementation of Building Product Models from an organisational perspective. Organisational issues therefore relate to the goals and perspectives of an organisation as a whole as well as the individuals making up that organization.

3.3.1 Evaluation of Technologies

The manner in which a technology is evaluated will greatly effect the perceptions of that technology. If a technology is evaluated in a positive way, then it is more likely to be implemented than one that is seen in a negative way.

The issues relating to the evaluation of technologies identified within the literature include those based on both cost and productivity. Both of these evaluation methods, if not used correctly, can result in a technology being seen in a negative light which could reduce the potential for that technology's implementation.

3.3.2 Over Reliance on Technology for Solutions

One possible issue to come from the evaluation of technologies is an over reliance on a technology as the result of an overly positive or optimistic evaluation of that technology.

Two main issues were identified within the literature as possibly leading to an over reliance on technologies. The first being the difference between the actual information made available by a technology and that received by an individual (Smith et al., 1977) and the second being the potential to rely on technology as a driver, with the assumption that a technology itself will result in beneficial changes. (Aouad et al., 1999).

3.3.3 Disappointment with Technologies

The over reliance on technologies can result in their failure to perform as expected, which can lead to disappointment. Based on the literature the main reason for disappointment with technologies is unfulfilled expectations, resulting from the implementation of flawed systems (Kamara and Anumba, 2001) or an over-reliance on a technology to provide benefits that were never realistically achievable (Sun and Aouad, 2000).

3.3.4 Ambiguity of Responsibility

Evaluating a technology in a pessimistic manner can lead to a number of factors affecting the implementation of a technology. The main issues identified in the literature that relate to ambiguity of responsibility are related to a fear of information overload, due to a perceived failure to determine participants' responsibilities (Emmitt and Grose, 2003), the fear of criticism over decisions with an increase in the number of participants potentially assessing a decision (Eastman, 1999), a perceived restriction to the design process due to the need to abide by another structure (Sun and Aouad, 2000) and the potential for confusion over the risk and reward distribution structure for a project, in that it could be unclear as to who is taking the risks and therefore who should receive the rewards (Loosemore, 1998).

3.3.5 Increased Structure

Another issue related to the pessimistic evaluation of technologies is that stemming from the fear of an increase in structure. This relates directly to the ambiguity of responsibility addressed above.

The literature suggests that the increase in structure could lead to a failure to allow for unintentional communication (Buckland, 1990), with information tending to be communicated through formal channels, a reduction to the unplanned access of information (Chang and Rice, 1993), and, finally, the possibility to increase the reliance on formal communications resulting in a reduction informal/relationship- building communications (Trenholm and Jensen, 1995)

3.3.6 Ownership & Control

Ambiguity over responsibility and the fear of an increase in structure can both relate directly to the ownership and control of project information. Professions currently have known ownership and control of information that is dictated by the traditional organisation structure. The literature suggests that this will change due

to the implementation of building product models, which could result in the fear of sharing information. This fear may be due to the concern that the shared information may be used against them or that they may lose control and therefore not gain the benefits of the information's use.

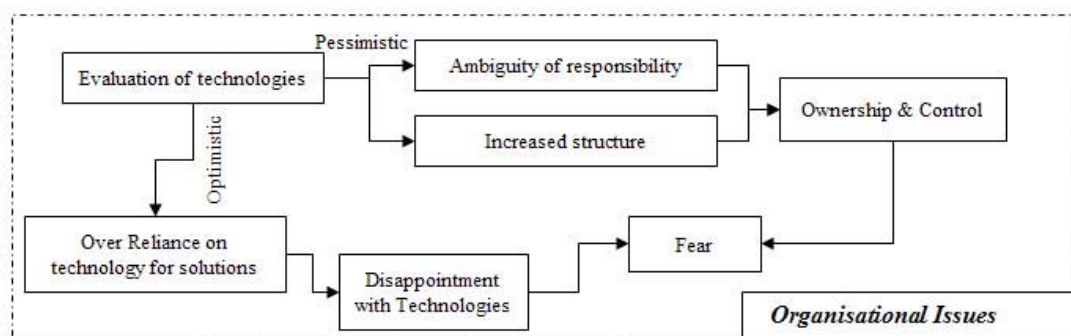
3.3.7 Fear

The final organisational issue that has been identified in the literature is that of fear.

The main issues identified were linked to the possibility for conflicting interests among participants (Grunederg, 1995), the protection of professions by their members with each profession seeking to protect their current position (Burkhardt and Brass, 1990), the fear of change (Hemmett, 1996), and the threats that are perceived by technologies which relate back to their pessimistic evaluation (Low and Sloan, 2001).

3.4 ORGANISATIONAL MODEL

The following model identifies a framework for the organisational issues identified above. It shows how these issues interact, from the way in which a technology is evaluated through to the potential for fear to develop as an obstacle to the implementation of a Building Product Model.



3.5 PROJECT

Project issues, for the purpose of this framework, are those issues that relate to the characteristics of a specific project. Project issues therefore relate to the way organisations within the industry interact within a single project.

3.5.1 Project Characteristics

The characteristics of a project directly affect the implementation of a technology. In assessing the characteristics of projects two main issues must be considered. The first is that of an organisation's technical capability and the second is the ability of the project members to coordinate their efforts.

3.5.2 Technical Capability

If an organisation displays insufficient technological capability then there will be an inability to implement a technology.

The technical capability of an organisation is therefore crucial and can be explored on two levels. The first is the skills possessed (McCreadie and Rice, 1999) and the second is the accessibility of the required hardware and software. If the participants within a project have neither the required skills nor hardware then this will impede the implementation of a technology.

3.5.3 Coordination

If the project participants possess the required level of technological capability, then the next issue that needs to be addressed from a project perspective is the ability to coordinate the various project participants within the given project environment. Through the literature it is suggested that a number of factors exist, including the possibility of the task being seen as too big for one organisation, with a large number of organisations needing to work together (Eastman, 1999). This also leads to the potential for an uncoordinated uptake of technologies, which may result from the failure to identify a common goal for the project (Hillebrant and Cannon, 1990); (Atkin and Potheary, 1994) The final issue identified in the literature would be a failure to address the requirements of the users within a project (Milis and Mercken, 2003).

3.5.4 Complacency

Should both the technological and coordination issues be adequately addressed by the participants involved and the technologies still fail to be implemented then the cause could be complacency. The issue of complacency has been viewed in a number of ways within the literature and can result from the industry's resistance to change (Mohamed and Tucker, 1996), the reliance on existing structures and procedures (Eastman, 1999), the task specific nature in which technologies within the construction industry are developed, the industry's reliance on incremental changes (Eastman, 1999), a failure to embrace technologies (McCreadie and Rice, 1999), and finally, the reluctance of users. (Milis and Mercken, 2003).

3.5.5 Industry Structure

Problems encountered in the coordination of a project may in part be due to the way the industry is structured. A number of factors that could contribute to failure to implement technologies have been identified, including the 'Traditional' organisational structure that now dominates the industry (Mohamed and Tucker, 1996) and the organisational stability that exists because of this (Burkhardt and Brass, 1990), the standard methods of communication that have been developed as part of this 'traditional' organisation structure (Eastman, 1999), the reliance that has developed by professions for these existing systems, especially those based around paper systems (Emmitt and Grose, 2003) and finally the professional cultures (Brownell et al., 1997) that have developed because of this traditional structure being developed over a number of years.

3.5.6 Industry Environment

The industry environment is seen as being made up of two factors. The first factor is that of legal requirements within which the industry must operate and the second is the social environment that exists.

3.5.7 Legal requirements

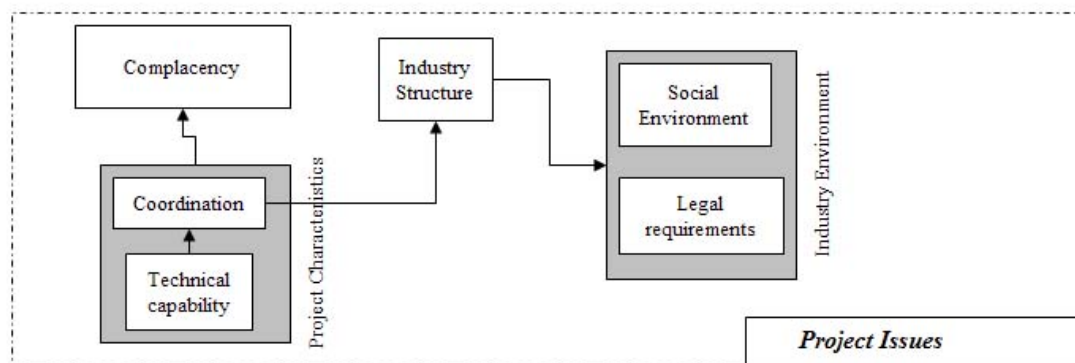
The construction industry's environment will be determined to a large extent by the legal constraints under which it must operate. These include the contractual requirements with which all participants must comply, the contractual nature of communications and the other bureaucracy requirements (Brandon et al., 1998) that exist as part of a project, including local and state government legislations.

3.5.8 Social Environment

The final issue to consider on a project level is that of the social environment. The social environment encompasses all the social issues that relate to the industry, including that of trust (Roberts, 2000) and the assessment of trust that exists between the participants in a project, the social context that exists, the participant's willingness to work within the system (Burkhardt and Brass, 1990), the profession-specific languages (Emmitt and Grose, 2003) that have developed, the need to work within the various organisational cultures (Brandon et al., 1998) and the context that is established for the remainder of the project to work within (Emmitt and Grose, 2003).

3.6 PROJECT MODEL

The following model identifies a framework for the project issues identified above. It shows how these issues interact on a project level and includes a number of factors identified within the literature that are said to affect the implementation of Building Product Models on a project level.



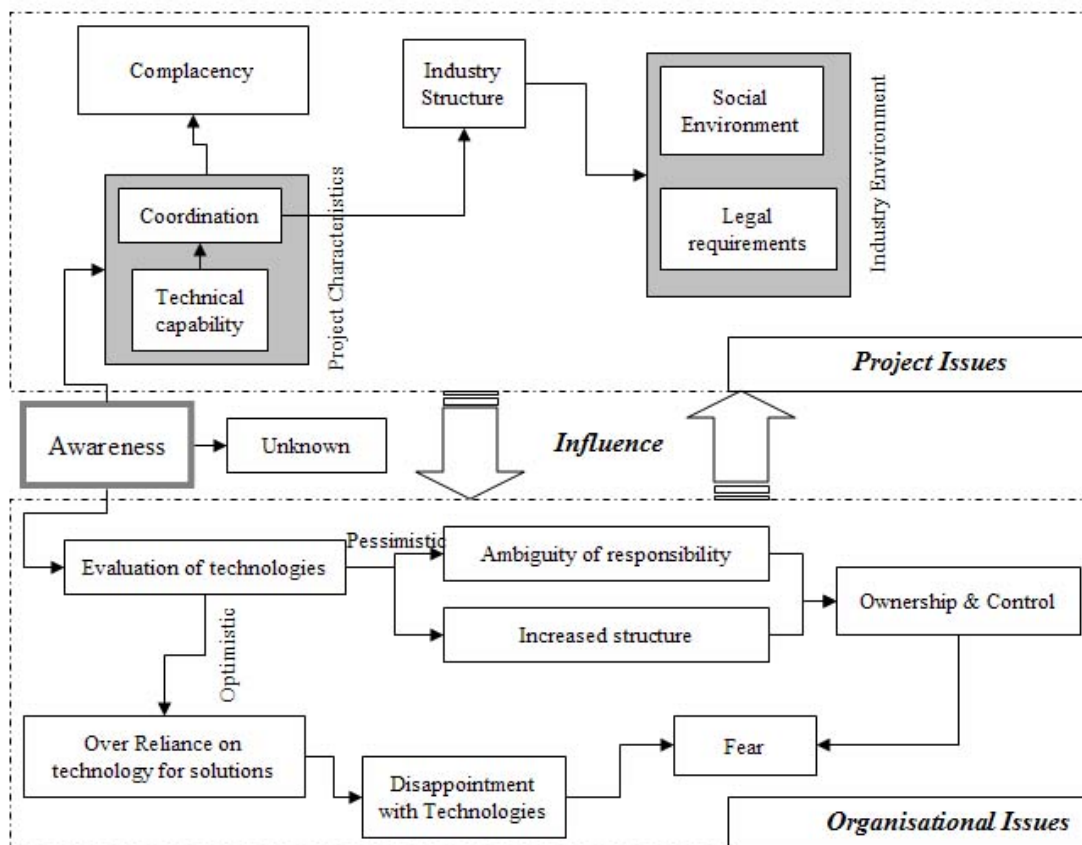
3.7 THE HOLISTIC MODEL

When exploring the implementation of Building Product Models it is initially advantageous to group the issues into a smaller number of key areas, so as to ensure a thorough investigation. However, to apply this at an industry level requires a more holistic view.

As such the development of a holistic model has been undertaken to identify the interaction that exists between these two groups.

Such interaction exists due to the interdependence of projects and organizations, in that a project is made up of a number of organizations, which are then directly influenced by the projects that they are involved in.

As such, the following model combines both the Organisational and Project Models to form a holistic framework of the issues affecting the implementation of Building Product Models.



The starting point for the above holistic model is that of awareness. While other studies have focused on technology as a starting point to the implementation of building product models, the above model takes a broader view and uses awareness as this starting point.

As can be seen in the above model, technology only forms one small part of the multitude of issues that can restrict the implementation of Building Product Models. By wrongly focusing on a single issue, such as technology, a large number of other issues are either neglected or misrepresented as being technical in nature.

The other benefit of this model is its holistic nature. To view these issues in isolation is misleading as all of these issues influence one another in some way. To consider an issue without also considering the context within which that issue exists could result in a misrepresentation of the issue; for example, if one is concerned about the control of information, they may fear the implementation of such a technology that relies on the sharing of information.

In this way the above framework allows for a holistic view of the issues affecting the implementation of building product models within the Australian Construction Industry.

4. DISCUSSION

The holistic framework established above brings together the issues currently affecting the implementation of Building Product Models within the Australian Construction Industry.

In order to test these issues, a number of factors have to be considered, such as the availability of data and its format, as well as the resource constraints that exist.

Due to the limited usage of Building Product Models within Australia there is a current lack of published data available as to such issues. As such it has been decided that use be made of a case study. Due to the limited number of projects currently available a single live case is to be used. Use of a single live case will allow for a rigorous investigation to be undertaken of each key project participant, while a project is being undertaken. By allowing for key participants to be investigated while a project is underway a better understanding as to the current issues will be able to be identified. This investigation is to take the form of a semi-structured interview that is intended to evaluate the framework that has been developed in this paper.

5. SUMMARY

A number of benefits to implementing Building Product Models within the Australian Construction Industry have been shown within this paper and evidence to support their eventual implementation given.

Although such benefits exist, the current limited level of implementation would suggest that the construction industry is currently struggling with their implementation.

The holistic model explored above has been created in an effort to identify the scope of issues restricting such implementation and to create a framework for their further analysis.

It is intended that such a framework be used as a starting point for the evaluation of these issues, and that such an evaluation will lead to the further implementation of Building Product Models within the Australian Construction Industry.

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PROCUREMENT AND RISK SHARING

Case Study

LYELL MCEWIN HEALTH SERVICE **REDEVELOPMENT STAGE A**

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Delivering a significant hospital project without a project manager and using a relationship contract.

An abstract that explores the achievements of an approach to major project delivery where the owner agency and procurement agency worked together to create an environment where better than usual outcomes could be achieved in the delivery of the \$91.4M Stage A redevelopment of the Lyell McEwin Health Service in Adelaide's northern suburbs.

LYELL MCEWIN HEALTH SERVICE REDEVELOPMENT

The Lyell McEwin Health Service (LMHS) at Elizabeth is one of South Australia's major acute hospital facilities. It had comprised a range of old and newer buildings with almost 50% of existing floor space greater than 40 years old. These buildings were dysfunctional, costly to maintain and no longer met the health requirements and health service delivery models of current practice.

In February 2000 Cabinet approved \$87.4m expenditure on the LMHS Redevelopment Stage A. The budget was later increased to a total of \$91.2m. Stage A has replaced the great majority of the outdated infrastructure and provided two new wards, CCU, Women's Health Centre, administration and education, CSSD, new emergency, imaging, ICU, HDU and operating theatres.

WHAT WERE WE TRYING TO FIX?

At the commencement of the Redevelopment Stage A project at LMHS, the Department of Human Services (DHS) and the Department for Administration and Information Services (DAIS) assessed the characteristics of the LMHS Stage A project and noted that it:

- was the largest single construction project stage being undertaken by DHS;
- was a project of high strategic value for DHS, the northern suburbs and Government;
- had a potential for providing significant economic benefits for the northern suburbs over a period of five years or more;
- needed the flexibility to accommodate changes in service delivery during the life of the construction (has occurred in regard to emergency, mental health etc);
- needed outstanding management of program and cost;
- justified significant focus on environmentally sustainable development (ESD) and building industry training initiatives.

Our experience with other such significant major projects, consistent with the experience in the private sector and nationally had been that in conventional delivery there was often:

- lack of consultant team cohesion;
- combative contractor and consultants/client relationships;
- poorly coordinated or incomplete documents;
- quality control concerns during construction;
- inadequate management of variations ;
- consultants working in a siloed, defensive culture.

Given the risks and opportunities profile of this very significant State government project it was decided that a relationship form of procurement (utilising a collaborative contract) would be used. In the past it has been perceived that high performance organisation principles could not be transposed into the building project arena but the experience at the National Museum in Canberra and then the Adelaide Convention Centre Extensions project showed that they could be and there are significant benefits from doing so.

WHAT WERE (ARE) OUR EXPECTATIONS OF THE RELATIONSHIP CONTRACT?

We believed the relationship approach would provide better opportunity to realise the significant opportunities that the project offered and also mitigate the risks by

- establishing the project team with equality of input and common objectives to manage all aspects of the project pro-actively with progressive negotiation/management of all project issues;
- expecting the project team to manage the project rather than a project manager;
- encouraging innovation and problem solving;

- setting objectives in addition to quality outcomes in design and construction including ESD, community relations and building industry training;
- offering performance incentives in support of key project objectives
- investing in team skilling and training in the relationship approach and in establishment of the right team culture;
- inclusion of the subcontractors in “The Team”

The implemented relationship contract was designed to establish a cohesive team including DHS, LMHS, DAIS, consultants, contractor and subcontractors with common objectives and shared accountability.

There were potential disadvantages identified as part of making the decision to proceed with a relationship contract and they were:

- relatively new approach with a “Leap of faith” required;
- expectation that project manager was required for success;
- complex briefing and tendering processes;
- greater investment in management and professional fees;
- no certainty of improved outcomes and difficulty in measuring improvements;
- if there was disputation it could be more serious than in a conventional approach;
- established project management practices could be compromised by the focus on new practices;
- the risk and reward arrangements are not well accepted by some sections of the professional community.

However we were confident that through engaging with the team in an open and consultative way, supported by JMJ in a coaching role, any concerns could be worked through and additional up-front costs could be made cost effective by the end result.

WHAT PROJECT OBJECTIVES DID WE SET?

Consistent with most major projects it was important to achieve time, cost and quality objectives in the project but the opportunity was taken to broaden those objectives given the very significant capital injection by the Government into the project. The key objectives were:

- achieve maximum value for the capital cost;
- achieve completion on time with minimum disruption to the operating environment; and
- deliver high quality;
- produce a new benchmark in Ecologically Sustainable Development (ESD).
- provide building industry training. The South Australian Government had a training initiative called Upskill SA in place but additional expectations were placed on the consultants and contractor to use the project as an opportunity to provide trainee, apprentice or work experience opportunities on site.

- achieve defect free completion. There was an obligation on the managing contractor to plan for and implement a regime of continuous inspection of the works to progressively identify and rectify defects. The advantage for the hospital would be an occupation process unencumbered by a requirement to continue to allow access to the contractor/subcontractors to address unfinished or incorrect construction items.
- develop community relations. The local community had become disillusioned with the state of its hospital and did not have the ownership of it that would be ideal. The project was seen as an opportunity to engage with the community through the design and construction process to rebuild ownership and interest.
- achieve outstanding results in industrial relations and workplace safety;
- demonstrate to the South Australian building industry that an alternative approach to project delivery was effective and in the interests of all stakeholders

SETTING UP AND MINDSET BEFORE WE STARTED

The contract was developed using as its basis the C21 Managing Contractor contract designed by the NSW Department of Public Works and Services modified for use in South Australia by DAIS and Crown Law.

A decision was taken not to engage a Project Manager for the project as it was seen that the usual hierarchical project management role was inconsistent with objectives of the relationship contract and equality among all stakeholders. It was agreed that funding set aside for the Project Manager would instead be committed to team development, training and coaching.

DHS and DAIS were supported through the tendering process for the managing contractor by the collaborative consultant JMJ and Associates (JMJ). Amendments to the already in place consultant contracts were also developed such that the team had a common set of contracts that incorporated previous contract commitments. By agreement the arrangement for a primary consultant contract was varied to direct contracts with the engineering consultants to ensure that all consultants had an equal say in decision-making.

Then with the appointment of the managing contractor, JMJ worked to gain team commitment to adopt a change in the way the project would be managed and to develop a collaborative approach to decision-making and problem solving. The JMJ coaching and development process developed team member skills in:

- listening and the pitfalls to achieving genuine understanding between team members;
- the fundamentals of achieving sustainable agreement (alignment) and commitment to team decisions on technical and management issues;
- the ability to communicate with a view to creating solutions, or tabling issues with clarity;
- real accountability for what each person says and the actions promised; and
- the responsibility to act in a positive and multiplying manner which addresses the expectation that a team working as one should be able to create more than a team working as a set of individuals.

An incentive process was developed by the project team in a workshop environment to act as a driver for high performance. The incentive was due to the Managing Contractor and Consultants on successfully achieving the five key project objectives-time, cost, training, ESD and community involvement.

WE HAD A LONG WAY TO GO:

As JMJ commenced the process of team development a number of issues came onto the table. SA generally has not had the disaster projects or the high levels of litigation that have been experienced elsewhere. Some in the existing team felt they needed no change and were wary of the relationship approach and whether or not the role of JMJ was adding value. Some viewed the investment in this form of risk management as wasteful others viewed it as an impediment to getting on with the work of design and construction effectively.

Initially there were several times when team members held back from taking responsibility for issues traditionally managed by a Project Manager. However over the first few weeks the team became accustomed to not looking to a Project Manager to fill in any management gaps and instead assigned responsibility to the person or group best able to manage the issue.

Senior bureaucrats and members of the Government were cynical about the “no blame” approach, having had more experience with “combative” contract forms. Some were wary of experimenting on such an important and significant scale project.

The degree to which individuals initially grasped and implemented the required higher levels of interpersonal skills varied but over time the culture of the team has changed substantially with these skills now evident throughout the team.

HOW DID WE GET GOING?

DAIS is a committed leader in the building industry in SA and DHS, with the largest capital investment program in buildings, is a leader in delivering an expert client role on its projects. We consulted interstate and reflected on the lessons learned from the Adelaide Convention Centre Extensions project.

The existing consultant team was engaged in the tender process for the relationship consultant with the result that JMJ, a specialist consultant was appointed ahead of other tenderers which were generally project managers offering a relationship approach.

We drew on the experience of JMJ on many relationship contracts in the civil and building construction areas and designed the Managing Contractor tender process to commence team culture change. JMJ excellence through facilitation of the process was critical in “proving” the need for relationship consultant to some team members.

THE KEY BUILDING BLOCKS AND MAJOR LEARNING

The key building blocks as the team embarked on the delivery of the project were:

- a vision and objectives we all owned;
- everybody “throwing their hat over the wall”;
- training to recognise our own non-collaborative / disempowering behaviour;

- identifying process champions
- discovering advantages of respectful plain speaking and acknowledgment of achievement;
- recognising that the project team included subcontractors as well;
- making key trades value based appointments.

Under the coaching of JMJ, the leadership group in the team became focussed on team empowerment; recognising key leaders and their needs for skilling, support and empowerment. A culture of anticipating how observations or opinions “were going to land” with others grew because it was recognised that it was easy to disempower people without awareness and sensitivity. When the Executive Leadership Team (Steering Committee) and the Integrated Management Team had difficulty finding balance between governance and empowerment the newly learned skills allowed the issues to be resolved effectively.

PERFORMANCE AGAINST OBJECTIVES SET

Achieving maximum value for the capital cost has been a significant success on the project. The construction contingency expenditure was only 2.5% from an allowance of 5% which has meant the release of \$1.7m for additional work and an increase to the Furniture Fittings and Equipment fund.

While there has been excellent results in regard to minimising disruption to the operating environment, as the project progressed it became clear the optimum management for best project outcome meant balancing time, cost and quality and there has been an acceptance that time will under perform to ensure outstanding results in quality and value. The project was 16 weeks later than planned after encountering Latent conditions and a significant EBA bargaining period.

The quality of the facility was generally exceptional and there were some areas such as the cabling systems where outstanding outcomes have been achieved. Feedback after several months of occupation was very favourable. There was an exceptional and collaborative work relationship between the project team and the hospital in commissioning the project, which supported the hospital in implementing the change management opportunities that existed within the new facilities.

In regard to the ESD the objective was the to be the most energy efficient hospital in Australia and:

- waste minimisation has achieved outstanding results including non-toxic demolition waste 100% recycled
- industry benchmark achieved for construction waste;
- energy efficient facades with high performance glass and all living space with natural light incorporated;
- sun shading doubles as safe access for cleaning and maintenance;
- solar availability maximised with solar hot water reducing energy consumption by 10%
- best practise building automation system installed.

The project has supported significant numbers of work experience students and worked with the local training authorities to provide traineeship opportunities. Graduates have also been given opportunities through the managing contractor and consultant groups. Upskill requirements have been exceeded and there is full safety training “Greencard” compliance. 41 traineeships and 29 work placements (including 10 long term unemployed) and 1 full time apprenticeship were offered through the efforts of the team.

The hospital staff and the subcontractors particularly appreciated the defects free completion in regard to minimising returns to site for rectification work.

After a series of initiatives to hold information forums, develop a website and publish newsletters along with Lions run bar-b-que events on site and several milestone celebrations, community awareness of the project was high with 80% satisfaction on communication from the project. The program to introduce art into the project through local schools and professional artists has been very well received.

EBA issues affected the site but not as significantly as other large site in SA. Safety standards exceeded industry benchmarks.

The relationship approach, integrated working and alternative project management model was a significant success and all team members and stakeholders recognise its benefits.

- The managing contractor effectively embraced a broader agenda than construction and tackled community involvement and ownership of the project, ESD opportunities and FFE procurement.
- Most subcontractors gave feed back that they valued the opportunity to genuinely join the team rather than simply be instructed and in particular the opportunity to contribute meaningful technical and constructability input.
- The consultant team are converts to the approach appreciating that there were real benefits through working collaboratively with the contractor through the design development and documentation stages. The documents were excellent.
- The experience has reinforced our view that project management can be a culture enhanced by a whole-of-team discipline rather than a role provided by an individual organisation.

WAS RELATIONSHIP MANAGEMENT HARD?

It is difficult to keep awareness raised about deliberately approaching all project issues in a fresh way and not reverting to “business as usual” when there were challenges or disagreements. While most projects give some consideration to these issues there was particular emphasis on applying good business practices including:

- A strongly supported vision;
- A clear set of objectives we all aligned on;
- Empowerment of all stakeholders in their respective roles;
- A commitment to make it work.
- A focus on being the team learning and culture to support achievement of the project and commercial objectives.

We don’t normally put that effort into human resource development in a project – rather we focus effort on the physical outcomes and processes.

IT WORKS!

The performance of the LMHS team was outstanding, achieving major savings of project cost despite a difficult tender market and industry resource and industrial dispute difficulties whilst achieving exceptional design and building outcomes.

The collaborative approach to the procurement has changed most people engaged with it. Members of the team advise that they have translated the learning, improvements in management and communication skills to their roles in the project and to aspects of other projects. The procurement method appears to effectively create the environment where better than normal outcomes can be achieved through the power of teamwork.

For the stakeholders:

- all have become better team operators on and off project;
- team members don't ignore problems but fix them;
- concept of alignment is a strong one;
- subcontractors are genuinely in the game
- so is the hospital
- longer term relationships have been built.

The team is currently one of the best running; most harmonious and integrated teams experienced and still has potential for more. In this regard there is a proposal to Government that the team should continue into the next major stage of redevelopment to build on their successes.

OUR NEXT CHALLENGES

Our next challenges is maintaining momentum during the next stage of LMHS (subject to Cabinet approval of contract extension). By the time the next stage is complete the team will have been working continuously for several years.

Another challenge is to use the learning on other major Government projects. Already however the building industry in SA has responded with several significant private sector projects adopting some of the principles and techniques implemented at the Adelaide Convention Centre and LMHS projects.

Getting the balance between investment in the team and its culture and investment in the physical outcomes of the project right is another issue. Some still see the investment in team as wasteful use of scarce capital resources and we need to develop ways of measuring and demonstrating the benefit to the overall project.

LIKELY OUTCOMES

Relationship contracting made a significant contribution to a very successful result in the LMHS Redevelopment Stage A project. The SA government has requested that the model be applied to the \$120M Stage 2 redevelopment at The Queen Elizabeth Hospital. It is anticipated that most projects in the SA Government Capital Investment Program will incorporate aspects of the relationship contracting approach in the future and several will adopt the integrated team project management approach in preference to the traditional project manager model.

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CLIENTS DRIVING INNOVATION

Case Study

RISK FACTORS LEADING TO COST OVER-RUN IN HIGHWAY CONSTRUCTION PROJECTS

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ABSTRACT

The change in project cost, or cost growth, occurs from many factors, some of which are related to each other, and all are associated with some form of risk. Determining the existence and influence of each of these cost overrun risk factors in projects may ultimately lead to better control on project cost estimates and assist in identifying possible solutions to avoid future estimate overruns.

This paper describes the PhD research project that is under way to study the risk factors related to cost growth in road construction projects and to evaluate influencing data from completed road projects. The paper details the literature research undertaken in the area of risks causing cost over-runs. It also identifies and describes historical cost factors which have contributed to excessive cost estimate overruns on 238 design-bid-build highway construction projects, each costing over \$1m. in Queensland, Australia during the period 1995 to 2003.

1. Introduction

Accurate, early cost estimates for engineering and construction projects are extremely important to the sponsoring organization and the project team. For the sponsoring organization, early cost estimates are vital for business unit decisions that include strategies for asset development, potential project screening, and resource commitment for further project development. Early estimates are critical to the initial decision-making process for the construction of capital projects. As such, the importance of early estimates to owners and their project teams cannot be overemphasized. Early estimates are typically plagued by limited scope definition (and thus the high potential for scope change) and are often prepared under stiff time constraints. Furthermore, reliable cost data are often difficult to obtain during the conceptual stages of a project, particularly if basic design and geographic issues remain unresolved. Early estimates, even when grossly inaccurate, often have become the basis upon which all future estimates are judged. For the project team, performance and overall project success are often measured by how well the actual cost compares to the early cost estimate. Initial cost estimates are the basis on which all future estimates are compared. Future estimates are often expected to agree with (i.e., be equal to or less than) the initial estimates. However, final cost often exceeds the initial estimate.

As in any other business operation, the cost of estimating must be balanced against the quality of the estimates produced. Estimates will not be perfect no matter how much is spent on them. We must be satisfied with forecasts of the future which will cost as little as possible and be accurate enough for our immediate purpose. The analysis of accuracy is also necessary for the improvement of a given estimating system. It can be used to diagnose trouble spots, to pinpoint areas where the greatest improvement can be obtained at the lowest expense, and to measure the improvement which takes place when a system is changed.

The change in project cost, or cost growth, occurs due to many factors, some of which are related to each other, and all are associated with some form of risk. Determining the existence and influence of each of these cost overrun risk factors in a project may ultimately lead to better control on project cost and assist in identifying possible solutions to avoid future overruns.

1.2 The PhD Research Project

This PhD research project has been developed to study the risk factors related to cost growth in Queensland Department of Main Roads (QDMR) funded road construction projects and to evaluate data from completed design-bid-build road projects so as to study the influence of those factors. The relationship between those risk factors and the project cost growth is also observed. A statistical model to predict the amount of certain cost contingency that is required to be incorporated into road project categories is then to be developed that will be based on the determination and analysis of these historical factors.

The objectives of the research are to:

- Ascertain the factors that may lead to variances between client cost

estimates and the final cost at completion of road infrastructure projects.

- Rank different factors according to their influence and impact on different road project categories
- Develop project contingency profiles for identifying risks that may need to be incorporated in project cost estimating processes.
- Develop a numerical model, based on statistical theories and concepts that can allow the user to predict the amount of cost contingency that is required to balance cost growth in road infrastructure projects using information available at the time of the design estimate

To achieve the purpose and objectives of the research, information regarding the risk cost factors which can have an impact on the project construction costs was gathered by way of unstructured interviews and a detailed literature evaluation on construction risk and project cost estimating.

Following this important process, the research is being conducted in several phases. The first phase involved the analysis of historical project cost information in the period 1995 to 2003 that had been published as public documents to determine the risk factors for project cost over-runs. The second phase of the research involved the further analysis of the published information so as to categorize road project types. The third phase of the research involved the factor analysis of both the risk factors and project categories in order to distill the findings down into a useable population. The forth phase of the research proposes a statistical model to be developed to predict the amount of risk contingency to allow for as cost growth, based on the cost estimate at the design estimate time.

This paper details the literature research and the initial data analysis and its findings.

1.3 The Construction Project Process

Construction of a project may be performed by several delivery methods. For the purpose of this research a traditional method was assumed because it is by far the most generic construction process (Gould 1997) and it is this model that is usually applicable to infrastructure projects such as found in the great majority of road construction projects. The diagram in Figure 1 is presented as the traditional construction process that consists of the feasibility or preliminary design, design, construction and operation phases. Although cost control is applied in all project phases this research project focuses on cost estimating accuracy that begins in the feasibility phase and intensifies in the design phase.

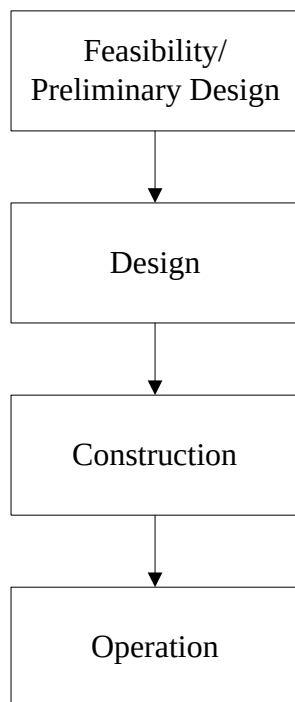


Figure 1. The Construction Project Process

Feasibility or Preliminary Design: Normally a project begins with a concept, where conceptual planning or a preliminary design will be performed and feasibility assessment will be made. During this feasibility phase conceptual drawings or a preliminary design is produced to help establish the feasibility of a project. The owner is also establishing requirements during this phase and therefore the concept's scope may fluctuate.

Design: If the project is feasible in terms of a sound business case, then a detailed design is performed. The design phase of a project will produce detailed drawings, specifications and quantity and cost schedules. During the design phase cost control is performed through scope control and value engineering. Value engineering is a team effort between designers, owners and builders to optimize the cost of a project. It is best applied in the design phase of a project and can result in savings of between 5-10% of construction costs (Mitten 1997).

Construction: During the construction phase the actual physical building of the project is accomplished. This stage is comprised of two parts, planning and execution. During the planning phase a detailed time schedule is developed and in the execution phase the actual project gets built.

Operation: The operation of a new facility begins once the construction is completed. This research project does not involve the risks or costs associated with a completed facility's operation.

For the purpose of this research project, the *total project cost estimate* includes the estimated costs of all component activities from the initiation of the project proposal to finalisation. These include the cost of:

- developing the concept design and business case,
- conducting investigations and developing the design,
- detailing the design,
- acquiring land,
- altering public utility plant,
- construction,

- project administration, and handover

Project cost over-runs create a significant financial risk to both contractors and owners; however, in spite of the risks involved, the history of the construction industry is full of projects that were completed with significant cost overruns. Sources of controllable and uncontrollable risks need to be proactively managed so as not to adversely affect a contractor's profitability (Akinci and Fischer 1998). Project performance is improved via systematic identification, appraisal and management of project-related risk (Chapman and Ward 1997).

Large-scale construction projects are exposed to uncertain environment because of such factors as planning, design and construction complexity, presence of various interest groups such as the project owner, consultants, contractors, stakeholders etc., resources such as materials, equipment, project funding, climatic environment, the economic and political environment and statutory regulations. Risk factors can also include the complexity of the project, the speed of its construction, the location of the project, and its degree of unfamiliarity. A highway or bridge construction project, for example is characterized by its linear complexity and limited design parameters in relation to certain design conditions such as ground or foundation conditions being exceeded. As well, the greatest risk lies below ground level due to the relatively larger footprint of a highway project, as compared with, say, a building structure.

1.4 Research into Construction Risk

Complexities of the project, location, type of contract, familiarity with the work and breakdown in communication are some of the significant contributors to risks in construction projects (Ahmed, Ahmed et al. 1999). Thompson and Perry (1992) state that evidence from projects worldwide show that project risks are not being adequately dealt with. Baker, Ponaniah et al. (1999) reports that in a survey of over 100 companies in both the oil and construction industries, most companies commonly respond to assessed risk, however the construction industry concentrated almost exclusively on the reduction of financial risk and less on managing technical risk. Perry and Hayes (1985) have suggested a checklist of risks that may occur throughout the life span of any project. Bent (1988), in introducing the concepts of control, said that: *the fundamental elements of control are the cost element and the project schedule* and are functions of the progress of technical performance. However, Might (1984) carried out a survey of the effectiveness of project control systems on high-risk US Department of Defence and NASA projects and his findings on control factors were unclear in respect of the effectiveness of specific control mechanisms. Uher (1994) identified thirty-four individual risks and categorised them into a single model, referring to some as "activity" risks that may affect individual activities, while other were "global" risks that were common to all activities. The majority of risks identified by Uher were global risks. Williams (1995) described various risk identification and analysis tools used by researchers and practitioners in project risk management. Tummala and Leung (1999) developed a methodology for risk management governing risk identification, measurement, assessment, evaluation and risk control and monitoring. They have applied it in managing cost risk for a transmission line project. Delphi technique has been used by Dey(1999) for identification of risk factors. Dey (2001) identified the following as the general benefits that can be

achieved from the application of risk management in any type of project:

- The issues of the project are clarified and allowed for right from the start.
- Decisions are supported by thorough analysis of available data.
- The structure and definition of the project are continually and objectively monitored.
- Contingency planning allows controlled and pre-evaluated responses to risks that materialize.
- Clearer definitions of the specific risk associated with a project.
- Builds up a statistical profile of historical risk for modelling future projects.
- Encourages problem-solving innovative solutions to problems within a project.
- Provides a basis for project organization structure and appropriate responsibility matrices.

The literature has several case studies of construction risk management from general building construction (Baker, Graves et al. 1995), offshore construction (Curole 1995) or highway construction (Wang and Chou 2003). In the field of project management, risk management is a recognized practice to help managers deliver projects on schedule and within cost (Project Management Institute PMI 2000).

Studies from around the world have consistently highlighted the recurring frequency of claims for unforeseen ground conditions. In America, studies by Halligan, Hester et al. (1987) on Federal Highway Administration funded state highway construction projects indicated that, whereas claims for ground conditions accounted for only 20% of all claims when categorized by root cause, they were responsible for approximately 35% of the total dollar amount paid to contractors for claims. A study in Hong Kong by Kumaraswamy (1997), aimed at identifying root causes of claims for extension of time and extra payments on construction projects, found that unforeseen ground conditions were ranked fourth in the "top ten" common categories of construction claims as perceived by contractors, owners and consultants.

1.5 Estimating Project Costs

The project cost estimate is primarily concerned with the cost of resources needed to complete the project activities and include all the processes which are employed to maintain financial control over a project. Abbasi and Al-Mharmah (2000), Hutchings and Christofferson (2000) and White and Fortune (2002) examined various management tools and techniques with seven that have been adopted which are the most popular used in estimating and cost control. They are:

- Analogous analysis
- Parametric estimating
- Detailed estimating
- Best guess estimating
- Cash flow/S-curve
- Variances
- Earned value

The accuracy of conceptual cost estimates for capital projects has been a major concern and a subject of much scrutiny for almost 40 years. (Hackney

1986) published a checklist for establishing a detailed definition rating for capital projects. He proposed the use of the definition checklist for applying contingency to capital cost estimates and then validated the checklist by comparing the definition ratings of 30 projects to their respective levels of cost overrun. Later he revised the checklist to specifically address process projects and developed a separate checklist to apply the definition rating method specifically to hazardous waste remedial projects (Hackney 1986). In the late 1970s, the U.S. Department of Energy recognized the importance of accurate conceptual cost estimates and contracted with the Rand Corporation to study the capital cost estimation problems associated with pioneer energy and also process plants. The study determined that 74% of cost growth is caused by underestimation, that is, improper estimation (Morrow 1988).

In 1991, the Construction Industry Institute (CII) assembled a research team to study the impact of pre-project planning on overall project success for capital projects (Gibson and Hamilton 1995). The team sought to quantify the impact by establishing a success index value to rate project success. The success index value was computed and compared to a pre-project planning index value for a variety of projects (Gibson and Hamilton 1995).

Hegazy and Ayed (1998) used a neural network (NN) approach to effectively manage construction cost data and developed a parametric cost-estimating model for highway projects. Eighteen highway projects in Newfoundland, Canada were the source of the cost data and they used weightings that produced the best cost prediction for the historical case studies to find the optimum neural model.

Oberlender and Trost (2001), and again in Trost and Oberlender (2003)) reported on quantitative data they collected and analysed from completed construction projects in the process industry. The resulting model, known as the estimate score procedure, allowed a project team to score an estimate and then predict its accuracy based on the estimate score. They identified five main factors affecting estimate accuracy and, in order of significance, were:

- basic design,
- team experience and cost information,
- time allowed to prepare the estimate,
- site requirements, and
- bidding and labour climate

Engineering designs have a high level of influence on project costs (Barrie and Paulson 1992). However, design performance is usually not satisfactory. Anderson and Tucker (1994) reported their survey that found that about one third of architectural/engineering (A/E) projects miss cost and schedule targets. Chang (2002) notes that, as reported by Smith (1996), there have been few instances where an engineering design was so complete that a project could be built to the exact specifications contained in the original design documents. Many construction problems are due to design defects and can be traced back to the design process (Bramble and Cipollini 1998). Chang (2002) reported that on four completed case study projects for environmental and engineering design services for roadway construction projects in California that were carried out on a cost-plus-fixed-fee basis, they experienced cost increases on average of 24.8%, based on the four sampled projects.

1.6 Cost Forecasting Models

The development of cost forecasting models has been summarized by Raftery and Ng (1993) as: first generation models –element cost planning in the U.K. and by bidding models in the USA; second generation models – by using the regression analysis; and third generation models – probabilistic estimates, frequently based on Monte Carlo techniques. Raftery (1994) suggests that 'range estimating' could be developed further to show the form/shape of project cost distributions. In 1996, Skitmore indicated this might be done parametrically for tender price forecasts, by fitting one of the standard probability density functions to the cumulative frequency of the tender price forecast/actual values (Skitmore 1996).

More recent research has attempted to apply artificial intelligence to the prediction of completed project costs. These efforts start with the *a priori* assumption that each project must be considered unique. Attempts have been made to develop extremely complex models that incorporate all of the many different factors and their interactions that can affect the cost of a construction project. Williams, Miles et al. (1999) described how simple linear regression models can be used to predict the completed cost of competitively bid highway construction projects in the USA using only the low bid as input. Touran (2003) proposed a probabilistic model for the calculation of project cost contingency to counter initial project cost estimates by considering the expected number of changes and the average cost of change. The model assumed a Poisson arrival pattern for change orders and independent random variables for various change orders and calculates the probability of cost overrun for a given contingency level.

1.7 Impacts of Project Changes

Ibbs and Allen (1995) defined project change as any event which results in a modification of the original scope, execution time or cost of work. Their research focused on the quantitative impacts that change has on the detailed design and construction phase of projects. They found that project change has a large effect on the financial performance of a construction project. In a study by Hester, Kuprenas et al. (1991), it was found that most project owners assume routine changes in the work will affect only the work in the change area, whereas the effects can extend well beyond. Thomas (1985) studied highway construction programs and reported on selected claims for project changes and cost/schedule over-runs on those projects.

1.8 Common Project Procurement Types

Pakkala (2002) found that, in a global perspective, delivery of infrastructure services and products for capital investment projects varies in practice from country to country. He evaluated road infrastructure project delivery in Australia, Canada, England, New Zealand, Sweden and the USA and reported that all use a common practice for the main delivery model, known as the traditional model, or Design-Bid-Build. This means that design/engineering services are produced first, and then another procurement contract is tendered for the actual construction or physical works, based upon the design/engineering portion of the contract.

Langford, Kennedy et al. (2003) investigated construction costs in 11 similar motorway project parcels in the UK between 1990 and 1995 where five projects were carried out by a traditional design, tender, construct method, and five were undertaken by a procurement system by which the contractor bid a lump sum for the work. As well, one project was done as a design and build project. The results of their analysis indicate that, in roadworks, the construction costs per kilometer were some 11% less expensive when lump sum contracts were used. Langford *et al* (2003) also reported that their research showed that lump sum projects were much more likely to be completed within budget and required less management by the client organisation, as well as delivering more harmonious working relationships between clients and contractors.

1.9 Literature Summary

The literature supports the notion that accurate, early cost estimates for engineering and construction projects are extremely important to the sponsoring organization. Accurate cost estimates are vital for business unit decisions that include strategies for asset development, potential project screening, and resource commitments for further project development. The literature survey has revealed several research studies, particularly in highway construction projects, that have been conducted in an attempt to predict the amount of cost a construction contract might increase, taking into account various factors that could be used in such predictions. Research to date has generally revolved around contract cost increase data in a macroscopic way across many projects. Objective, quantitative measures for predicting the accuracy of early project estimates have been scarce. There is little research evidence that utilises a more intensive microscopic analysis of total project cost overruns using historical cost overrun data to develop cost contingency factors that can provide better estimated final project costs for project owners.

1.10 Research Project Data Analysis Methodology

The analytical procedure followed in this project entails disaggregation whereby parameters for any proposed cost overrun contingency model is based on individual projects and their data, rather than on generalization.

Microsoft Excel software is used to store and analyse the collected project data and is used to create the "base file" for the statistical analysis. The commercial statistical software package SPSS version 12 for Windows is also planned to be used for the variety of statistical and mathematical analyses. SPSS has been tested extensively and provides specific operations and functionality such as factor analysis, creating indicator variables for a qualitative variable and multivariate statistical analysis. SPSS supports Excel data files and makes the transition from one to the other very convenient.

1.11 Road Project Cost Overrun Variables

The analysis of the cost over-run risk factors was carried out on 238 road construction projects throughout Queensland between 1995 and 2003 whose initial estimated project cost was more than A\$1m and whose final cost exceeded the original estimate by greater than 10%. The total combined project value was A\$1015b All road infrastructure data collected and analysed

in this research is obtained from a single Government road source, namely the QDMR. It should also be noted that some of the initial research project findings may be strongly related to economic conditions and contracting climates that may vary from time to time.

The 238 road projects were analysed by means of a systematic review of each project and the reasons documented for each project and a list of 39 cost overrun variables was obtained. Table 1 below shows the 39 cost overrun variables derived from the published project data. As well, Table 1 also shows the occurrence of each of the cost overrun variables over the 238 projects.

Reason Code	Reason for Variation	Occurrence
D	Design/project scope change	95
TH	Contract tender price higher than original estimate	35
DD	Design scope change - Drainage	33
Q	Quantity increased measure	31
DM	Design Scope Change - pavement materials/depth	23
LUS	Latent Condition - Remove and replace unsuitable material	21
DE	Design Scope change - Environmental issues	19
CT	Constructability - under traffic	17
S	Services relocation costs	12
MP	Material cost increase – Pavement Materials	11
C	Constructability difficulty costs	10
R	Resumption/accommodation works	10
P	Project Administration Cost Increase	8
WW	Wet Weather Effects/Rework	8
LR	Latent Condition - Rock encountered	7
O	Remote location costs	7
SC	Specification Change	7
EU	Extras Unspecified	6
A	Project acceleration requirement	5
DSA	Design Scope Change - Safety Audit Requirement	4
H	Cultural heritage issues	4
LD	Latent Condition - requires design change	4
MPS	Material cost increase - Principal supplied components/materials	4
GCD	Government Initiative – Contribution by Developer	3
LSG	Latent Condition - Additional Stabilising	3
ME	Material cost increase - Earthworks	3
DF	Design Scope change - Design error	2
MQ	Material/Process Quality Issue	2
TL	Contract tender price lower than original estimate	2
DN	Design – Reduced scope change saving \$	1
DPL	Design Preload Requirement	1
DSG	Design Change to Subgrade	1
G	Government Initiative - Employment continuity	1
GCLG	Government Initiative - Contribution by Local Government	1
GCR	Government Initiative - Contribution by Rail	1
MA	Material cost increase - Asphalt	1
MB	Material cost increase - Bitumen Price	1
N	Contract failure-New contract establishment costs	1
TCI	Contract Tender Price Increase due to inflation	1

Table 1: Cost Overrun Project Variables and Occurrences.

An analysis of the cost overrun which has 10 or more occurrences in the 238 projects is shown in Figure 2 below.

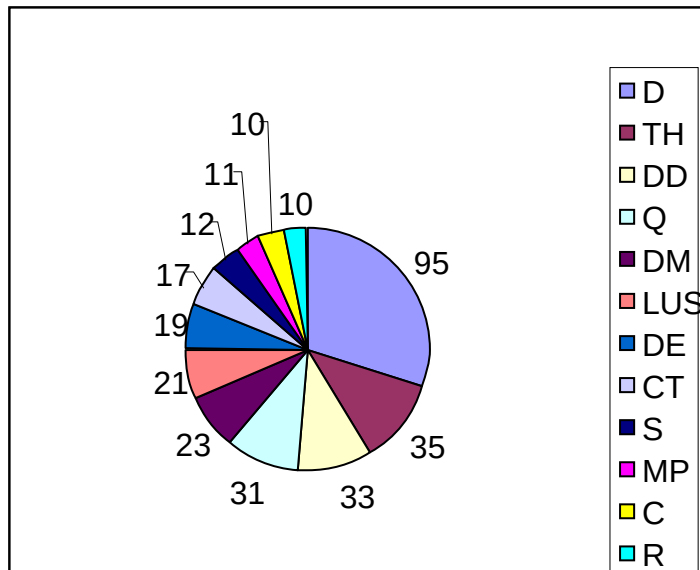


Figure 2: Major Cost Overrun Variables Occurrences

LEGEND	
D	Design/project scope change
TH	Contract tender price higher than original estimate
DD	Design scope change - Drainage
Q	Quantity increased measure
DM	Design Scope Change - pavement materials/depth
LUS	Latent Condition - Remove and replace unsuitable material
DE	Design Scope change - Environmental issues
CT	Constructability - under traffic
S	Services relocation costs
MP	Material cost increase – Pavement Materials
C	Constructability difficulty costs
R	Resumption/accommodation works

The Design/project Scope Change (D) variable amounts to 31% of all the cost overruns in the 238 projects and is by far the variable that contributes to the highest incidence of overrun. Contract Tender Price Higher than Original Estimate (T) is the second highest variable occurrence and amounts to 11 of the measured factors. Design scope change – Drainage (DD) and Quantity Increased Measure are the third highest occurrences, both with 10%.

Figure 3 below shows the percentage occurrence of the 12 highest cost overrun variables.

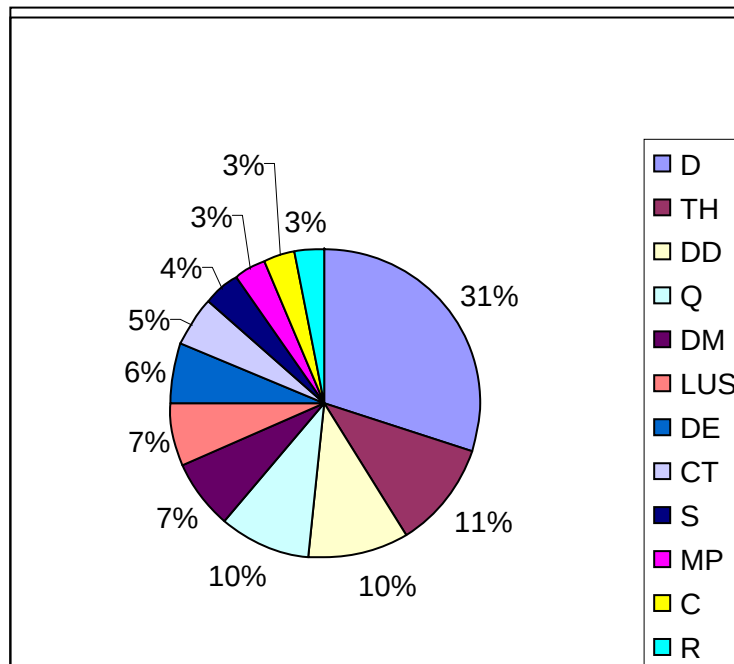


Figure 3: Percentage Distribution of Top Twelve Variables.

LEGEND

D	Design/project scope change
TH	Contract tender price higher than original estimate
DD	Design scope change - Drainage
Q	Quantity increased measure
DM	Design Scope Change - pavement materials/depth
LUS	Latent Condition - Remove and replace unsuitable material
DE	Design Scope change - Environmental issues
CT	Constructability - under traffic
S	Services relocation costs
MP	Material cost increase – Pavement Materials
C	Constructability difficulty costs
R	Resumption/accommodation works

Appendix A provides a description of the 12 cost overrun variables in the context of highway construction.

1.12 Planned Further Data Analysis

Because all the identified variables relate to the issue of cost overrun and estimate accuracy, and many were related to each other, multicollinearity is identified as a distinct problem. The next stage in the planned data analysis will utilise factor analysis on the data to overcome any multicollinearity problem. This analysis will provide a deterministic method to group variables into meaningful subdivisions, the number of which can be anywhere between one and the total number of variables.

2. Conclusion

The change in project cost, or cost growth, occurs due to many factors, some of which are related to each other, and all are associated with some form of risk. An analysis of the cost over-run risk factors was carried out on 238 road construction projects between 1995 and 2003 whose initial estimated project

cost was more than A\$1m and whose final cost exceeded the original estimate by greater than 10%. The road projects were analysed by means of a systematic review of each project and the reasons documented for each project and a list of 39 cost overrun variables was obtained. The Design/project Scope Change (D) variable amounted to 31% of all the cost overruns identified in the 238 projects. Contract Tender Price Higher than Original Estimate (T) was the second highest variable occurrence and amounted to 11% of the measured factors. Design Scope Change – Drainage (DD) and Quantity Increased Measure were the third highest occurrences, both with 10%.

Further planned data analysis will utilise factor analysis on the data to overcome any multicollinearity problem and should provide a deterministic method to group the cost overrun variables into meaningful subdivisions

Determining the existence and influence of these cost overrun risk factors in road construction projects may ultimately lead to better control on project cost and assist in identifying possible solutions to avoiding future overruns.

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APPENDIX A: Cost Overrun Variable Description

C Constructability difficulty costs

This project cost can occur where the tender price is based on an approved construction process or sequence and this has to be varied by the Principal for certain reasons. The most prevalent cause of this cost might be that the foundation design criterion might not be achievable due to unforeseen site conditions. Also, constructability difficulty costs might be incurred in a project where certain traffic arrangements must be maintained that severely restricts the economy of scale of certain construction processes such as paving runs, of concrete placement in drainage and bridge structures.

CT Constructability - under traffic

Increased project costs due to having to construct certain road construction processes under flowing traffic conditions can be substantial in highly trafficked areas. Whilst, generally all contracts for projects in such situations are specific in detailing the construction risks of process continuity and efficiency, there does arise situations in contracts when the contractor's obligations are compromised by instructions and directions from the principal that would require the contractor to incur costs other than provided for in the contract provisions. Limiting a contractor's work schedule to out of peak traffic times due to otherwise unforeseen peak hour traffic congestion is one example where such additional project costs due to lower daily productivity might need to be borne by the principal. In urban areas, even say a traffic problem occurring on a nearby (arterial) road can force traffic through construction projects which normally would not have attracted such higher flows and subsequent congestion and safety issues.

Side tracking of traffic in some urban and rural projects is also a safe and efficient means of managing traffic during construction. Again, there are times when contingent emergencies or processes can occur that will disrupt this orderly traffic management strategy that results in construction processes having to be carried out under flowing traffic conditions. Again, this may be outside the control of the contractor and then could be deemed the cost responsibility of the principal.

D Design/project scope change

This is a general category into which all non-defined project scope changes that increase the cost are allocated. They exclude the specific areas of: drainage, environment, design error, pavement materials and pavement depth, earthworks preload, changes to pavement subgrade and changes as a result of physical site safety audits.

This variation category includes such design scope changes a vertical and horizontal alignment changes that can result in changes in quantities, as well as rework. It can include scope changes in traffic guardrail, traffic signage and kerb and channel and traffic island changes. Changes in this category are generally limited to one or a number of locations within the project and would not generally include a major design change such as the addition of further traffic lanes to the full length of the project.

DD Design scope change - Drainage

This category is for design scope changes specifically related to drainage and

can include the addition of drainage structures where pre-existing structures are deemed to be inadequate upon detailed site inspection. In many cases, detailed site inspections cannot be adequately carried out without heavy excavation equipment. In some cases, especially where the design calls for the extension or addition to existing drainage structures, the condition of the existing drainage structure is not fully revealed until excavation work is carried out in the vicinity of the structure. Site investigation can then reveal substantial deterioration to the extent that the existing structure requires full replacement or substantial repairs. Where existing drainage structures have been constructed of corrugated helical steel pipes, it is often found that the inverts have rusted through, even resulting in scouring out of fill behind the structure. In most cases, this fact is not obvious at the time of site investigation for design because inverts can be permanently under water, or heavily silted.

Drainage design scope changes can occur when an increase is required in the flow capacity due to changes in hydraulic gradients due to conflicts with underground service installations or other expensive obstructions. In some urban and semi-urban areas, changes in zoning in upstream catchments can result in older drainage designs requiring redesign due to revised runoff coefficients as a result of planned land use. Sometimes, such design changes can be argued to be the cost to upstream developers if time permits, but in other cases, when the time horizon is sufficient far away that the additional costs would not be reimbursed from others.

A small factor that sometimes requires design consideration is when new metric drainage installations are required to join to old imperial drainage pipes and cells. The design modifications are small, but real.

DM Design Scope Change – pavement materials/depth

Pavement materials: This category occurs when there is a need to change the specified pavement materials to a different specification. This can happen for a number of reasons. Primarily, a change in material could be required where the excavated pavement box might have poor drainage and there is a possibility for moisture to build up due to difficulty in draining adequately. It may be deemed more economical to improve the specified material quality rather than install additional pavement drainage. This occurs sometimes in rock cutting subgrades where cement stabilisation might be ordered in lieu of drainage blankets or additional drainage lines. In some instances in urban construction, specified granular paving materials may be changed to asphaltic material where construction is required under traffic and there is the potential for the granular material to disperse under heavy turning traffic or create undue dust where the material cannot be kept wet due to the creation of then slippery road conditions that could cause traffic accidents. There also may be the need to install temporary traffic white lining for traffic directions and control, even overnight, which requires installation on a sound surface.

Pavement Depth: Changes in pavement depth predominantly occurs when the field measured strength of the pavement subgrade is weaker than the assumed strength for what the pavement design was based on. There is then a requirement for a revised pavement design, usually resulting in an increased pavement depth. In most cases, this also requires the raising of the grade line by the same amount that the pavement was increased. Minor regrading at

bridges and new drainage culverts may be required if the pavement redesign extends over any substantial distance.

LUS Latent Condition - Removal and replacement of unsuitable material:

This process is used to overcome situations where foundation materials for pavement, drainage structures and structures are found to be inferior and the material is ordered to be removed to a specified depth and replaced with material of a certain quality. In some situations, the knowledge of the presence of unsuitable material can be ascertained by bore probes or other testing methods and adequate provision made in the schedule of quantities to cover such treatments. In cases where none or limited testing is carried out in the design stage, then it is appropriate to include only a nominal provision in the quantities to cover the risk of discovering and having to replace unsuitable material. Usually, contract provisions allow for such variations as a cost to the principal.

MP Material cost increase – Pavement Materials

Pavement design changes can substantially increase paving volumes which can lead to the risk of increased pavement materials and hence increased costs. In addition, for certain project locations, there may be no economically suitable source of paving materials and hence the material then has to be transported large distances from established quarries to the project. In some rural projects, there may be raw material suitable for paving gravel production close to a rural project but no suitable crushing equipment. It may then be a matter of establishing crushing facilities at the material source, if suitable equipment can be enticed there. In this case, the volume of paving material to be produced can be the important economic factor in determining the supply price of the paving material. Either supply option can be significantly more expensive than conventional quarries close to projects and so can have significant influence on the final cost of a project.

R Resumption/accommodation works:

Where private land is required on to which all or part of the project is to be built, the land can be purchased outright from the owner, or can be compulsively acquired under the powers of the Government. In the latter case, the land owner also has recourse to an appeal mechanism that can take a considerable period of time. The outcome of this appeal mechanism can in some circumstances increase the cost of acquiring the land for the project. In addition to compensation for the taking part land parcels, the Government is obliged to carry out accommodation works adjacent to the resumed land so as not to affect the amenity of that land. This can be costly and can increase project costs over that estimated at the time of commencement of any land procurement.

S Services relocation costs:

The road reserve is also used by services (utility) authorities under their various legislation heads. Whilst pre-approval is usually required for the service authority to install their particular facility, this approval usually obliges the road authority to pay for the cost of relocating such existing services where a new road project design conflicts. The physical relocation work is usually carried out on an actual cost basis and this can be substantially greater than preliminary estimated costs. These preliminary estimate costs are what are generally used when developing road project estimates. Actual cost figures

can be greater than estimated costs for a number of reasons, the most common is workplace safety provisions that are required for workmen who are required to work sometimes under dangerous traffic conditions. This can lead to additional installation of temporary protective measures and/or the need to have the work carried out at night or on weekends when traffic conditions and the potential for congestion is lessened.

TH Contract tender price higher than original estimate:

The project estimated cost is based on the forecast tender cost of the construction component of the project delivery. Where the actual tender cost is higher than the original estimate, then there is an adjustment required to the project estimate.

VISUALISATION AND INFORMATION

Case Study

WHAT ABOUT THOSE ANTS? SWARM INTELLIGENCE FOR VIRTUAL ENVIRONMENTS

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ABSTRACT

The use of 3D virtual worlds has spread rapidly in recent years. These worlds have various uses ranging from computer games to urban design simulation systems. However, the spread of 3D virtual worlds has been impeded due to the problem of users not being able to find their way in and around virtual worlds. Hence improving wayfinding has become a crucial area of research. As virtual worlds become more advanced, they will be better equipped to run complex design scenarios highlighting potential design faults and areas for improvements. If virtual worlds technology is to become an effective and reliable design tool for the construction industry, wayfinding must also be developed to minimise wastage and inefficiency that may arise out of users not being able to find routes to their destinations. Swarm intelligence, with its distributed information gathering crawlers, points to a promising area of research for those who seek to broaden the capacity of wayfinding aids.

Keywords: **Virtual Environments, Wayfinding, Swarm Intelligence, Construction Industry**

1. INTRODUCTION

The use of 3D virtual worlds has spread rapidly in recent years. These worlds have various uses ranging from computer games to urban design simulation systems. However, the spread of 3D virtual worlds has been impeded due to the problem of users not being able to find their way in and around virtual worlds. Improvements in graphics technology have enabled the virtual worlds to become more realistic and detailed than previously possible. Hence improving wayfinding has become a crucial area of research. Attempts to improve wayfinding thus far assume the world to remain static over the course of the interaction, and hence offer no dynamic adaptivity. This paper begins by outlining current wayfinding efforts in the literature. This is followed by the ideas behind swarm intelligence. I propose to employ swarm intelligence to address the problem of wayfinding in virtual environments.

2. BACKGROUND

2.1 WHAT IS WAYFINDING?

No widely accepted definition for wayfinding exists in the literature. Various definitions focus on different aspects of wayfinding, and researchers have not yet reached a consensus. However one general definition is provided by Gluck (Gluck, 1990) who defines wayfinding as “the process used to orient and navigate.” He argues the fundamental goal of wayfinding is “to accurately relocate from one place to another in a large-scale space” (Gluck, 1990). Arthur and Passini (Arthur and Passini, 1992) concur as they describe wayfinding as “finding one’s way to a destination.” They further explain wayfinding to be a “spatial problem solving” which comprises of “three interdependent processes: decision making, decision executing, and information processing” (Arthur and Passini, 1992). Similarly, Peponis et al. (Peponis et al., 1990) describe wayfinding as “the ability to find a way to a particular location in an expedient manner and to recognize the destination when reached.”

Wayfinding, therefore, simply means knowing where you are, where you want to go, and how you get there. In order to achieve this, researches in wayfinding have used, to name a few, landmarks, maps, thumbnails, visual cues, multiple views, guided tours, and queries. Wayfinding efforts can be roughly categorised into two categories: environment focused and user focused. Environment focused approach aims to aid wayfinding by manipulating the environment in order to enable users to gain spatial knowledge. User focused approach, on the other hand, allows users a limited control over their interaction with the virtual world. What is lacking in both approaches is dynamic adaptivity. Both approaches assume the environment to remain static. Hence when the world changes, the wayfinding aids—whether they be maps or a some kind of knowledge-rich database—also need to be updated. The changes can only be made while the user is not using the environment. A brief overview of current research in wayfinding is given below.

2.2.1 Environment Focused Approach

The environment focused approach improves wayfinding by manipulating virtual environments to aid users (Elcacho et al., 2001; Ramloll and Mowat, 2001; Todd Elvins et al., 1997; Vinson, 1999). The areas of improvements in the virtual environment include:

- Landmarks/Visual cues (Chittaro and Scagnetto, 2001; Elcacho et al., 2001; Noser et al., 2003; Raubal and Winter, 2002; van Luin et al., 2001b; Vinson, 1999)
- Maps/Thumbnail (Barkowsky et al., 2000; Casakin et al., 2000; Kitamura et al., 1998; Ramloll and Mowat, 2001; Saretto, 2001; Todd Elvins et al., 1997)
- Multiple views (Kitamura et al., 1998; Ramloll, 1997)

2.2.1.1 Landmarks

Landmarks are distinctive environmental features that function as reference points (Vinson, 1999). These landmarks are critical in providing visual information for wayfinding (Evans, 1980; Golledge et al., 1985; Lynch, 1960). The landmarks also influence the search strategies used by users (Todd Elvins et al., 1997). Without a priori knowledge of a destination and its surroundings, a user performs an exhaustive search of the region. Landmarks are used as directional cues with which to steer such a search. Even with a posteriori knowledge of the destination and its surroundings, the user navigates to the destination by survey, procedural, and landmark knowledge (Todd Elvins et al., 1997). Vinson (Vinson, 1999) presents design guidelines for landmarks for use in virtual worlds. In it, Vinson argues that only those landmarks which are both noticeable and helpful to the navigators to remember their positions in the environment should be created. Any attempt to improve user's orientation skill is ideal. The problem with this type of solution is that every time the world changes, new landmarks also have to be created in order to distinguish the newly created objects from the rest.

2.2.1.2 Maps

Just as there are maps available in the real world, there also are maps for the virtual worlds. Most 3D environment browsers provide functionalities to view the world in miniature for the users to gain survey knowledge (Todd Elvins et al., 1997). Stoakley et al. (Stoakley et al., 1995) extend this idea by creating a miniature world and embedding it within the main world as shown in figure 1. From WIM given in the browser, the user can reposition the contents of the virtual world as well as themselves. The main world updates to reflect the changes made in WIM. This solution helps users to orient themselves within the environment. However this solution still leaves the wayfinding task to be undertaken by the users.

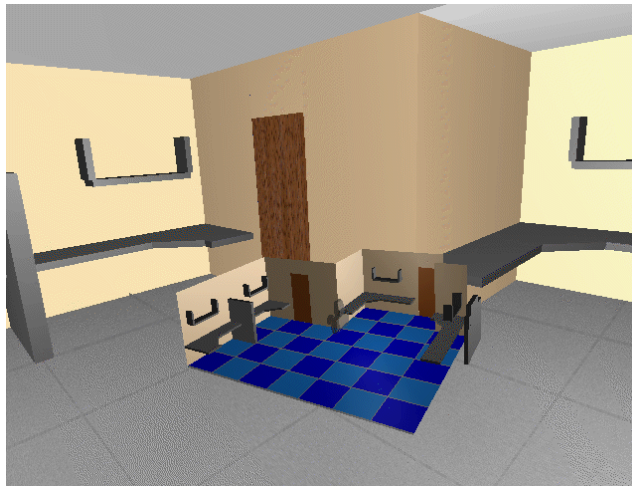


Figure 1 World in Miniature (WIM) shown within (Stoakley et al., 1995)

2.2.2 User Focused Approach

The user focused approach overcomes the problems identified with the environment focused approach by employing various means. They include:

- Guided Tours (Chittaro et al., 2003; Gaylean, 1995; van Luin et al., 2001a)
- Queries (van Ballegooij and Eliëns, 2001; van Luin et al., 2001a)
- Agents (Bertoletti et al., 2001; Maes, 1995; van Dijk et al., 2003; van Luin et al., 2001a; Zwiers et al., 2000)

2.2.2.1 Guided Tours

Guided tours offer the opportunity for users to experience whatever the virtual environments offers. This is the first genuine attempt at solving the problem of getting 'lost-in-cyberspace'. Being gently guided around the worlds, the users are no longer 'lost-in-cyberspace'. Gaylean (1995) implemented this notion of a guided tour with the use of "the River Analogy". In this, users are restricted to follow a predefined navigational path and follow it "like a river flowing through a landscape" (Gaylean, 1995). Gaylean describes it as the user being in a boat "floating down this river with some latitude and control while still being pushed and pulled by the pre-defined current of the water" (Gaylean, 1995). The user still has the control over what is seen on the screen.



Figure 2 A Virtual Guide presenting an object (Chittaro et al., 2003)

Another implementation of guided tours is developed by Chittaro et al. (Chittaro et al., 2003), as shown in figure 2. They adopted the use of an avatar, called the H-Anim character, to be both a wayfinding aid and an information aid. This H-Anim character leads the user on a tour of the world that includes all the specified objects and/or places in a predefined order. At each specified object/place, the avatar stops the user possibly to present pre-recorded information as shown above. For each world, a new touring path needs to be generated with information regarding tour items.

2.2.2.2 Queries

Van Luin et al. (van Luin et al., 2001a) present an ongoing research where the users query an interface agent, called Karin, in a natural language. The system is built around a virtual theatre. This is where the difference ends compared to the examples mentioned above. In this system, Karin accesses three different databases. The first database stores information relating to physical objects that are present in the theatre such as objects, names, locations, and sizes. The second database stores information relating to imaginary objects such as performances. The third database contains knowledge about the relationship between objects. These databases are queried according to the questions asked by the users.

Querying is an adequate method of giving a complete control to the user of his/her interaction with the system. However, it should be noted that the kind of spatial knowledge displayed as a result of a query is highly dependent on the kind of data stored in the databases. If the information stored in the databases is out dated or limited, then querying will not be so effective in aiding wayfinding. Moreover, giving directions to a destination in terms of any landmark present might not be sufficient for users to navigate smoothly, especially if users are not aware of the very landmarks the directions mention.

2.3 SWARM INTELLIGENCE

Swarm intelligence is defined as “any attempt to design algorithms or distributed problem-solving devices inspired by the collective behaviour of social insect colonies and other animal societies” (Bonabeau et al., 1999). In this paradigm, two concepts are of concern: self-organisation, and stigmergy. However I focus only on the notion stigmergy.

2.3.1 Stigmergy

Stigmergy is a type of communication which is conducted “by altering the state of the environment in a way that will affect the behaviours of others for whom the environment is a stimulus” (Kennedy and Eberhart, 2001). Bonabeau et al. (Bonabeau et al., 1999) explain stigmergy as an indirect interaction between two individuals “when one of them modifies the environment and the other responds to the new environment at a later time” (Bonabeau et al., 1999). Ants communicate via sign-based stigmergy using pheromones. Pheromones are chemicals used by ants as a method of communicating with others.



Figure 3 Ideal path travelled by ants to food source

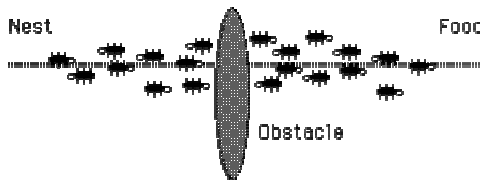


Figure 4 An unexpected obstacle laid on the path

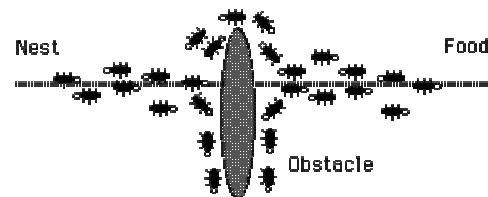


Figure 5 Initial direction of travel chosen by ants

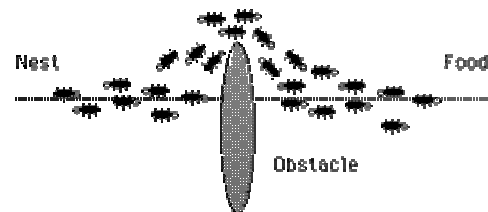


Figure 6 Shortest path chosen by ants

Interacting with each other, ants can perform complex tasks even when their behaviours are unsophisticated. Trails of pheromones are laid down by a given ant, which encourages other ants to follow. The stigmergy is illustrated by an experiment which is summarised as follows. The researches on live ants illustrate that “when food is placed at some distance from the next, with two paths of unequal length leading to it, they will end up with the swarm following the shorter path” (Kennedy and Eberhart, 2001) as shown in figures 3 to 6 (Dorigo, 2003). This observation is made possible by the fact that the shorter path to the food source will have a higher concentration of pheromones deposited on it compared to the longer path. Hence an individual ant tends to follow the path with stronger scent.

3. WAYFINDING SWARM OF CRAWLERS

In order to solve this problem in wayfinding, I employ swarm intelligence with the emphasis on the use of stigmergy and the design of pheromones. The overall system features, as shown in figure 7, a personal agent that interacts with a user in various ways. Using simple natural language processes, the user can query the location of a particular destination. This allows the agent to control macro-level behaviour of crawlers which move about in the world to discover different routes to the destination.

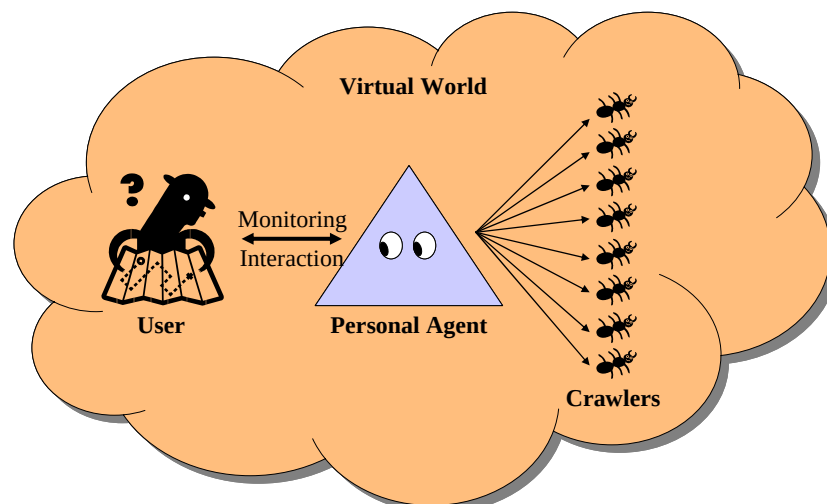


Figure 7 Overall system architecture

The information retrieval crawlers are the most critical component in the overall system, shown in figure 8. They are effective information gatherers and I utilise them in order to gather wayfinding information in the virtual world. Each crawler is a simple rule-based agent having a localised knowledge of the world around it. Crawlers have the capacity to construct the needed knowledge in order to find the best wayfinding route without relying on an already existing knowledge base. Hence as the virtual world changes, the crawlers simply move about in the world to gather new wayfinding information.

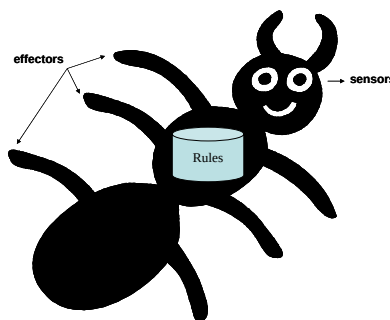


Figure 8 Wayfinding crawler

Typical foraging ant models assume one of the randomly moving ants find a food source, the path to which is marked with pheromones. Since the ants do not communicate directly with each other, they use pheromones dropped on the trail to the food source. The pheromones then become the stimuli for other ants to follow the trail. This process of indirect interaction by ants is called stigmergy. I employ this method of indirect communication through the environment in my design of crawlers with one important difference. Pheromones which are used among ants to attract other ants are used among crawlers as repellents. Electronic pheromones will encourage other crawlers to find alternative routes to the destination.

This is a novel approach to wayfinding which eliminates the need for a database containing information about the world that needs to be updated whenever the world changes. The use of crawlers allows the world to be changed without limiting wayfinding capacity as crawlers continuously search

for alternative routes to a destination within a dynamically changing complex virtual environment.

4. THE WAY FORWARD

The nature of stigmergy in virtual environments needs to be examined further as well as the composition of electronic pheromones. Swarm intelligence offers an exciting opportunity to enhance wayfinding without having to rely on a previously composed database. As virtual worlds become more advanced, they will be better equipped to run complex design scenarios highlighting potential design faults and areas for improvements. If virtual worlds technology is to become an effective and reliable design tool for the construction industry, wayfinding must also be developed to minimise wastage and inefficiency that may arise out of users not being able to find routes to their destinations. Swarm intelligence, with its distributed information gathering crawlers, points to a promising area of research for those who seek to broaden the capacity of wayfinding aids.

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PROCUREMENT AND RISK SHARING

Practice / Case Study

PROCUREMENT AND RISK SHARING

Ross Williams

1. INTRODUCTION

A pre-condition to effective contract management is an effective contract.

An effective contract is one in which there is a fair and sensible allocation of risk and responsibilities. Of particular importance to principals and contractors alike is the management of time, cost and quality.

The construction field is a fertile area for disputes, a product of the myriad of issues and interests at stake, the amount of money and effort invested in a construction project, the high level of complexity of projects and the climate of inherent risk and uncertainty in which projects are performed.

This paper will examine the traditional models of contract delivery vis-à-vis more recent developments in contract delivery, particularly alliance contracting. Each will be evaluated as to their effectiveness for principals and contractors, with an emphasis on their method of allocation of risk, to determine the best method of contract delivery for particular projects.

2. TRADITIONAL MODELS OF CONTRACT DELIVERY

Traditional models of contract delivery denote a theme of imbalanced risk allocation and concentration on the end dollar. Methods such as 'construct', 'design and construct' and 'project management', generally allocate a great proportion of the project's risks to the designer and contractor. This inevitably creates a dispute-riddled environment, with each party seeking to attribute liability to the other. In this climate, issues such as buildability of designers' designs and the quality of contractors' work were high on the agenda.

2.1 DESIGN AND CONSTRUCT CONTRACTS

2.1.1 *Adequacy of the Design Brief*

Failure on the part of the principal to provide an adequate design brief for the contractor will inevitably result in delays and increased costs. The principal will be required to clarify the design brief, usually by way of variations to the contract works.

Initial design brief deficiencies will have adverse time and cost implications. If changes or clarification to design are effected by way of principal-directed variations, many contracts will provide that the principal is liable for any delays caused by those variations, in terms of dollars and time lost on the

project. The contractor may have prolongation claims against the principal in this regard. Moreover, principals may find that a deficient design brief results in a reduced quality of the end product. In any case, adverse implications for time, cost and/or quality are likely results of a deficient design brief.

These issues should therefore be considered by the principal at the outset, by ensuring an adequate design brief is delivered at first instance and ensuring any time limitations on delivery of variations by the principal, delivery of variation proposals by the contractor and action on variations by the contractor, are complied with.

2.1.2 Risk Allocation

Allocation of design responsibility is an important issue in design and construct contracts. Although design and construct contracts place the responsibility for design and construction of the project in the hands of one player, these contracts have high potential to create new risks for the principal.

Contracts should specify the extent of the responsibility of the principal and the contractor as regards design. Issues to be considered may include:

- the extent of the contractor's duty to inspect and verify any of the principal's consultants' plans prior to commencement of construction; and
- the principal's obligations as regards time and costs arising from a need to rectify design briefs after commencement of construction.

2.1.3 Conclusion

As with all traditional models of contract delivery, the design and construct contract has the benefit of its familiarity, the parties' general understanding of its delivery and administration and well-established contract documentation.

2.2 GUARANTEED MAXIMUM PRICE (GMP) CONTRACTS

The GMP contract is applicable to contracts both in traditional models and in alliance contracting. Its distinguishing feature, to be examined here, is its allocation of a high proportion of risk on the contractor, which would usually be apportioned as between the contractor and the principal on the contractor. Of particular significance is the apportionment of risk as regards time and cost.

As discussed earlier, a construction site is a fertile area for disputes. This is also true of cost fluctuations. In a GMP contract, a contractor's bottom line is subject to a range of external and internal factors, many of which are out of the contractor's control. The contractor is required to accept the risk of increased costs arising due to industrial actions, subcontractors' defaults, environmental conditions, variations and deficiencies in the principal's design brief.

Therefore, the GMP contract's allocation of risk favours the principal and provides the principal with greater certainty at the expense of the contractor. This risk allocation means that GMP contracts are more common in competitive marketplaces. Contractors are often rewarded for the additional risks by higher tender prices.

2.2.1 Conclusions: Traditional Models of Contract Delivery

Often the casualties in traditional delivery models are time, cost and the quality of the works. However, the benefits of traditional contracting methods are clear: they are 'tried and true' methods of contract delivery, in that they have been the subject of judicial review, parties are well-versed in their operation and administration and there is a bank of appropriate documentation available for their effective delivery.

2.3 ALLIANCE CONTRACTING

The concept of alliance or relationship contracting has developed in answer to the problems posed by traditional contracting models. Alliance contracting acknowledges the inherent risks involved in construction and project delivery and provides mechanisms to deal with disputes as they arise. Alliance contracting aims to ensure effective project delivery and resolve any disputes which arise, with a focus on the collaborative relationships between the alliance participants.

Large scale capital works projects are exposed to inherent risks, including political, economic, environmental and industrial factors arising from within the project and externally. Project alliancing has been employed as a means of dealing with an uncertain construction environment in which conventional contractual models may fail to offer the best outcomes for the parties.

Project alliancing is characterised by pro-active collaboration whereby all parties work together to achieve optimum outcome, whilst minimising inefficiencies associated with adversarial conduct. The enhanced ability of alliance participants to work together, embrace risk and uncertainty and deal with these factors in an innovative and collaborative fashion is the key to optimising outcomes for all participants.

Alliance contracting adopts a 'no blame' approach to contracting. On completion, the alliance participants share pain or gain collectively, effectively creating a situation whereby all participants "win" or "lose" at the end of the day. Thus, the risks and benefits associated with the project are shared between the alliance participants.

Furthermore, the alliance agreement usually provides that any failure by alliance participants to perform an obligation to or discharge a duty under the agreement will not give rise to an enforceable obligation at law or in equity, except to the extent that the failure also constitutes 'wilful default'. Alliance agreements will generally define 'wilful default' to mean intentional acts or omissions by alliance participants carried out without regard for the harmful consequences for other alliance participants, but not any acts or omissions performed in good faith, whether negligent or not.

In furtherance of the objectives of trust and dispute avoidance, alliance agreements commonly contain clauses which provide that the parties will not have recourse to arbitration or litigation in the event of a dispute. This emphasises the collective rather than individual accountability which alliance contracting seeks to establish.

The relationship of dependence created by the alliance agreement demonstrates effective risk sharing and illustrates the need for trust between the alliance partners in completing their contractual obligations.

Alliance contracting may be used to deliver a project which has been riddled with disputes. Adopting an alliance contract will assist in getting the project 'back on its feet' by re-distributing risk and responsibilities, motivating the parties to work in an environment where they know they will share the benefits and losses of the project. The parties will be required to undertake a significant change in thought process as to how they fit into the project, under an alliance agreement. A shift to an alliance agreement is also likely to preserve the parties' business relations by shifting from an relationship focussed on apportionment of liability to one where liabilities are shared.

2.3.1 Problems with the Alliancing Contract Model

The new contract structure of an alliance project inevitably has some teething problems. The success of an alliance contract is dependent on a number of factors.

Firstly, the nature of the project will have significant bearing on the success of an alliance contract. An alliance contract is generally best suited to large-scale projects which involve many parties which are required to work together on the project. Its use in smaller-scale projects may prove more difficult to manage in terms of the parties' "gainshare - painshare".

Secondly, as it is a developing area, there does not exist a body of contractual documentation as to alliance contracting and the administration of such contracts. Traditional standards may be used as a starting point, however careful and clever drafting will be required to adapt the alliance agreement to the particular project and alliance partners.

2.4 PROJECT REALIGNMENT AND ALLIANCE CONTRACTING

Project realignment is required where a project is required to be 'resuscitated' - where the project is not meeting required time, cost and/or quality indicators, where the parties are in dispute, or when changed circumstances dictate that there is a need to do a new deal.

Often, the parties will best succeed where the traditional 'hard-money', commercially-driven contract is abandoned in favour of an alliance agreement. An alliance agreement avoids the issue of apportioning blame between the parties, as any pain or gain is shared between the alliance partners, the alliance relationship is inclusive, rather than exclusive of any particular party or interest, and the alliance agreement forbids recourse to litigation in the event of a dispute. The alliance relationship also means that no particular party will be bearing the risk of the continuation of the project, in contrast to the situation under a traditional contract arrangement.

Breaking from the traditional contract to an alliance agreement will re-focus the parties on the end result and provide a new motivation for completion of the project.

2.5 FINDING THE BEST METHOD OF CONTRACT DELIVERY

Parties should take into consideration the advantages and disadvantages of the traditional methods and alliance contracting in determining which style of contract will govern their relationship for the construction of a project.

It should be remembered that traditional methods can be adapted to suit the parties' needs. This maintains the benefit of certainty which attaches to the traditional method, whilst ensuring that the parties' needs are met.

In other circumstances, particularly large-scale developments which involve numerous parties, alliance contracting may be the best method of contract delivery.

Parties should consider the range and levels of risks involved in each delivery method and ensure that their contractual obligations and responsibilities are well documented and understood. Furthermore, parties should attempt to project-specific information, such as design and liability issues, prior to commencement of the project.

In essence, risks should be allocated to the party who can best bear that risk. Whether it is the contractor or principal in any individual circumstance, the risks borne by each party should be realistic from the outset.

3. CASE STUDY

PROJECT ALLIANCE - CONSTRUCTION OF THE NOWRANIE CREEK SECTION, BARKLY HIGHWAY (MOUNT ISA TO CAMOOWEAL), QUEENSLAND, AUSTRALIA.

An example of the successful strategic use of an alliance agreement for major construction works is the Project Alliance Agreement made between the State of Queensland (acting through the Department of Main Roads), Leighton Contractors Pty Ltd and Myuma Pty Ltd (a subsidiary of the Dugalunji Aboriginal Corporation), for the construction of the Nowranie Creek Section of the Barkly Highway (Mount Isa to Camooweal) in north-west Queensland ("the Project").

The Project comprises an upgrade of the Barkly Highway and construction of several new bridges on the highway.

The Project is unique as the land on which the Project is to be constructed is the subject of native title claims, the region has a large indigenous population and is cultural significance to the Indjilandji and Dithanoo peoples. The Alliance Agreement therefore aims to address the significant cultural and environmental issues in the planning, construction and administration of the Project, in addition to the time, cost and quality parameters usually the subject of traditional contracts. The Alliance Agreement requires that the parties develop, implement and maintain policies and procedures relating to the construction of the Project which take into account the cultural and environmental interests.

In planning the Project, the Department of Main Roads consulted with the

local communities and particularly with the Indigenous Traditional Owners (ITO) groups. The Department entered into an agreement with the Dugalunji Aboriginal Corporation, as representative of the Indjilandji and Dithanoo peoples, to enhance the employment and training opportunities for ITO groups from the region and to provide opportunities for ITO groups to tender for the supply of products (particularly locally produced products) and provision of labour and services required for the Project. Myuma Pty Ltd will represent the interests of the ITO groups throughout the duration of the Project.

The alliance therefore addresses not only the commercial drivers for the project, such as the time, cost and quality parameters, but it also makes provision for the inclusion and representation of the indigenous peoples of the region, as well as cultural and employment considerations. This is exemplified by the requirement in the Alliance Agreement that the Department of Main Roads and Leighton act with full liaison and consultation with Myuma. Just as the Department of Main Roads is required under the Alliance Agreement to pay Leighton, Leighton is required to pay Myuma, and Myuma is required to provide labour and services, supply materials and perform a consultative role in the construction of the Project. Furthermore, the Alliance Agreement provides for an environmental management plan, a cultural heritage management plan, community liaison and ITO groups employment management plan.

Given the unique characteristics of the Project, the Alliance Agreement is the most appropriate method for project delivery, not only for the benefits of risk sharing, technical and financial output and savings generally associated with an alliance, but also because the alliance bridges the parallel between the private sector focus on commercial delivery on the one hand, and cultural, environmental and social demands and considerations on the other. The alliance agreement is a practical and legally binding method of bringing the two opposing interest bases together, to achieve set standards and outcomes effectively and efficiently.

PROCUREMENT AND RISK SHARING

Case Study

SUSTAINABILITY AT WILLIAM MCCORMACK PLACE

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ABSTRACT

The paper describes project management processes and tools used to deliver sustainable building initiatives at William McCormack Place in Cairns in Northern Queensland. From project initiation, the property's facilities management team was given responsibility for planning, design and construction.

A fundamental project requirement for this \$17.5 million four-storey commercial office building of 4568 m2 net lettable area was that the building design, fabric and services elements were to be selected with regard to energy efficiency and life cycle costs. The aim was to prove that such a project could deliver strict building environmental and social sustainability targets at no additional capital while remaining economically and commercially viable in operations.

After one year fully occupied and operational external audits showed the office building used 40% less energy than comparable buildings to achieve the highest five-star Australian Building Greenhouse Rating. It also achieved a 4.5 star rated ecologically sustainable office fitout conforming to new Queensland Government's Guidelines.

The project demonstrated that typical Australian commercial office buildings present a range of opportunities for efficiencies that prudent building owners should recognise as they very significantly reduce building outgoings thereby increasing the asset value. William McCormack Place is a practical working model of how to incorporate best practice sustainability without, in any way, compromising quality, cost, time and scope parameters.

Keywords: Sustainable Building, Fitout, Facility Management, William McCormick

1. BACKGROUND

The Queensland Department of Public Works (QQPDW) manages a 821,000m² portfolio of government owned and private sector leased commercial office space in Queensland. Each year, the QPDW office accommodation program provides for construction or refurbishment of over 50,000m² of office fitout. The program's aim is to contribute to the Queensland Government's environmental objectives by providing ecologically sustainable office accommodation according to the Queensland Government (2000) award winning ESD Guidelines.

At Sheridan Street Cairns, the building is a four-storey commercial office building of 4568m² net lettable area owned and managed by the QPDW. Construction was by a private sector manager under a two stage, design and construct contract with a budget of \$17.5M including fitout and public art. Innovative planning and tactical responses were exploited from project initiation.

Rather than the very significant technical innovations, the innovative management leadership had the greatest overall impact on project success. Manley (2003 and 2004) individually characterised innovations as advanced proven effective and simple building, services and fitout technologies. In this project it was the integration of proven advanced technologies to work efficiently as whole building systems that was most technically innovative.

2. INTRODUCTION

The context for the energy savings targeted in this project as reported by Jones et al (2003) found, building sector share of Queensland greenhouse emissions generation (GGE) was 22% in 1999 and residential and commercial operations dominated as shown in Figure 1.

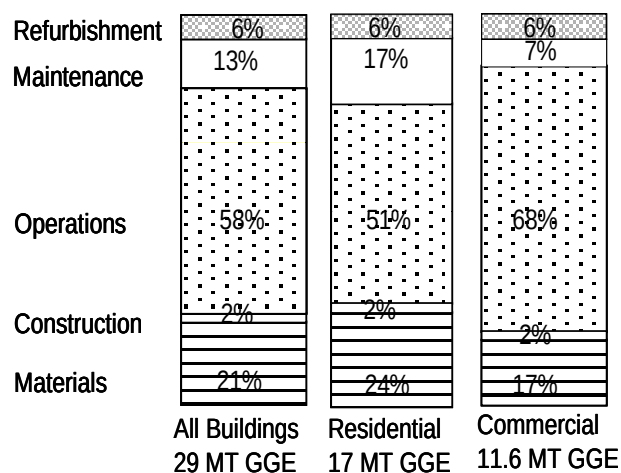


Figure 1 1999 Buildings GGE by Source (MT) & Phase (%)

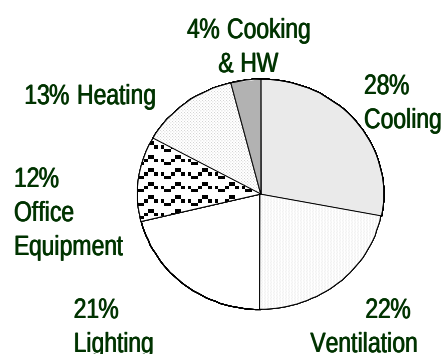


Figure 2 1999 Commercial GGE share (%)

As shown in Figure 2, the same studies estimated Queensland commercial building operational energy end-use shares as 28% cooling, 22% ventilation 21% lighting and 12% equipment.

2.1. PROJECT FOCUS AND GOALS

One aim of the building owner was to prove that an office building could be planned, designed and built to meet strict energy and sustainable fitout targets while remaining economically and commercially viable in a normal commercial market. Project goals included that the project was to be a:

- Four star National Building Greenhouse Rating (NBGR) (SEDA, 2001);
- Four star rated fitout ESD Office Fitout (Queensland Government, 2000)
- Commercial viable building without any Government financial incentives.

Design goals were that the property was to:

- Suit the owner, manager and tenant over the long term building life;
- Be flexible and manageable considering a historically high churn rate;
- Minimise lifecycle environmental, social and economic costs; and
- Employ local businesses to capture and improve their knowledge base.

3. METHODOLOGY

To ensure integrated planning from investment to operational management, the building owner gave overarching project control at project initiation to:

- A team with the property's future management responsibility;
- Ensure decisions retained long-term perspectives for the property's operational and functional performance; and
- Maximise functionality and manageability and deliver on time and budget.

The Building Owner's Brief sought:

- Economic consideration for local firms, material and apprentices;
- A project brief specifying key environmental performance and use targets;
- More sustainable economic, environmental and social outcomes;
- Integrated teamwork under FM project leaders with industry experience;

The Project Planning Brief called for building:

- Design, fabric and services with reduced energy and lifecycle costs;
- Compliance with a four-star ABGR rating in operations; and
- Compliance to a four-star ESD Office Fitout rating in operations.

The Project Design Brief called for delivery of:

- Passive design elements to conserve energy in-use over the building life;
- A safe, accessible and pleasant work-place with landscaped curtilages;
- An open streetscape, low roof-line, and shade trees in a tranquil setting;
- A bright coloured 'tropical' look incorporated into the building exterior.
- Culturally sensitive large-scale artwork and reflective space outdoors.
- Artwork developing built, natural, social and cultural linkages
- Indoor aspects making a pleasant place for occupants' work;

The Interior Design Brief called for compliance with Queensland Government Ecologically Sustainable Office Fitout Guidelines. These provide designers, contractors, tenants and occupants with strategic advice required to ensure:

- A healthier ecologically sustainable fitout;
- Reduced risks associated with hazards; and

- Liaison with industry to improve sustainable trade and employment.

The Building Services Brief required selection of active systems considering:

- Year-round air-conditioning in a hot, humid climate; and
- Simplicity, reliability and redundancy levels to compensate for occasional difficulty in obtaining spare parts in the semi-remote location.

Major project participants were

- Barclay Mowlem Construction Ltd as Managing Contractor;
- Design team lead by Cox Rayner and Cairns-based CA Architects;
- ARUP Structural/Civil/Fire Engineers;
- MGF Consultants (NQ) P/L Mechanical/ Electrical Engineers; and
- QPDW Project Services Office Interiors Design and Fitout.

4. RESULTS AND DISCUSSION

Results of project milestones, major achievements and key innovations are described initially followed by environmental outcomes in planning, design, construction, fitout, operations and disposal phases before economic and social outcomes.

4.1. MILESTONES

All project milestones were achieved on time and on budget including:

- Project approval and appointment of managing contractor in 2001;
- Completion of the design development stage in May 2001;
- Commencement of site works in May 2001;
- A fitout design freeze implemented in September 2001
- Practical completion in June 2002 and fully occupied July 2002; and
- ABGR Energy Audit August 2003 found it exceeded a four-star rating.

4.2. MAJOR ACHIEVEMENTS

William McCormack Place became the first full-scale Australian commercial office building officially awarded a five-star energy rating. Indeed its performance exceeded that rating by 15% to set a new benchmark. Success in this project confirmed that:

- Clear objectives and thorough design reduced risks to accepted levels;
- Savings in system design and construction balanced any added costs;
- Regional firms were key technology leaders and knowledge providers.

Manley (2003) found that the innovative air-conditioning saved 37% energy costs and 61% in capital and maintenance costs compared to conventional systems. Passive building design for daylighting, fitout design for reliance on natural daylight in layout and high-efficiency luminaires acted together to significantly reduce lighting energy fuel consumption.

Tenants also selected efficient office equipment to reduce energy consumption. Improved performance, largely achieved without increased costs, was mostly due to combining proven advanced compared to typically technology.

Quantity survey reports show the cost of building environmental enhancements was no greater than a comparable ordinary commercial building. Along with attaining a new benchmark for reduced greenhouse gas pollution it set another

benchmark for a commercially, community and environmentally friendly fitout for future commercial office buildings. Many systems improvements incorporated throughout acted together to achieve these benchmarks.

4.3. KEY INNOVATIONS

Some improvements relied on state-of-art technology while others exploited simple lessons learned in owning and operating QPDW's office portfolio. The innovative project delivery focus on integrating whole building systems successfully demonstrated achievement of new sustainability benchmarks without compromising quality, cost, time or scope. The innovative plant room depicted in Figure 3 houses the highly energy efficient, simple, reliable and highly redundant air-conditioning system with:

- A pre-conditioning unit with thermal wheel recovering 61% exhaust heat;
- Plant with rotary screw chillers on duty/standby each carrying 105% load;
- Pumps/Fans variable speed drives and zoned variable air volume boxes
- 15,000l chilled water storage tank to eliminate long period of low load and
- Building management system to control/monitor after hours operation

To improve performance in-use and maintenance proven technologies were innovatively integrated as whole building systems including:

- Extended eaves for shade and maintenance staff access without lifts;
- High performance glass and wall insulation to reduce solar heat gains;
- Recyclable cut-pile carpet tiles to reduce life cost 21% over loop-pile tiles;
- Flexible office space: through strategic columns placement; and
- Zone lighting control, occupancy sensing to limit conditioned air delivery.

An innovative response ensures ease of safe access to all parts of the building exterior with walkways incorporated into the sun shading, depicted in Figure 4, give access to all parts of the façade for cleaning and maintenance without the use of lifting machinery.



Figure 3. The Plant Room



Figure 4 Shades For Maintenance

4.4. ENVIRONMENTAL OUTCOMES IN PLANNING

Thorough planning, open and honest business relationships between project stakeholders and good communication fostered the climate of change needed to incorporate environmental sustainability into all aspects of the project's development. Sustainability was not just an add on but the essential foundation for the project.

The planning and consultation phase had the greatest long-term influence to reduce the property's environmental impact as decisions made during this

critical period affect the way buildings perform over its lifetime. Strategies applied in this phase ensured that vital life cycle environmental issues were addressed early enough to be successful and cost effective. Particular attention was paid to the passive building design, active air conditioning, electrical systems, interior daylighting and layout for facility flexibility, adaptability and simplicity.

Project planning incorporated features to minimise lifecycle costs, environmental impact and enhance manageability throughout construction, use, maintenance and eventual demolition. This was achieved through use of long lasting, low maintenance and recyclable materials so that with correct timely maintenance will last as long as possible. Examples of this approach include use of:

- Colorbond♥ steel cladding and
- Pre-finished aluminium sheeting façade;
- Colour-render rather than painted concrete and minimal applied finishes;
- Low maintenance materials such as stainless steel and aluminium;
- Low maintenance floor/wall finishes to minimise use of chemical cleaning;

4.5. ENVIRONMENTAL OUTCOMES FROM DESIGN

Design for clean lines and visual amenity ensured it did not impose on nearby government and commercial premises as shown in Figures 5 and 6.



Figure 5. Clean lines



Figure 6. View of the Environs

A low structure houses the top of the cooling towers as the only protrusion above the roofline and the lift motor rooms were located on ground floor and other plant rooms on level one. Passive elements incorporated in the design include that for the:

- Building shape and orientation to minimise façade exposure to direct sun;
- Façade material and glazing to minimise heat transmission to the interior;
- Extended roofline incorporating wide eaves to shade the façade;
- Window shade for 100% all seasons without impeding interior sight-lines;
- Efficient roof insulation and air-tightness to
 - Minimise untreated outside air influx and
 - Control of waste air egress to maximise heat recovery potential.

As depicted in Figure 7, a perspective across the garden, the importance given in design to bring the natural and built environment together is evident. Public area artwork was designed on natural environmental and community themes. Major pieces commissioned after expressions of interest from artists include:

- Hew Chee Fong and Lorretta Noonan's Water and Earth, sculptures in the forecourt as in figure 8, an apparently wet dry waterfall in granite; and
- Claudine Marzik's series of sculptural "Weather Report" panels in the forecourt and garden paths representing Cairns' tropical rainstorms.
- Wik Elder, Arthur Pambegan Jnr's foyer centrepiece as pictured in Figure 9.

These exterior artworks link natural and built environments while the entry foyer artwork brilliantly articulates the local indigenous people's ongoing spiritual connection to nature and the land.



Figure 7. View over a Forecourt



Figure 8. Carved Granite Waterfall

4.6. ENVIRONMENTAL OUTCOMES OF CONSTRUCTION

As a direct result of the concise contractual requirements set out in the project brief, site environmental issues that arose were minimal and were dealt with swiftly. Thorough construction planning and design also minimised rework and wastage.

The imposition of the fitout design freeze nine months before practical completion was effective as it allowed the seamless integration of the 'hard fitout' into the construction program without the need to demolish and waste any already completed work. Fitout construction incorporated seamlessly into the shell construction and was completed shortly after the building itself. The partition, air conditioning duct work, and electrical and communication cabling hard-fitout was carried out by the managing contractor as a main contract variation to ensure it was incorporated in original construction and to avoid wastage due to removal or changes to work already completed.

4.7. ENVIRONMENTAL OUTCOMES IN FITOUT

The fitout is by QPDW's Office Interiors designers who engaged in consultation with EPA and staff to facilitate successful outcomes with features including:

- Open plan workstations near windows for daylight as Figure 10 shows;
- Offices and meeting rooms to the centre of the floor as Figure 11 shows;
- A highly flexible and open workspace with minimal built zones; and
- Demountable partitions and furniture of modular design.

The design features reducing environmental impacts include:

- Doors of uniform size to allow for future re-use;
- Assembly with mechanical connections to promote reuse;
- Very low off-gassing materials used throughout;
- Wide use of recycled materials in the furniture;

- Mobile units, partition screens and shelves of recycled waste polymers;
- Screen fabric upholstery from recycled plastic bottles;
- Timber products from sustainably managed sources.
- Carpet selected for environmental/ economic life cost benefits including:
 - Installation using water based solvents and
 - Low off-gassing of VOCs from the carpet or solvents;



Figure 9. Wik Elder's artwork.



Figure 10. Window Workstations

4.8. ENVIRONMENTAL OUTCOMES IN OPERATION

The building is a low and unobtrusive structure set back from the street with complimentary landscaping, seating, public art works and local native planting providing a visually attractive and inviting presence appealing to staff and visitors. Indeed tenant surveys show that staff generally feel good about working there and EPA staff feel they 'practise what they preach' at work.

Environmental and economic benefits derived from a building's energy efficiency are both immediate and ongoing throughout its life. Passive design elements maximise daylight as shown in Figure 10, as well as minimising thermal penetration into the air-conditioned space. In turn active systems maximise heat recovery to reduce the air conditioning heat load.

These are extremely cost effective ways to reduce energy use over the building life. In typical building active systems the energy contained in the already conditioned waste air is simply lost as the air is allowed to leak from the building. However, in this building the waste air exhaust is controlled to facilitate recovery of a large percentage of the otherwise lost energy it contains.

As previously noted a common pre-conditioning unit provides all the outside air into the building. Used air is also exhausted through this unit where a thermal wheel recovers energy from the conditioned exhaust air to cool/dehumidify incoming outside air before it flows to ventilate/condition the main chiller plant room. This flow path effectively 'wrings' the last useful energy from the air before it finally leaves the building. The advantages of this system are:

- Humidity removed from supply air without inefficient reheat systems.
- 61% energy recovered from otherwise lost heat in waste air and then this

Normalised energy consumption is 109kWh/m²/annum and emissions 108kg CO₂/m²/annum. The project brief called for a minimum of four stars having a normalised energy consumption of 179kWh/m²/annum, normalised emissions of 180kg CO₂/m²/annum and total actual emissions of 1,074,175kg CO₂/annum. The results show a reduction over the original consumption target of 40% and annual saving of 317t greenhouse gas emissions.

- Exhaust air to ventilate and cool chiller plant room without added fans.



Figure 11 A Plan of the Interior Layout

4.9. ENVIRONMENTAL OUTCOMES IN DISPOSAL

Upon eventual demolition of the building the bulk of the materials used in its construction will be recyclable. Construction as well as office recycling was facilitated via provision of space for bins and recycling service contractors. The generic design of the building facilitates future adaptive reuse as office space or for some other use. Even stripping back to its structural shell will involve minimal waste as most façade and internal components are recyclable.

The fitout with modular workstation components of recycled materials and mechanical fixings rather than glues, facilitates disassembly and adaptive reuse. The carpet tiles selected for environmental and economic lifecycle cost benefits can be 'remanufactured' to give an extended life and benefits include:

- 15 year 'first life' prior to lifting, minimal remanufacturing and re-laying;
- Backing recycling of the carpet is finally replaced;
- 30 year useful life, 4 times broadloom that is discarded to land fill;
- Sections more easily replaceable than with broadloom; and
- Replacement runs can be supplied so spares are minimised.

These concepts are being used in the 33 Charlotte Street fitout, a 15,000m² new development for the QPDW in the Brisbane CBD.

5. ECONOMIC OUTCOMES OVER PROJECT LIFE CYCLE

The business case described the project economic objectives as a commercial venture. Inclusion of environmental and sustainability initiatives in property development did not increase project economic cost, reduced operating costs and contributed to improvement in the market rental position.

The project also aimed to provide short and long term economic benefits for the Cairns community. The Queensland Government's requirement to employ local people under its Local Industry Policy meant that maximum use was made of local consultants, contractors and suppliers for the project. This policy had a major effect on the Cairns economic environment.

During design and construction, the project generated 12,550 person weeks of work. Two new full time positions were created for direct building operation. In addition many local contractors and suppliers are employed in the day-to-day

operation and maintenance of the property adding to the 'economic mass' of the Cairns region.

The success of the project ESD initiatives and its resultant high profile increased exposure and business opportunities for many of those involved. In particular, Cairns firm MGF Consulting gained industry-wide exposure as the designer of the mechanical services and electrical systems that contribute greatly to the building's active systems energy efficiency.

QPDW has developed strategies to communicate the success of this project to interest groups in the construction and facilities management industries including promotion of the project with various industry groups; making it available for case studies; and facilitating the flow of project information and data to students and others through Internet publications. It is a practical working model of how environmental sustainability can be addressed without compromising quality, cost, time and scope parameters.

6. SOCIAL OUTCOMES

It was important that William McCormack Place contributed to the social environment of the community of Cairns as much as it achieved environmental and economic outcomes. Tenants actively participated in the design development process that valued the contribution and worth of individuals and connections between tenant organisations and the local community.

The project has delivered a safe, accessible, inviting place connecting with those living and working nearby, that reflects local area cultural and heritage values. Low-targeted external lighting, prominent entry and limited 'blind' corners contribute to a safe secure place for staff and visitors, day and night.

Pedestrian and cycling access from all directions is incorporated into the building that is designed to be fully accessible by people with disabilities. Occupants and visitors can recognise visible environmental aspects of a building made to ensure it is a pleasant place to work as well as to visit as it has features incorporated including:

- Seating near shade trees in a tranquil space for occupants and visitors
- Open streetscape and artworks for a pleasant soft visual impact and
- Cycle parking with change room facilities for staff cycling/walking to work;

Public art works feature prominently and to reflect the intrinsic diversity of the local community works of local indigenous cultures are integral in the building to celebrate reconciliation and difference. The artworks also promote concepts of community engagement and shared ownership. Some aspects of the project have been far-reaching and found to be contributing to the social capital of the area in unforeseen ways. Wik Elder Arthur Pambegan Jnr produced a large-scale version of his traditional work that encapsulates his people's story of the flying fox legend. While many of his pieces are displayed in galleries in larger southern cities now locals can see his work close-by in Cairns.

7. EXTERNAL VALIDATION OF PROJECT OUTCOMES

Compared to a 3½ star 'average', the building consumes 45% less energy, saves 419t GGE and costs \$68K less in a year to run. It sets benchmarks for new buildings and demonstrates how to go about improving energy efficiency. This project provided QPDW with an ideal opportunity to develop a building that realised the State Government's objectives for sustainable office accommodation. While William McCormack Place is a practical example of

ecologically sustainable design with best practice environmental outcomes it is also achieved best practice economic and social outcomes planned and achieved at every lifecycle phase and for the building's lifetime.

An official energy audit in August 2003 resulted in it being the first new commercial office building in Australia awarded the highest rating, a five star energy rating in the Australian Building Greenhouse Rating Scheme. It was also the joint winner of the 2004 Facility Managers Association of Australia Sustainable Energy Authority Environmental Excellence Award.

8. CONCLUSIONS

The key project goal achieved was to prove that an office building could be constructed to meet strict environmental targets while remaining economically and commercially viable. The paper confirms that the project demonstrates that inclusion of environmental and sustainability initiatives in property development need not increase project economic cost, can reduce operating costs and contribute to improvement in the market rental position. William McCormack Place surpassed initial targets for energy consumption.

The success of this project was largely due to the owner engaging a strategic approach to the project's development and providing the means to implement sustainable solutions and strategies. From project initiation, the team responsible for the day-to-day property management, showed how facility management resolves lifecycle environmental, social and economic issues.

Those involved in the project are taking the knowledge and experience back to their respective organisations in a practical way that will provide the basis for ongoing improvements to practices and processes. Ongoing monitoring, analysis and reporting of the outcomes will contribute significantly to the knowledge base on sustainable development and improvements in similar developments in the future. Sustainability lessons from this project are that

- System savings balanced out cost of improved design and construction;
- Sound objectives and design process reduced risk for builder and client;
- Early facility manager involvement lead to optimal building performance;
- Regional firms can be leaders in technology as well as local knowledge;
- Clients managing risk can lead industry in showing benefits of innovation.

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PROCUREMENT AND RISK SHARING

Case Study

A CONCEPTUAL FRAMEWORK TO INVESTIGATE THE PERFORMANCE OF FINANCIAL INCENTIVE MECHANISMS IN CONSTRUCTION PROJECTS.

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ABSTRACT

Implementation of financial incentive mechanisms in the contractual arrangements of a construction project can impact significantly on the motivation of contractors and hence project performance. Positive incentives (as a component of the project delivery strategy) aim to motivate contractors to align their goals with those of the client, via a financial reward.

These incentive mechanisms take many forms in construction contracts, including: profit sharing in cost plus incentive contracts, bonus performance provisions attached to various lump sum and cost reimbursable contracts, and multiple financial incentive mixes.

The optimisation of financial incentive mechanisms depends greatly on how they are designed in the context of specific project environments. For example, if the client/contractor relationship is poor, the contractor may perceive the financial incentive as calculative and hostile, and therefore will be less committed to the client's goals than the incentives intended.

In order to establish a starting point for further research into this topic area, this paper outlines the results of an international review of the literature on financial incentive contract types and the factors that influence the motivation of contract agents under these arrangements. The paper then goes on to propose an analytical framework that is to be used in the evaluation of optimal financial incentive mechanisms in construction projects, drawing on economic and psychological motivational theories. The findings of this review provide a sound basis for the empirical work to follow in a PhD project investigating the optimisation of financial incentive mechanisms in the Australian commercial building industry.

Keywords: financial incentives, construction, contracts, motivation, effort.

INTRODUCTION

Use of financial incentive mechanisms within construction contracts is common. They aim to reduce contract cost, minimise contract duration; and achieve performance standards in areas such as quality, program efficiency and productivity, safety and innovation. The optimal performance of a financial incentive mechanism is determined by its ability to increase and direct the contractor's effort to achieve above minimum standard levels, based on the client's project goals. It is argued in this paper that although incentives are commonly employed, they often do not operate effectively due to lack of information about the factors that shape their performance (Bresnen & Marshall, 2000). The value of such incentives is not questioned here, however, there is a need for further definition and understanding of the motivational environment when designing and implementing appropriate mechanisms.

Against this background a large-scale research project is being undertaken to evaluate the performance of financial incentive mechanisms in Australian commercial building projects and explore the contextual attributes that influence motivation in various project configurations. This paper is the result of the first stage of this project, involving a comprehensive literature review and development of a conceptual framework that will be used to guide the case study fieldwork. This paper proposes a set of eight generic motivational variables, established from the integration of psychological and economic motivational theory principles that can be used to guide the performance evaluation of financial incentive contracts. The framework can also be employed to reveal the specific contextual attributes that influence the optimal implementation of such incentives in construction projects.

FINANCIAL INCENTIVE DESIGN IN CONSTRUCTION CONTRACTS

CONTRACT STRATEGY AND FINANCIAL INCENTIVES

The standard lump sum and cost reimbursable contract types have significant problems in promoting motivation to attain client specified goals that are above 'business as usual' levels. Despite incentive for cost-reduction efforts, the restrictive nature of the price in lump sum contracts increases the contractor's risks and thus increases their price contingency. This can lead to compromises in other areas of the project such as quality (Howard *et al.*, 1997). On the other hand, standard cost reimbursable contracts fail to motivate the contractor to minimise project costs and achieve other project goals above minimum standards (Berends, 2000). Financial incentive mechanisms built into standard contract conditions aim to alleviate these problems and direct and sustain contractor motivation towards achieving goals above 'business as usual' standards.

Many contractual arrangements between construction clients and contractors are confrontational, reflecting considerable mistrust and leading to increases in contractors' premiums to avert significant risk levels (Zaghloul and Hartman, 2002). According to

Turner and Simister (2001), a significant issue that must be considered when formulating an appropriate contract strategy is achieving goal alignment between the client and contractor. Improved use of contracting options such as incentive mechanisms can balance the risk allocation between project parties and reward goal alignment.

HM Treasury's (UK) Central Unit on Procurements (1991) devised a set of benefits that can be achieved through the incentivisation of a construction contract. These benefits include lower cost through the appropriate allocation of risk and greater price stability; timely delivery of service without compromising quality of workmanship; enhanced achievement of desired outcomes; and improved management, control and monitoring of contract deliverables.

The primary aim of financial incentives is to "simply take advantage of a contractor's general objective to maximise their profits by giving them the opportunity to earn a greater profit if they perform the contract efficiently" (Bower *et al.*, 2002, 43). This can be achieved when the contractor shares in the client's success. Financial incentive mechanisms can be applied to either fixed price or cost reimbursable contract variations, depending on the incentives structure.

In cost plus incentive contracts, the client's target cost is introduced into a reimbursable contract, and acts as the basis for the incentive mechanism. A cost under- or over-run is split between the contractor and client in predetermined portions (Broome and Perry, 2002). The contractor and client work together to minimise actual costs— the contractor is motivated to maximise their profit margin above their specified fee, and the client is motivated to minimise the total cost paid out (Broome and Perry, 2002). Thus, the contractor is motivated to take a share of the benefits of reduced project costs.

The second primary type of incentive mechanism used in construction contracts is the bonus/penalty performance incentive. These can be used in fixed price and cost plus contract types. The main purpose of bonus performance incentives is to motivate the contract agent with a financial bonus that is additional to their prescribed fee for meeting or exceeding minimum acceptable levels of performance (Washington, 1997). This award is based upon evaluations undertaken during and/or after the project to determine the amount of reward to be applied (Washington, 1997).

'Bonus' financial incentives can be used to motivate the contractor in many areas of the project other than cost, which is primarily managed in the cost plus incentive contract mechanism. Important to the success of bonus incentives are specific, mutually agreed and measurable performance targets (HM Treasury, 1991). However, such targets can be time consuming and difficult to apply due to the potentially subjective nature of assessment (Washington, 1997). 'Bonus' incentives include schedule incentives and technical incentives, which can include operation, non-disturbance, safety, quality and design integrity.

Schedule bonus incentives are being used more often in construction contracts, offering a bonus to the contractor for completion earlier than the target dates. Schedule performance incentives are usually based on a day unit rate of measurement, such as an predetermined amount paid for each day of early completion, and are very closely linked to project costs, since schedule delays usually increase costs (Arditi and Yasamis,

1998). Therefore, schedule incentives should be negotiated concurrently with cost incentives, as incentives encouraging early completion will reduce construction costs.

Technical bonus incentives may also be applied. These pertain to:

- Operation – A bonus incentive for efficient operation, based on the premise that improved operational performance would increase the chances for project success. Operation rewards can include site and project management, subcontractor management, quality and timeliness of reporting; cooperation and problem solving skills (Lahdenpera and Koppinen, 2003).
- Non-Disturbance – A bonus incentive for minimising the disturbance caused by the project. This may include minimising the disturbance to clients, third parties, the environment or existing buildings. Assessment criteria can be subjective and may include the number of interruptions to operations; noise levels; the use of surrounding spaces during construction; external impact of traffic (Lahdenpera and Koppinen, 2003).
- Safety – A bonus to minimise the risk of accidents on the construction site, as the direct and indirect cost of accidents to the contractor and client can be major (Lahdenpera and Koppinen, 2003).
- Quality – A quality performance bonus works on the premise that contractors are offered additional profit if they are able to achieve predetermined performance levels (Bower *et al.*, 2002). When assessing product quality, standardised systems should be used, and should be applied selectively to the most important aspects of the work (Lahdenpera and Koppinen, 2003). However, a major problem with quality assessment is that it is subjective and can be difficult to measure.

Quality performance measurement tools have been developed by public clients with a high level of repeat construction, such as those used by Singapore's Construction Quality Assessment System (CONQAS) and Hong Kong's Performance Assessment Scoring System (PASS) for public housing (see Tam *et al.*, 2000). Criteria may include quality of workmanship, flaws and defects; functioning of design and implementation and amount of rework (Lahdenpera and Koppinen, 2003). The aim of the bonus is to reward the contractor for outstanding quality, and not to penalise them for work that is less than outstanding, yet still satisfactory. Important to the success of the bonus incentive is that the definitions of performance, levels of the bonus, and units of measurement are agreed at the beginning of a project (Washington, 1997).

- Design Integrity – Bonus incentives can be provided for maintaining design integrity on a project, and are especially suited when major changes are to be made to the design throughout the project (eg. Hampson *et al.*, 2001). Design integrity means the honourable representation of the original design intentions.

A major argument outlined in the construction literature is the combined use of multiple financial incentive mechanisms, to counteract any imbalance in the contractor's

priorities, and to attain all incentive goals (eg. Arditi and Yasamis, 1998; Lahdenpera and Koppinen, 2003). For example, if the incentive contract is purely focused on motivating the contractor to meet objectives within a fixed or target price, this may lead to poor performance against the client's other goals, such as quality.

FINANCIAL INCENTIVES AND THE PROJECT ENVIRONMENT

The optimisation of a financial incentive mechanism relates to its ability to motivate a contract agent to increase and direct their effort towards attaining project goals that are above minimum standards.

It has been argued that incentive mechanism motivation is influenced by its integration with the construction project environment (Bresnen and Marshall, 2000). Thus, the context in which the incentive is implemented directly influences its effectiveness. For example, if incentives are implemented in a project relationship that is plagued by underlying suspicions, the incentives are unlikely to induce a deep level of motivation and commitment, and could be seen as exploitation (a psychological response), causing their effectiveness to suffer significantly.

The construction management literature has argued the importance of a project environment that fosters cooperation and trust (e.g. Walker *et al.*, 2003). Traditional procurement methods, characterised by inappropriate risk allocation between project participants and the failure to develop a cooperative relationship which aligns participants' goals, have discouraged innovation and resulted in poor project performance (Kumaraswamy and Dulaimi, 2001).

The use of incentive contracts in 'relationship-based' environments such as under partnering or alliancing which are open in their dealings with risk, reward and project goals, can improve their chances of success. Relationship-based procurement attempts to achieve project outcomes that are acceptable to all parties involved. These methods have addressed the adversarial culture of traditional construction procurement, replacing it with strategies aimed at fostering cooperation and trust (Bennett and Jayes, 1995; Kadefors, 2003; Cheung *et al.*, 2003).

INDIVIDUAL AND ORGANISATIONAL FINANCIAL INCENTIVES

The level at which the financial incentive is administered (i.e. individual or group) influences the level of effort and output performance and should be considered when designing optimal solutions. Goals sought by individuals and goals sought by an organisation may not always be closely correlated (Bresnen and Marshall, 2000). Therefore, despite consensus within a project team on how it responds to an incentive, there may not always be a direct relationship between the organisational and individual response, which can lead to unachieved outcomes. Financial incentives should be applied to individuals and organisations to ensure that the motivational effects are harnessed at all levels. However, this may be dependent on the characteristics of the team's outputs.

Client-driven incentives for individuals and/or subcontractors 'on the ground' in construction projects have been limited. Bresnen and Marshall (2000) found that project staff had very little direct connection with project incentives, rewards and appraisal systems. In the past, decision-makers in construction industries have presumed that individual reward systems are unnecessary, which is in contrast to the attitudes of other industrial sectors in promoting motivation at all organisational levels (Bresnen and Marshall, 2000).

An example of the success in 'driving down' organisational financial incentives was the US Air Force's Peace Shield Project. The Hughes Aircraft company was awarded the ground/air defence systems contract, which was based on a mixed cost plus incentive/fixed price incentive contract, with cost (profit sharing arrangement) and schedule 'bonus' incentives built in (Kausal, 1996). Due to the scheduling pressures of the contract, Hughes decided to set aside 20% of the contract's incentives for the workers and subcontractors, which would then be distributed pro rata down the supply chain. The results for the client were significant, including a final product of extremely high quality, which was delivered more than six months ahead of schedule, and below cost. This success was closely attributed to the distribution of financial incentives down to the individual workers (Kausal, 1996). Incentives need to be tactical and strategic to motivate individual workers, and may include short-term incentives to meet interim milestones, and long-term completion bonuses.

In summary, there are many powerful financial incentive options available to a client to motivate the contractor to achieve goals above 'business as usual' standards and alleviate the motivational problems that are encountered with standard contract types. However, there is inadequate guidance for clients on selecting and implementing optimal arrangements. The next section discusses the motivational literature, which provides the basis for appropriate design of financial incentive mechanisms.

MOTIVATIONAL THEORY AND FINANCIAL INCENTIVES

It has been established in the construction management literature that financial incentive mechanisms can promote motivation and commitment to clients' goals. It is argued that their ability to motivate is founded in the principles of economic and psychological motivational theories. This section outlines the psychological and economic streams of motivational theory, as the key contributors to our understanding of motivation. It then discusses current efforts to integrate these theories.

Maehr and Braskamp (1986) define motivation as a process where an individual or group uses resources such as their time, talent and energy, and allocates them as they see fit. If motivation is a representation of effort, incentives aim to energise, focus and sustain motivation, leading to increased effort and enhanced direction of effort.

Motivation indirectly influences performance. Mullins (1996) argues that ability and motivation determine performance. Also, performance is influenced by external factors such as market fluctuations. These factors are referred to as 'noise' elements in the organisational management literature (eg. Moers, 2000(b)). Combining these ideas,

contract agent performance is determined by ability, motivation (effort) and external factors.

CONTRIBUTIONS FROM PSYCHOLOGICAL RESEARCH

The motivational effect of incentive mechanisms on individuals and semi autonomous groups in the psychological literature is based on the cognitive 'process' motivational theories. Prominent process theories include expectancy theory, equity theory, goal setting theory and attitude theory.

Expectancy theory (Vroom, 1964) is based on the principle that contract agents will adapt their behaviour to achieve a desired outcome and will select the behavioural option with the greatest motivational force. Expectancy theory states that when an individual determines the motivational force (MF) of the behavioural option, they consider three perceptions. These perceptions are Expectancy (E), Instrumentality (I) and Valence (V).

$$MF = E \times I \times V$$

If any of the perceptions equal zero, then the whole equation equals zero because the motivation force is the product of all three perceptions (Vroom, 1964). '*Expectancy*' is the perceived probability that one's effort will attain desired performance goals. '*Instrumentality*' is the perceived probability that, if performance goals are met, the reward will be received. '*Valence*' is the perception of relative attractiveness or value an individual places on the desired outcome or reward. This perception depends on the individual's values, goals, needs, and preferences.

The basis of equity theory, originally developed by Adams (1963), is that individuals/groups are motivated by their need for fair treatment and will develop comparisons between one another in determining what is fair, just and reasonable. For incentive systems, the valence of the reward is determined by how fairly inputs are balanced against outcomes (e.g. money), and how this compares to the inputs/outcomes of others. If the input/outcome balance is not equal, it will lead to a loss of motivation, resulting in a potential loss of productivity.

Attitude theory states that an individual's motivation will depend on their attitudes (or their perceived beliefs) towards their environment (Ajzen and Fishbein, 2000). In a work environment, an individual who has favourable attitudes towards their work and their organisational setting will be more highly motivated to perform (Katzell and Thompson, 1990). Major work-related attitudes include job involvement (the importance of the job to the employee) and job satisfaction. Beliefs and values are major elements of an individual's self-concept (Katzell and Thompson, 1990). The principles of this theory suggest that an agent's motivation is partly influenced by their belief system and intrinsic job satisfaction.

Goal setting theory argues that goal commitment is a central determinant of motivation (Locke and Latham, 1984). For an individual or group to be committed to set goals, the goals must be challenging but realistic, clearly understood and meaningful. The theory

also states that for goals to promote effort, timely and accurate feedback is required at appropriate intervals. Feedback will inform an individual that progressive goals have been attained, thus maintaining effort levels (Locke and Latham, 1990). Under certain conditions, specific but difficult goals can lead to higher levels of motivation than vague or easy goals.

A major conclusion from psychological theories of motivation is that it is very important to understand the perceived limits of financial incentives to motivate groups and individuals and to be aware that financial incentives may only reinforce calculative trust, through financial gain. The use of other intrinsic motivational drivers, such as tools to foster close inter-personal relationships and cooperation between principal/agents can complement financial rewards, leading to increased levels of motivation and individual/team performance.

CONTRIBUTIONS FROM ECONOMIC RESEARCH

From an economic perspective, incentives are founded in principal-agent theory, which is characterised by a principal (employer or client) who hires a contract agent (employee or contractor) to undertake actions on behalf of the principal (Jensen and Meckling, 1976). There are three assumptions in principal-agent theory; the agent is self-interested, the agent is risk-averse, and the agent possesses knowledge and information that is not available to the principal. These three assumptions lead to what principal-agent theorists call 'moral hazard'.

Agent self-interest is based on the assumption that agents only do what they perceive to be in their interest, and that they may be immoral in their undertaking to fulfil their personal gain (Howard *et al.*, 1997). Fehr and Falk (2002), argue that this is a narrow and empirically questionable view of human motivation.

The second assumption of principal-agent theory is that agents are risk-averse. Therefore, the agent will expect additional financial compensation if they are to retain the principal's risk. The agent will try to minimise risk and maximise compensation. It is also assumed that if compensation does not equal the level of risk retained by the agent, they will attempt to balance this inequity, to the potential detriment of performance (Jensen and Meckling, 1976). For example, if a contractor is allocated the full risk of cost overruns in a construction project, they will attempt to minimise, or avoid if possible, these risks, to the potential detriment of other project attributes such as quality and workmanship.

The final assumption of principal-agent theory is that irregularity of information can occur in the principal-agent relationship. The agent possesses knowledge and information that is not possessed by the principal. Therefore, the principal has limited information on their agent's actions, and the level of their effort. This theory argues that under conditions of uncertainty and incomplete information (a characteristic of all contracts), problems arise from the agent's self-interested behaviour.

Reciprocity theory and the acknowledgement of 'social preferences' in the economic literature have been used to challenge the 'self-interest' principle of principal-agent

theory (Fehr and Falk, 2002). Reciprocity theory states that agents prefer a condition of fairness in the exchange relationship with the principal. Depending on the behaviour of the principal, the agent perceives the value of the material incentive as positive or negative (Fehr and Falk, 2002). If the agent views the incentive as 'calculative' or hostile, their commitment to the principal's goals may be affected.

Other motivational theories do not completely discount principal-agent theory principles as they are, to a degree, prevalent within all principal-agent transactions. However, even the founders of principal-agent theory now acknowledge the importance of considering the psychological influences on behaviour when designing incentive contracts (Jensen, 1994).

INTEGRATION OF MOTIVATIONAL THEORY PRINCIPALS

Recently, attempts have been made to cross-pollinate the theoretical concepts to fully determine the effect of incentive systems on effort in the experimental organisation management literature. For example, Van Herpen *et al.* (2002) used principal-agent theory and cognitive evaluation theories to study the motivational effect of a compensation system in a Dutch manufacturing company. Fehr & Falk (2002) combined principal-agent theory and intrinsic motivation principles to identify the non-financial motives in the economic environment, such as the desire to reciprocate.

Kunz & Pfaff (2002) identified an urgent need to incorporate intrinsic motivational principles into principal-agent theory. Although they acknowledged the difficulties in defining and measuring the effect of intrinsic motivation on financial reward, their investigation argued that financial rewards do impact on intrinsic motivation and voluntary cooperation.

To fully explore the role that financial incentives play in motivating individuals and organisations, it is clear that both psychological and economic principles should be taken into consideration. As discussed, there have been moves in this direction in recent empirical studies in organisation management research (e.g. Van Herpen *et al.*, 2002). However, such efforts are in early stages of development, and there is a need to extend the work, particularly in relation 'project' environments, with their attendant challenges. In the construction industry environment, motivation is influenced by both economic gain and the psychological intrinsic drivers of semi-autonomous project teams.

MOTIVATIONAL VARIABLES INFLUENCING EFFORT IN FINANCIAL INCENTIVE CONTRACTS

This section outlines the generic motivational variables derived from the economic and psychological streams of motivational theory literature. These variables have been incorporated into a conceptual framework outlining the key factors that influence the level and direction of effort (as a proxy of motivation) and their relationship with performance. This conceptual framework will be used in empirical work to follow, evaluating the performance of financial incentive mechanisms in Australian commercial

building projects and to guide the exploration of the contextual drivers that are influencing the performance of financial incentive mechanisms.

Figure 1 illustrates the theoretical relationships that are argued to influence motivation in a construction project, focusing on the impact of financial incentive rewards on effort. This includes the level of effort (motivational force) and the direction of effort.

As illustrated in Figure 1, the motivational variables are broken down into expectancy theory categories including: (a) the contractor's perception that their effort will translate into performance (b) the contractor's perception that performance will lead to the financial reward and; (c) the perceived value of the financial reward to the contractor.

The 'level of effort' motivational variables are:

Motivational variable 1: Controllability of Performance

The ability of an agent to control their performance in an incentive contract will affect their level of effort (Baker, 2002).

If the agent believes that a performance goal is risky and they have limited control over whether they can achieve it, they will be less motivated to attain the goal. This is based on the concept from principal-agent theory that an agent will attempt to minimise risk to attain maximum profitability. Moers (2000(b)) shows that an agent's perceived ability to control his/her performance is dependent on the degree of 'sensitivity' (the effect the agent has on performance) and the level of 'noise' (the environmental uncertainties outside the control of the agent that effect performance). The greater the noise, the less control the agent has on performance. Performance objectives that can be adequately controlled by the agent should be the target of financial incentive mechanisms, so the agent perceives their increased effort will translate into performance.

Motivational variable 2: Goal Difficulty and Self-Efficacy

The perception of goal difficulty and personal competence influences an agent's motivation. If the incentive target is perceived to be too hard, this will lower the contractor's self-efficacy (perceived competence to attain the target), leading to a low expectancy level, and low motivational levels.

This variable is based on goal setting theory and argues that incentive targets must be realistic to attain in consideration of the agent's perceptions of their competency to attain them. As agents are risk-averse (according to principal-agent theory), incentive targets that are set too high will lead to decreased effort because the increased costs of reaching the target exceed the benefit gained (Howard *et al.*, 1997). Financial incentive targets should be set in accordance with the perceived competence of the contractor and the reward intensity (see variable 5).

Motivational variable 3: Goal Clarity and Feedback

Goal clarity influences the perceived controllability of performance. If the goal is vague, the agent may believe that they do not have control over its performance, and will limit their effort. Goal setting theory states that performance targets must be clearly understood to induce motivation and increase the agent's perception that their effort will translate into performance. Thus, financial incentive mechanisms should have clearly set goals. The theory also suggests that timely and accurate feedback at appropriate intervals is useful in maintaining effort (Locke and Latham, 1990). Similarly, Spinkle (2000) (cited by Moers, 2000(b), 10) states that feedback on performance goal achievements facilitates learning, which 'makes performance more effort-sensitive', thus increasing motivation.

Motivational variable 4: Procedural Justice

Van Herpen *et al.* (2001) identified two aspects that influence the effectiveness of an incentive contract's performance measurement system. These are transparency and fairness of the procedures. These elements affect the agent's perception of procedural justice. Procedural justice reinforces the agent's perception that their performance will ultimately lead to the financial reward, thus influencing motivation, according to expectancy theory.

The transparency of the performance measurement system relates to the agent's understanding of the methodologies and measures that are implemented to assess performance. If the contract agent does not fully understand the performance measurement procedures, they will be less likely to be committed to its goals (Van Herpen *et al.*, 2001). Therefore, a clear understanding by all parties of the financial incentive methodologies will assist in maintaining equity in the process.

The second aspect is fairness. The economic predictions of fairness and trust are not well developed. However, from the psychological perspective, perceived fairness and trust in the assessment procedures of a compensation system influence the level of effort exerted by the contract agent (Van Herpen *et al.*, 2001). Merchant (1989) identified the importance of measurement accuracy to the perception of fairness. Measurement accuracy depends on verifiability (it can be duplicated and confirmed) and objectivity (free from bias or external influence). If the agent believes the measurement procedures are inaccurate, it can decrease their motivation due to the uncertainty that performance will translate into the desired financial reward (Moers, 2000(b)).

Motivational variable 5: Distributive Justice – Reward Intensity

Financial incentives should be set at an appropriate intensity to compensate for the agent's risk and promote effort. Incentive intensity, according to economic principal-agent theory, is the main determinant of an agent's level of effort in an incentive contract. This is because higher intensity increases the agent's margin in response to their increased effort. The reward must be significant enough to motivate the agent but should not exceed the value of the benefits to the principal. This is also supported by equity theory from the psychological literature (Adams, 1963), where, if the size of the incentive mechanism does not fairly equate with the desired level of performance, it will

fail to motivate. Washington (1997) recommended allowing the agent to significantly contribute to the development of appropriate rewards for goals. This ensures the principal establishes the reward at a level that is perceived as worthy.

Motivational variable 6: Fairness of the Reward Intention (Reciprocity)

According to the psychological motivational ideals, the perceived honesty of the principal has significant impact on an agent's motivation. This variable is based on reciprocity theory, which states that the agent prefers an environment of fairness, where the principal's incentive intention is perceived to be honourable. If an agent perceives the financial incentive to be 'calculative' and hostile, they will be less committed to the incentive and will fail to increase effort (Fehr and Falk, 2002). This variable depends on the agent's perception of the reward intention in relation to the environment in which it is administered. If there is a lack of trust and cooperation in the working environment and the agent is questioning the principal's honesty, they will be likely to perceive the reward as hostile.

Motivational variable 7: Intrinsic Work Satisfaction

Intrinsic work motivation refers to when individuals or groups undertake behaviour because of the enjoyment or the self-gratification of that behaviour. The behaviour itself is the motivational force. Intrinsic motivation is a psychological concept and is driven by human values such as decency, honour and dignity (Frey, 1997). Intrinsic work satisfaction is argued to have significant impact on the optimisation of financial incentives. Despite the arguments of the 'crowding out' effect of financial rewards on intrinsic motivation (see Deci, 1971), intrinsic work satisfaction has been argued to influence the level of effort, alongside extrinsic motivation (Kunz & Pfaff, 2002). Intrinsic work satisfaction should be taken into consideration when evaluating the worth of incentives in construction projects (Bresnen and Marshall, 2000).

Motivational variable 8: Performance Measurement Characteristics (Direction of Effort)

The characteristics of performance measures used in an incentive contract determine the direction of effort, according to the principal-agent relationship (Moers, 2000(a)). The assumption underlying the direction of effort in an incentive contract is that the agent will direct the majority of attention to the areas of the job that are being measured (Holmstrom and Milgrom, 1991). The agent may manipulate the effort to maximise their incentive reward, possibly to the detriment of unmeasured areas, thus 'what you measure is what you get' (Moers, 2000(a), 4). The empirical evidence shows that financial incentive mechanisms should be designed to ensure that there is a proper balance between cost, schedule and performance incentives, according to the priorities of the principal (Arditi and Yasamis, 1998).

The selection of appropriate performance measures is dependent on the level of information asymmetry. If the principal cannot directly observe all of the agent's actions,

they should implement comprehensive performance measures to align the agent's goals with their own. There is also the potential for 'distortion' of the performance measures, that is, they can be manipulated to promote the wrong behaviour (Baker, 2002). The distortion of a performance measure depends on the types of measurements used. A diverse range of performance measures including subjective and objective measures can prevent distortion.

Also, illustrated in Figure 1 are the contextual drivers that influence the performance of the motivational variables, to be fully explored in the empirical work to follow this paper. These include: (i) Financial incentive mechanism design attributes, (ii) Project environmental attributes, (iii) Contract agent's intrinsic attributes.

Factors influencing incentive project performance (attainment of client's incentive goals) are also shown in the conceptual framework. As discussed previously in this paper, the optimal level and direction of effort (B and F), as the primary objective of an incentive mechanism, is a major contributing factor in the attainment of the client's incentive goals (D). The achievement of incentive targets is then evaluated according to the performance measurement system (E). Effort is accompanied by ability (C) and the external project performance factors (A) such as weather and market prices.

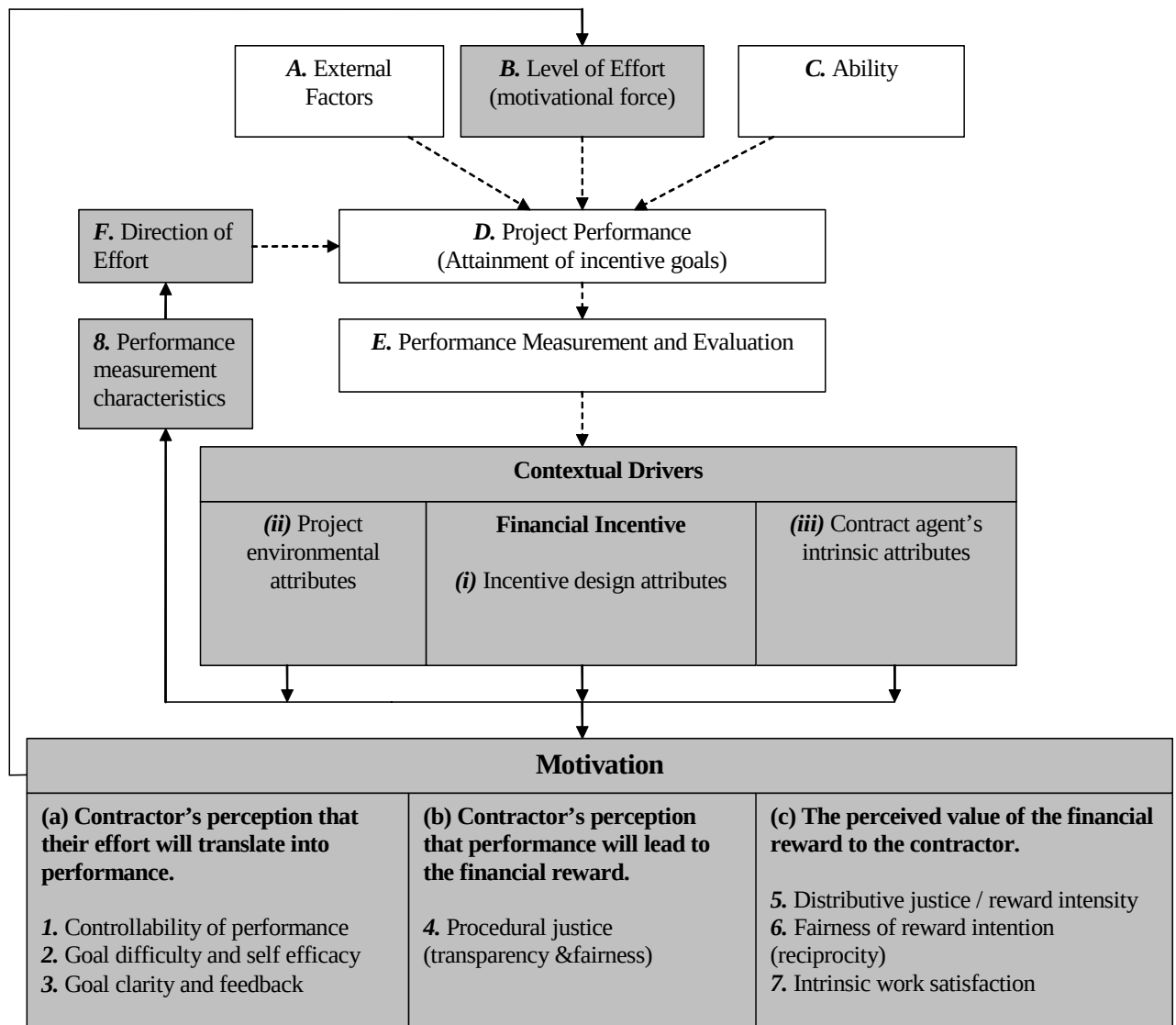


Figure 1: Conceptual Framework - Interrelationships between financial incentives and their contextual attributes, level and direction of effort, performance and the theoretical motivational variables influencing contractor effort under financial incentive mechanisms.

CONCLUSION

With guidance from the construction management and organisation management literature, and drawing from motivational theory literature, this paper has identified a number of motivational variables which are argued to influence the motivation of contractors in financial incentive contracts in construction projects. These variables are

integrated into a conceptual framework that outlines the relationships to be explored in an up-coming empirical study of Australian commercial building projects.

The conceptual framework developed from the review of related literature contributes significantly to the construction management research. There has been very little research identified that has comprehensively investigated the performance of financial incentives in a construction project, particularly from an integrated motivational theory approach. This work extends early attempts to guide the implementation of optimal incentive arrangements in construction projects, by combining economic and psychological motivational theory principals to evaluate incentive performance. It also provides a basis for the further exploration of the contextual drivers influencing their performance. It is anticipated that the performance results derived from the future empirical work will shed new light on the motivational environment of construction projects and provide recommendations for optimising the impact of financial incentive mechanisms in future projects.

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