A Framework for Fostering Estimating Practices and Procedures of Labour-Only Sub-Contractors

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Abstract

Labour sub-contractors play a vital role in national development. Their continued sustenance depends, amongst other things, on their ability to quote realistic and competitive rates for construction work. In a survey of 35 sub-contractors, this study provides a first time understanding of practices, procedures, and problems encountered by them when quoting rates for three different items of masonry work. A distinction is made between estimating 'practices' and 'procedures'. A three-pronged framework is synthesised to foster their 'estimating' practices whilst presenting seven factors that underpin development. Additionally, a methodology is presented on how to establish levels of productivity suitable for establishing work-norms along with a model for estimating rates suitable for labour only sub contract work in line with the proposed framework for development.

Keywords: *Labour sub-contractors, productivity, estimating, piece rate.*

INTRODUCTION

Sri Lanka has witnessed unprecedented change since her attempt towards globalisation almost two decades ago. Construction entrepreneurship has been on the rise with the number of contractors entering the market growing exponentially especially in the early years. So was the case of the growth of small-scale labour subcontractors who entered mainstream construction to share the 'economic pie'. They handle a large volume of work, with concentration in main cities, not limited to the formal sectors of the construction industry but also in the informal sector of residential construction.

Despite their noticeable presence and contribution to national development, hardly any attempt has been made to foster their development. Their continued sustenance depends, amongst other things, on their ability to cost and price construction work appropriately. Based on a survey of 35 sub-contractors, this study provides a first time understanding of how they estimate their rates with respect to three major items of masonry work and what needs to be done in the future. Do they really follow the well known methods of estimating? Are their methods of measurement similar to the standard methods of measurement? If not, why are they different? What strategies need to be adopted to foster their development in the new millennium? These are some questions that this paper endeavours to address in order to lay a framework for developing the estimating skills of labour sub-contractors.

THE BACKGROUND

Types of sub-contractors

Sri Lankan labour sub-contractors can be categorised into three main types based on the clients they serve, i.e. those who work for:

(a) main contractors (MC);
(b) property developers involved in residential construction; and
(c) directly for people building their residences.

No indication can be given on the relative proportions of contractors working for different clients due to a paucity of data.

Technology

Brickwork

Neither bricks nor walls in Sri Lanka conform to standard sizes and vary widely, with significant departures from the norms of other organised construction industries (Abeysekera, 1997b). This is a phenomenon not unique to Sri Lanka, but appears to be common in other South Asian countries as well (Abeysekera, 1997a). These variations have prompted sub-contractors to use three different units of measurement for brickwork as discussed in section 4.2.

Despite such variations, walls of standard widths are built using an ingenious age-old technology known as 'Chapparu' (Abeysekera, 1997d). A lack of appreciation of the value of this technology, and a lack of knowledge on how to optimise costs and time (Abeysekera, 1997c) has prevented the industry from capitalising on potential opportunities. The method of laying bricks in Sri Lanka is significantly different from the British practice of 'buttering' and 'butting' the bricks. In contrast, the current method of 'spreading and shoving' mortar into joints is found to be quite efficient and ideally suited to Sri Lankan conditions as cement sand mortar used is generally coarse.

Plastering

Almost all walls in Sri Lanka are plastered on both faces which makes buildings with exposed brickwork rare. In almost all situations the plasters are of single coat. Generally, all external plaster is finished rough whilst internal plaster is finished smooth with lime putty. A standard Bill of Quantities (BoQ) description would usually specify a thickness of 20mm.

Floor rendering

One of the commonest ways in which brick or concrete floors are finished is to have a cement sand render finished smooth. The thickness of this coat varies from 20 to 40mm.

Estimating Procedures

The procedures of estimating or rates for construction work has been well established worldwide. However, there are hardly any studies that have been undertaken to examine how subcontractors actually carry out this vital function.

As will be seen later, this study finds considerable differences in practices and procedures adopted by labour-only subcontractors, which become the base for pursuing the development of a framework to foster the development of these practices and a methodology for estimating rates for labour-only sub-contract work.

THE STUDY METHODOLOGY

The study focused on interviewing 35 labour subcontractors working in and around Colombo (i.e. the commercial capital of Sri Lanka) using an interview guide. Subcontractors were selected by soliciting the assistance of main contractors and property developers except for those working directly on house construction projects. Only those who had at least 5 years of experience as a sub-contractor were selected whilst restricting the choice to one subcontractor per organisation. As for subcontractors working directly for people constructing their residences, selections were made by random visits to house construction sites.

The sample of 35 subcontractors comprised 15 from main contractors, 10 from property developers, and a further 10 from those working directly for private clients. The study focused on three trades viz. brickwork, wall plaster, and flooring, often handled by the same sub-contractor. Interviews obtained data such as those on productivity, the basis adopted for estimating labour rates, units of rates quoted, and current rates. Care was taken to avoid prompting responses when eliciting information on procedures adopted for estimating.

ANALYSIS AND FINDINGS

Estimating Practice

Five different practices are adopted as shown in Table 1. Notably, none of the subcontractors adopted a mixed approach (such as Type 2 combined with Type 4).

Type 1: Accept rates given by main contractors
Type 2: Estimate unit cost of output and add a fixed amount (for overheads and profits)
Type 3: Quote a rate and adjust labour wages so as to make a profit
Type 4: Quote current market rates (even at a loss)
Type 5: By experience.

Table 1 Extent of practices of labour sub-contractors with respect to type of client served and trade

Practice	*Brickwork*				*Wall Plastering*				*Floor Rendering*			
	No. of responses				*No. of responses*				*No. of responses*			
	MC	*PD*	*Ind*	*Total*	*MC*	*PD*	*Ind*	*Total*	*MC*	*PD*	*Ind*	*Total*
Type 1	7	-	-	20%	7	-	-	20%	7	-	-	20%
Type 2	4	8	9	60%	4	8	10	64%	4	8	10	64%
Type 3	1	-	1	6%	1	-	1	5%	1	-	1	5%
Type 4	-	-	1	3%	-	-	-	0%	-	-	-	0%
Type 5	3	1	-	11%	3	1	-	11%	3	1	-	11%

It is clear that the majority adopt the ‘conventional’ method of estimating (i.e. Type 2) with the exception of adding a ‘fixed’ amount as overheads and profits as against a ‘percentage’. Nevertheless, all subcontractors working for main contractors appear to use the rates given by them. Informal discussions with estimators of contractors’ organisations revealed varying practices. Some use standard norms (Department of Building, 1990) whilst others adopt their own. A notable feature however was that these main contractors frequently called information from their site engineers/quantity surveyors on the rates subcontractors would require on future jobs. This approach would then evoke responses similar to Types 2-5, meaning that the Type 1 response is, to a large extent, a function of Types 2-5.

Of all the responses, Type 5 (i.e. 'estimating by experience') was the most ambiguous. Possible explanations include arriving at an estimate using trial and error methods, quoting market rates (as a Type 4 response) or as explained above.

Notably, none of the subcontractors used an 'estimating-guide'. This is to be expected as there are no such publications. Additionally, calculations were done mentally; calculators were rarely used despite their free availability and affordability!

Clearly, not all subcontractors follow the same methods of estimating. As such, is there a case for a universally acceptable standard practice for estimating rates? Would the levels of numeracy affect the practices adopted (i.e. fixed versus percentage addition for overheads and profits, or the additive versus factor approach mentioned above)? Should subcontract rates be published (to facilitate Types 4 and 5 practices)? Given the understanding reached here, it is argued that:

(a) standard rates be published and be made available freely (to facilitate Types 4 and 5 practices);
(b) norms for estimating rates be published (including an estimating guide in local languages);
(c) cost control concepts be promoted (i.e. as in Type 3 practice);
(d) methods used be transparent (not factor based as explained in 2.3); and
(e) methods of estimating be made simple to avoid a high level of numeracy (e.g. choose addition of fixed sums as against percentages when allowing for overheads and profit)

Units of Measurement

It is clear from the data in Table 2 that subcontractors still use imperial units although Sri Lanka changed to the metric system in the late seventies. Despite its existence for over two decades, not a single subcontractor adopted metric units to quote rates. Additionally, units in use differ from those specified in the standard method of measurement. For example, in floor rendering, 80% of the labour subcontractors interviewed quoted rates in a non-standard unit (and preferred the smaller unit); in brickwork and wall plastering, not less than one third quoted rates in 'non-standard' measures with a number of different types being used (with a preference to the use of a larger unit). Whilst it is not clear why subcontractors adopt a smaller unit for some work and a larger unit for the rest, there is certainly a case for standardisation as a solution to this chaos. Clearly, the status-quo will prevail (especially in the short term) unless there is a major 'intervention' such as effort to:

(a) ensure 'units of measurement' relate to the metric system;
(b) ensure 'units' are standardised;
(c) standardise building elements; and
(d) adopt units promoting greater accuracy in estimating.

Table 2 Extent of different units of measurement used when quoting rates for different trades

Unit	*Brickwork*	*Wall Plastering*	*Floor Rendering*
Per brick	3%	-	-
Per sq.ft.	-	37%	80%
Per sq.	63%	63%	20%
Per cube	34%	-	-

Every effort must be made to achieve (a) and (b) as the diversity in using different types of units for the same type of work would be reduced. For example, in the metric system, only square-metres could be used as a measure for flooring or plasterwork, as against squares and square-feet in the imperial system. However, with floor rendering, there is no diversity in the units used (as seen in Table 2). This mismatch with the standard method will also be eliminated if the metric system is introduced vigorously.

However, achieving (b) would be difficult. For example, when bricks of random sizes are used in industry, and widths of walls vary to suit brick sizes (Abeysekera, 1997a), it is not surprising that subcontractors use different types of units for quoting rates. In fact, the emergence of the 'per brick' rate is a direct result of this chaos. To standardise units used for quoting, building materials and building elements (i.e. say a wall width) should be standardised as well. This is a potential problem with brickwork in Sri Lanka and other South Asian countries (Abeysekera, 1997b). Hence, rates will continue to be estimated differently with much difficulty. However, the emergence of the rate 'per brick' is interesting. Despite its non-standard nature, it has its advantages in focusing directly on brickwork productivity using a very 'simplistic' measure, i.e. number of bricks laid per bricklayer per day as the basis for estimating and receiving payment. In fact, there appears to be a greater opportunity to increase the level of accuracy of estimating when the 'per brick' unit is used with respect to brickwork in South Asian countries; a unit which copes better with non-standardisation!

Productivity

Brickwork

Resource combinations

Five different resource combinations were cited for one brick thick walls in ground floor (see Table A1 in Appendix) although eighty percent (80%) of the subcontractors cited a 'mason to labour' ratio of 2:2. Thus the perceptions of most labour contractors with respect to a suitable resource mix appear to be similar.

Output for a 2:2 resource mix

There were three different units used when quoting output, viz. in bricks, square feet, and cubes, making it difficult to translate these outputs into a common unit because of the varying sizes of bricks and wall widths used in industry. Statistics related to these outputs are shown in Table 3 below. Investigations showed that neither higher productivity nor low productivity was associated with lower rates, with a particular client type of client served, or estimating-practice.

Table 3 Subcontractors' productivity of brickwork using a 2.2 skilled to unskilled resource mix

Output quoted in	*No. in sample*	*Average*	*Mode*
Bricks/m-day	4	550	500
Sq. ft. /m-day	18	58	65
Cubes/m-day	6	0.45	0.50

Abbreviation: m-day refers to mason-day

Productivity suited for estimating rates

Predicting the level of productivity that is suitable for estimating purposes is an issue which can lead to considerable debate, especially when the rate quoted by the labour subcontractors has to be applicable across many different types of walls. For example, productivity of brickwork in constructing a boundary wall would be much higher than when constructing a wall in a residence. Similarly, the productivity of constructing a gable wall would be much higher than constructing a short internal wall. Needless to say, many factors, both soft (motivation) and hard (method etc.) affect the level of productivity.

Jayawadena *et a.* (1995) have advocated the use of regression models to predict the standard times of brickwork activities by estimating the standard times for macro activities and then utilising the technique of 'synthesis' to arrive at these estimates. Thomas et al (1990) and Abeysekera (1997a) have indicated that these models are inaccurate and inefficient. The fundamental assumption that the rating of 100 on which 'standard times' are based relates to an average output which a qualified, motivated, worker using specified methods would naturally achieve is contentious. In fact, these and similar models by Harris et al (1985) are based on similar assumptions. For example, how do such values relate to average values of output observed in industry if the frequency distribution can be equated to a normal distribution? On the other hand, if distributions are skewed and peaked as shown in Fig. 1, how does the average or the mode relate to the 'standard time'? Additionally, how do these models explain the variability of the responses received under this study? Clearly, these models are impractical for 'estimating' purposes.

The task of arriving at an estimate of productivity suitable for a 'norm' appears to be even more daunting when data in Fig.1 are examined. With a very broad range, it appears that brickwork output has much flexibility, meaning it is stretchable. This distribution is peaked as well (kurtosis=0.583) with a concentration of values around the mode (112.5) and median (111.3). Accordingly, the output of approximately equal number of sites would be on either side of the modal output. It is also seen that in 66% of the sites (i.e. 30 out of 59), the output had been greater than 75 bricks/mason-hr. Additionally, if a lower rate of 50 bricks/mason-hr is considered, the output recorded in 88% of the sites has been greater than this figure. Would subcontractors feel 'secure' enough to consider an output of 400 bricks/mason-day (i.e. 50 x 8 hrs) for estimating purposes or would they prefer 900 bricks/mason-day (i.e. 112.5 x 8 hrs) as a more reasonable estimate? Although different prepositions could be made for arriving at an appropriate value, it is extremely difficult to justify any of these prepositions except the mode productivity at which the distribution is peaked. As such, the procedure adopted in this study, of seeking the 'perceptions' of subcontractors on achievable outputs, appears to be justifiable on the basis of the above analysis. However, it would be useful to compare these values with the data obtained under this study (see Table 4).

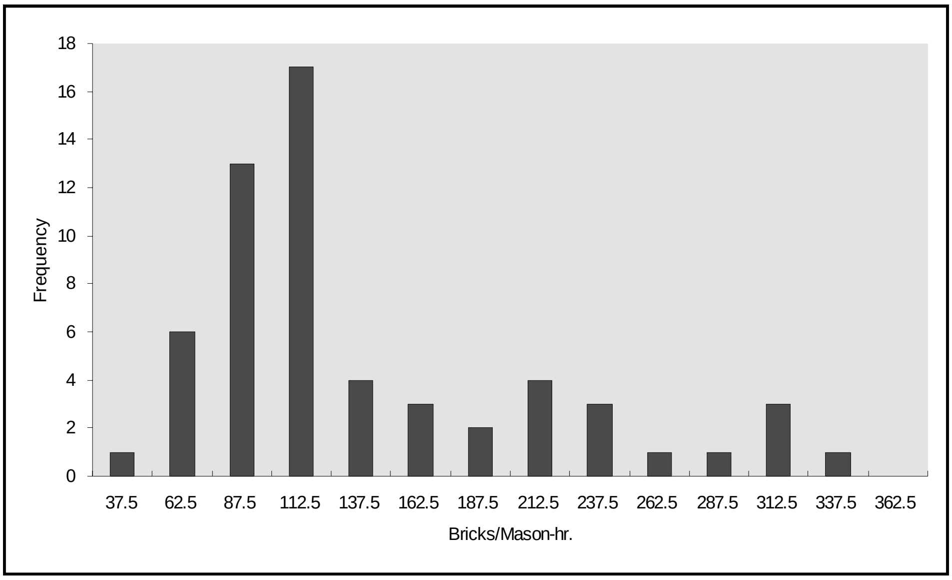


Fig. 1 Brickwork productivity across 59 sites: One brick thick straight walls without openings in ground floor (with one measure per site)

(Source: Abeysekera, 1997a)

Table 4 Questionnaire survey data versus direct field observation data

Productivity by	*Units*	*Average*	*Mode*	*Remarks*
Subcontractor survey (S)	Bricks/m-day	550	500	Small sample size in ‘S’
Direct observation (DO)*		1120	900	
S	Sq. ft. /m-day	58	65	Moderate sample size in ‘S’
DO		80	60	
S	Cubes/m-day	0.45	0.50	Small sample size in ‘S’
DO		0.52	0.49	

Abbreviation: m-day refers to mason-day; *relates to outputs of single brick thick walls in ground floor (without openings) translated to daily output by multiplying hourly outputs by 8.
(source: Abeysekera, 1997); S- Subcontractor survey (see Table 3).

There is a similarity of values relating to modal productivity (see shaded cells in Table 4). In fact, this leads to a hypothesis which has not been tested:

There is an insignificant difference between the mode values of productivity obtained from direct field observations and direct interviews.

On the face of these data, one feels inclined to place greater reliance on mode values for estimating purposes. However, note that these direct observations were made on straight walls without openings meaning that their productivity levels must be higher than walls with openings or with short walls. From this perspective, it appears unrealistic to adopt the mode value. On the other hand, it could be argued that as there is much ‘elasticity’ in brickwork output with a concentration of values around the mode (based on direct field observations as mentioned before), adopting the mode value as an estimate of the achievable levels of brickwork productivity would be acceptable despite the fact that clients, main contractors, and consultants alike require a ‘single’ rate from subcontractors for different work sometimes under ‘unknown’ situations.

Plastering

Resource combinations

Six different resource combinations were cited by subcontractors for rough-cement-sand plaster to ground floor external walls (see Table A1 in Appendix). Sixty nine percent (69%) of these subcontractors cited a ‘mason to labour’ ratio of 1:1.

Output for a resource mix of 1:1

Ninety percent (90%) of these subcontractors quoted two discrete values of output equally between the two output values of 1.0 and 1.5 squares per mason-day (with an overall average of 1.25 sq. per mason-day). Further investigations showed that, higher productivity was neither associated with lower rates nor with a particular type of client served or estimating-practice.

Productivity suited for estimating rates

This wide difference in output values makes it difficult to arrive at a standard norm, or more precisely a single value of productivity suitable for estimating purposes. Clearly, this distribution is not ‘uni-modal, but ‘bi-modal’. Of the two modes, the smaller value appears to be ‘favourable’ (i.e. achievable and reasonably risk-free) as it has a greater potential for reaching acceptance by the subcontractors. As before, productivity levels were not associated with rates quoted, or with a particular type of client served, or estimating-practice. No doubt, direct field observations (similar to those of brickwork) would have been useful to validate this data.

Productivity for different types of work

When questioned on how these productivity values varied with respect to different types of work and work at different elevations, the subcontractors could not make any distinction with regard to output. Therefore, prices for different types of work were never estimated using a Type 2 estimating practice. Instead the 'base-price' for activity was adjusted by small amounts to cater for changes in work (such as work involving scaffolding, for transport of materials to upper floors, and plastering with lime). This is a 'simplistic' approach facilitating mental calculations; an approach based on experience (a Type 5 response). Thus, a 'mixed' approach is seen to be adopted by sub-contractors which is conceptualised in Fig. 2.

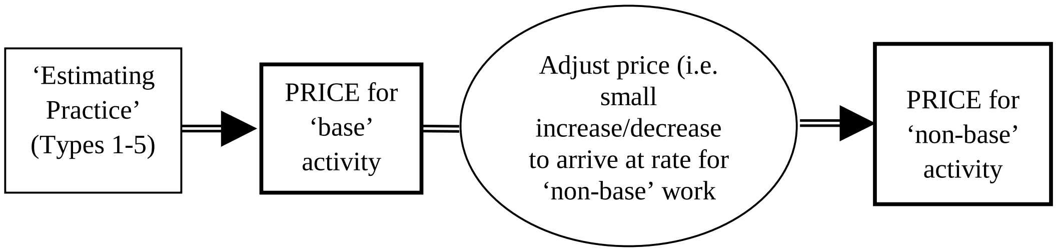


Fig. 2 Conceptualised process for estimating rates for non-base work using the 'simplistic approach': 'Base-rate adjustment' estimating

Therefore, is there a case for promoting this rather simplistic approach with subjective adjustments to arrive at rates for other work, or should a more rigorous approach similar to the conventional approach be promoted? Whilst there is no objection to promoting the latter (in training programmes etc.), there is certainly a case for promoting the former; it is a practice which could be adopted by experienced sub-contractors – specialists in their own trades; all too often, similar approaches are adopted successfully in industry. Why does the industry not pursue 'simplicity'?

Floor rendering

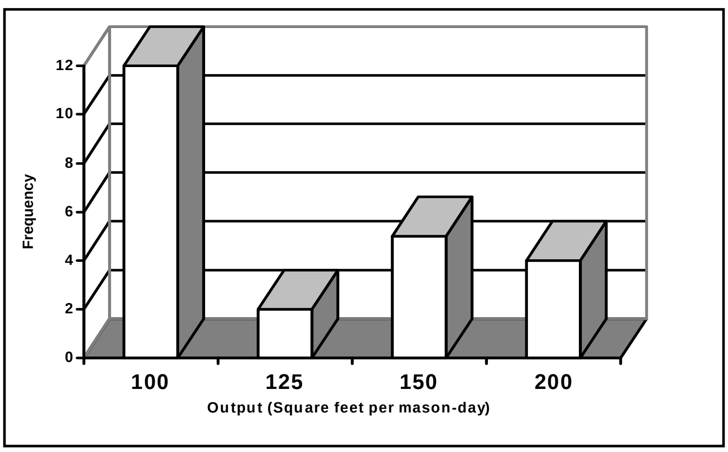
Resource combinations

Seven (7) resource combinations were cited for smooth cement-sand floor rendering (see Table A1 in Appendix). The 'mason to labour' resource mix of 1:1 accounted for 65% of the responses.

Output for a 1:1 resource mix

The output frequency distribution relating to this resource mix is shown in Fig. 3 with a mode of 100 sq.ft./mason-day. As with brickwork, there appears to be much 'elasticity' in the productivity levels and these levels were neither associated with rates quoted, nor with a particular type of client served, or estimating-practice. As no direct field observations were made, a comparative could not be carried out as for brickwork.

Fig. 3 Productivity responses for floor rendering



Productivity suited for estimating rates

Two different approaches had been adopted thus far, i.e. the 'peaked-modal-value' approach and the 'lowest-bi-modal-value' approach (when the former approach cannot be used). Clearly, in this situation, the former approach is more suitable as the distribution is peaked at the modal output (i.e. at 100). Additionally, almost 50% (i.e. 11 out of 23) had cited an output above the modal output (as seen in Fig. 3). Therefore, based on the reasons presented in 4.3.1, the modal output of 100 sq.ft. per mason day is considered appropriate for the purpose of an estimating norm.

Differentiating productivity with respect to different work

Subcontractors found it difficult to differentiate productivity levels with respect to different types of work and with respect to work at different elevations. Accordingly, rates were never estimated using a Type 2 approach for all items of work and the comments made in 4.3.2 above equally applies.

Overheads and Profits

It was observed that the concept of 'overheads' was almost non-existent in the methods adopted by these subcontractors. They usually operate from construction sites which serve as their office and temporary abode, their permanent homes being situated away from major cities of construction. Working implements such as pans, wheelbarrows, water hoses and hoes, are usually provided by the client or the main contractor whilst small tools are brought-in by the craftsmen themselves. Thus, there is hardly any overheads carried by these subcontractors. Hence the reason for the relative absence of this concept when rates are built-up.

The concept of 'profit' is absent too. Its recognition comes from a totally different context. Usually a days salary of skilled worker is recovered for their sustenance by adding this fixed sum to the basic cost of employing a gang of workers for a day (based on the optimum resource mixes mentioned before). In fact, it is from this 'fixed sum' that the subcontractors recover their salaries and pay for other incidental costs (i.e. salaries of subcontractors are not included in the overheads as in conventional estimating). On this basis of estimating, the greater the number of activities handled at one given time by a subcontractor, greater would be the profit. However, in order to be competitive, subcontractor's salary must be generated (and recovered) not necessarily from one piece-rate activity but from a number of such activities performed at a given time. Clearly, this will depend on the subcontractor's work load. As such, the method shown in Fig. 4 is recommended for adoption as a basis for estimating rates. This method of 'estimating' is desirable over the conventional method (whereby a profit is added as a 'percentage'), due to the following reasons:

i. profit is an 'alien' concept not rooted in contemporary labour subcontracting;
ii. recovery of salary is a 'tangible' concept as against the recovery of 'profit' which is an 'abstract' concept;
iii. the difficulty of establishing a 'suitable percentage' from basic costs is significantly reduced as the consideration under this 'method of estimating' is subcontractor's salary;
iv. it is more satisfying and self assuring to recover a 'good' salary rather than an abstract percentage of profit from a psychological point of view; and
v. the use of a 'percentage' addition requires higher numeracy skills as against a lump sum addition.

Investigations into actual rates showed differences based on market conditions. For example, according to Table 4 rates for independent clients are always greater than those for main contractors. It is necessary to investigate this phenomenon further to ascertain the underlying reasons. However, it brings to light the need to adjust the computed rates to suit market conditions. Additionally, the Type 4 estimating practice has resemblance to this approach.

Table 4 Subcontractors' estimating practice, by type of client

Estimating Practice	*For all types*			*Type 2*		
Type of Client	*Brickwork*	*Plastering*	*Flooring*	*Brickwork*	*Plastering*	*Flooring*
Main contractors	100	100	100	100	100	100
Developers	85	109	107	87	96	87
Independent clients	115	111	134	110	100	114

Sample size = 35; Base year – 1996

FRAMEWORK FOR FOSTERING DEVELOPMENT OF ESTIMATING PRACTICES OF LABOUR SUB-CONTRACTORS

Estimating methods and practices: This study takes the view that there is no a case for a universally accepted standard practice of estimating; diversity is preferred over standardisation (i.e. Types 1 through to 5), as familiarity of practice is an incentive to development. This approach is one of 'empowerment with choice' to achieve an end result. As explained in 4.1, the publication of information on labour rates will facilitate Types 4 and 5 practices. Cost control concepts could be mooted through the Type 3 practice it could be introduced into training programmes. The Type 2 and Type 4 practices are further reinforced by the estimating model proposed in 4.4; an approach which prefers 'simplicity' over 'complexity' (for example with regard to numeracy skills, number of norms required for estimating, etc.), transparency (due to the elimination of the use of factors for overhead and profits), encouragement of a 'mental' approach as against a calculator or a computer based approach; an approach that takes into account of market conditions; and in addition an approach that takes into account the 'cultural context' of the 'concepts' associated with estimating.

Units of measurement: The use of the metric system (as against the imperial system) eliminates the use of different types of 'units' for the same activity. As such, national governments, professional and trade organisations must intensify their efforts to speed up the transition from the imperial system to the metric system. Ideally, the units used should promote the accuracy of estimating and enable contractors to cope up with problems related to non-standardisation of building materials. The 'per brick' unit for brickwork appears to have much potential in this regard (in a developing world context) especially with regard to small and medium scale brickwork operations undertaken by labour sub-contractors.

Rate Analysis for BASE ACTIVITY

(A) BASIS FOR ESTIMATING: ONE DAY'S WORK

- Data:
  - Resource mix = X (skilled): Y (unskilled)
  - Daily output = P
  - Skilled daily wage = s
  - Unskilled daily wage = u
  - Wage of subcontractor = w
  - Number of piece rate activities done simultaneously = N
- Computed piece rate:
  - Cost of labour = sX + uY = L
  - Apportioned daily wage of subcontractor = w/N = W (i.e. Contribution to the subcontractor's wage from each piece rate activity)
  - Computed piece rate = **(L + W) /A**
- Market conditions rate:
  - Going rate (based on market conditions) = R (if available)
  - Adjust rate depending on whether R is greater or lesser than computed piece rate.

(B) Rates for NON-BASE ACTIVITIES

Rate for base activity = B

Rate for non-base activity = B ± Δ

(Δ being a small addition or deduction)

Productivity levels for estimating norms: Whilst many different combination of resource mixes were cited, it was always possible to identify a modal-mix which matched the perceptions of the majority of sub-contractors. This study also demonstrated that the 'interview' technique can be used effectively to establish a level of productivity defined by the modal output related to the modal resource mix. In the absence of a defined modal output, it is possible to utilise the lowest of the bi-modal outputs as a suitable estimate. It is recommended that further studies be undertaken to observe field outputs as means of validating data connected with plastering and flooring. The data so established can be used to develop a meaningful guide for estimation of labour rates. The estimating model proposed above does not necessarily require establishing productivity levels with respect to different types of work as they are to be accounted for by using the 'simplistic' approach to estimating suggested above and illustrated by Fig. 2. The ensuing discussion brings to focus the framework for fostering the development of estimating skills of labour only sub-contractors presented in Fig. 5.

Learning areas:
Practices
Methods of estimating
Methods of measurement
Productivity levels and resource mixes
Market conditions
Facilities provided by main contractors
Public relations

Skills:
Communication and language
Competitiveness
Self-management
Information
Low level numeracy

Underpinning development factors:

- Familiarity (of practices)
- Choice (of practices)
- Simplicity (of procedures/methods)
- Standardisation (through metrication)
- Cultural context (of concepts)
- Consensus (of perceptions re productivity)
- Brevity (of estimating items)

Fig. 5: Framework for fostering development

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APPENDIX

Table A1 Number of responses for different resource mixes categorised trade-wise

Resource mix (Mason:Labour)	*Brickwork*	*Plastering*	*Floor rendering*
1:1	02	24	23
1:1.5	-	01	-
1:2	01	04	05
1:3	-	-	01
2:1	-	-	01
2:2	28	03	03
2:3	03	-	-
2:4	-	-	01
4:3	01	01	-
3:2	-	02	-
3:3	-	-	01

Sustained Development of the Local Contracting Industry in a Developing Country

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Abstract

The Ghana Highway Authority since its inception has been developing the local construction industry to support its road maintenance and rehabilitation programs. A review of the state of the industry indicates that though the program has been largely successful, there are a few areas requiring further attention if the growth of the industry is to be sustained. One serious problem which has retarded the growth of otherwise potentially viable local enterprises is their management. Almost all the local companies are run as family businesses. The directors are usually the owner and his or her spouse, and sometimes their children or other close relatives. There is no properly defined organisational structure and hence no proper definition of responsibility and accountability. All decisions of any importance rest with the owner. Such enterprises are therefore unable to attract, more so retain qualified professionals. This invariably stunts the growth of the enterprises and limits their profitability in a rather highly competitive market. This paper discusses the problem and other factors militating against the sustained growth of the local industry. Attempts being made to resolve the problems are also discussed.

Keywords: *management; responsibility; accountability; competition; development.*

INTRODUCTION

The Ghana Highway Authority (GHA) recognises the need to develop and sustain the local construction industry, to support its road maintenance and development programs. The Authority has since its inception, and now supported by the Ministry of Roads and Transport, therefore embarked on the development of the local road construction industry through a number of programs with the support of agencies like the International Development Association of the World Bank. Contractors were initially provided with equipment and given work to enable them to pay for the equipment.

A contractor's registration scheme has been put in place since 1988. The registration is to ensure that any classified contractor maintains a minimum resource pool of identified labour and equipment ready for mobilisation commensurate with his class. This conscious development of the industry has yielded a number of positive results. Among these are the increased contracting capacity. The increased capacity has allowed the shift from the use of direct labour to the use of the private sector contractors for road maintenance/rehabilitation works.

The condition of the road network continues to improve and the road delivery agencies have been able to reduce staff thereby improving efficiency. Despite these positive strides, a number of problems need to be tackled if the growth of the industry is to be sustained. Some of the issues which require urgent attention include the management of these enterprises, the excessive number of contractors especially in the lower classes and the need to pay for work carried out by contractors promptly.

By far the biggest of the issues identified is the lack of proper management for these enterprises. By 1989, it had been realised that the lack of managerial skills for the majority of local contractors constituted a major problem for the growth of the industry (MRH, 1989). However, there has been little progress made on this issue. The problem of management and other identified problems are discussed. Recommendations are also made to help address the problems.

MANAGEMENT OF LOCAL ENTERPRISES

The Structure of Local Enterprises

A study of the structure of most local enterprises indicates that almost all of them are being run as family businesses. The Directors are more often than not the owner and his or her spouse. In some instances children or close relatives may be Directors. The owner is normally the Chief Executive Officer (CEO) and Chairman. There is usually no properly defined structure either for the total organisation or at the project level. All decisions rest with the owner/CEO. The unfortunate thing with this type of management is that the owners/CEOs usually have little formal training in construction or management.

With the requirement that enterprises desiring to qualify for registration to certain classes should have employed certain minimum numbers of some prescribed professionals, the contractors do initially employ these professionals. However it does not take long for such professionals to become disillusioned.

Due to the lack of proper organisational structures, the professionals end up without well-defined job descriptions and responsibilities. The lack of well-defined job descriptions and responsibilities also creates a situation where there is no accountability. Eventually the professionals leave the enterprise. The turn over of professionals in these companies is therefore very high. A number of professionals from some enterprises interviewed indicated that they left because they remained unfulfilled. They indicated that sometimes projects were delayed because even the smallest spare part purchase had to be approved by the CEO. This meant that decision making was necessarily slow or erratic, the profitability of the companies suffered leading invariably to financial difficulties especially when payments for work done were delayed.

The high turn over also results in the lack of continuity and the need to progressively learn from previous experiences. The growth of the companies is thus stunted. The problem could not have been worsened with the present policy that all jobs should be tendered for. With the high number of contractors, competition is fierce and a number of otherwise potentially viable enterprises are thus being forced out of business. A number of CEOs interviewed indicated that they had at one point in time entrusted a lot of responsibility to other people who have taken advantage of their trust and therefore the need to control all aspects of the company themselves.

Unfortunately background checks in these cases indicated that the people who are supposed to have abused the trust of the CEOs were usually siblings who were no better placed in terms of formal training in construction or management to run such enterprises in a competitive environment. The need for each CEO to control his enterprise directly has deprived these companies the opportunities available through joint ventures and it is very rare to encounter a joint venture operation between two local construction firms. It is therefore necessary that the management for these local enterprises change to enable them grow to support the GHA’s road maintenance and rehabilitation programmes which have the objective of providing a safe and reliable trunk road network.

However, in a free market it is impossible to legislate how anybody should run his or her business. Nevertheless, there are a few things thT could be done to remedy this situation. For ease of acceptance it would be prudent to carry out any reforms with the active support and involvement of the local contractors' association. This calls for a strong contractors' association with a properly organised secretariat staffed with people capable of appreciating the issues and communicating them effectively with the membership.

In the medium to long term there may be the need to set up an independent construction industry development board which would be charged with regulating the industry and empowered to deal with issues affecting the local contracting industry. It must be pointed out that some attempts have been made at remedying the problem of poor management. This has however been limited to running seminars in management for the CEOs and top management of these local enterprises. Invariably, the CEOs end up sending their "top management" to these seminars and workshops and the desired target group is missed.

It is suggested that the Ministry of Roads and Transport, with the support of the association of road contractors, set up a competent team to carry out Organisation and Management studies of these companies. The result of the studies would be a set of recommendations for each individual company. Through the studies, the companies could be encouraged to reform their managements. Part of the reforms could be the formation of expanded boards of directors for these companies. The boards would include non-executive directors but who have experience in the construction industry. A well chosen board could assist in providing the necessary direction for the companies, guide the chief executive officers in the day-to-day management of the companies; and help run the companies on sound business principles. The reforms would also include the employment of competent professional staff with proper employment contracts, and well defined responsibilities.

In as much as the reforms would necessarily benefit these enterprises in the long term it would be prudent to provide short-term incentives to companies who agree to be restructured. The incentives could include the provision of medium term credit to such companies to enable them address shortcomings in their companies identified through the studies. To help the contractors also realise the need for good management, road agencies should ensure that personnel schedules are properly filled and given serious attention during bid evaluation. The agencies through their project supervision teams should also ensure that proper site management teams as indicated in the bid submissions are provided during project execution.

EXCESSIVE NUMBER OF REGISTERED CONTRACTORS

As part of the industry development program, contractors for the road sector have been classified by the Ministry of Roads and Transport since 1988. (Addo-Abedi and Hammond, 1997).

Road contractors are categorised under:

- Class A - Qualified for Roads, Airports and Related structures
- Class B - Qualified for Bridges, culverts and other drainage structures
- Class C - Qualified for Labour Based Works
- Class S - Qualified for structures
- Class M - Qualified for miscellaneous Road related works.

These classes are further subdivided into subclasses 1 – 4 based on the number and qualification of the contractor's permanent staff, equipment/machinery, previous experience and financial status. Each sub-class has its minimum requirements of personnel, equipment, experience and financial position, A1 being the highest with no limits placed on the value of contracts that can be executed by them.

Currently there are over 750 contractors registered with the Ministry with only 5 in the A1 Class whereas there are over 500 in the A4 and B4 classes. The S & M classes being for specialist works have less than 5 in each class. The C has 70 registered members. These contractors work mainly on feeder road projects.

With an available budget per year of around US$200m for road works for all classes of local contractors, the number of registered contractors appears excessive. With current emphasis on multi-year budgeting and strict budgetary controls there is only a limited number of projects that can be let in a year. This has led to excessive competition. It has been argued that competition can only be to the advantage of the consumer but excessive competition can and do sometimes hurt an industry. With the anxiety to secure work, some contractors do seriously undercut prices leading in some cases to the abandonment of work and in a few instances to bankruptcy.

It may be countered that competition should be allowed to weed out the weaker ones but it must be remembered that this can only be done at a cost. Project management for non-moving projects become very difficult at best. The projects are not completed at all or are delayed unduly leading to cost overruns thereby defeating the objective of improving the road network condition at optimum cost. In addition, the growth of the industry could be retarded if this situation is allowed to continue.

It must be pointed out that with a relatively mature network in place, the steadily improving network condition means that work available in the road sector would be stabilising. This is estimated to occur around the year 2002 in Ghana. This means that there is little room for sustaining much more work than it is being done now. These lead to the conclusion that the number of registered road contractors is rather high and if the industry is to be sustained steps should be taken to limit the proliferation of road contractors, especially at the low end.

It is therefore recommended that the requirements for entry, especially at the lower ends of the scale should be raised to make entry into the industry a little more difficult. This recommendation is made with the conviction that the entry requirements for the lower classes such as A4 and B4 are low allowing too large a number to be registered. It may also be advisable to freeze entry into the lower grades and rather encourage entry directly into the A3/B3 and A2/B2 classes for a period. The present system of classification would have to be modified to rather give more relevance to the experience of the directors and management personnel if this option is adopted. This is because the present classification system puts more emphasis on the experience of the company as a whole rather than that of the individual directors and management personnel.

DELAYED PAYMENTS

Another issue which has not helped with the growth of the local contracting industry is delayed payments to contractors for work carried out. For small and medium sized enterprises who do not have easy access to credit, this can hurt seriously and may drive some out of business. This problem is gradually being addressed. A road fund which derives its revenue from fuel levy and road/bridge tolls was set up in 1985 to provide funds for road maintenance works. The fund was controlled by the Ministry of Finance and releases were not usually made on time leading to delays in payment for work done by contractors working on maintenance works. The total income to the fund also was only about 25% of the total annual requirement for maintenance with the remainder coming from central government resources. The lack of timely payments to local contractors apart from its detrimental effect on the road infrastructure was also not helping in the development of the contracting capacity.

In 1997 therefore, an enhanced road fund was put in place through an act of parliament. The fuel levy which accounts for about 94% of the revenues to the road fund has been increased by one (US) cent per/litre/year from four (US) cents/litre in 1997. This increase is to be sustained till 2002 at which time it would be pegged at 9.5 (US) cents/litre. The revenue to be generated from the road fund would by then be approximately US$132m/year which is estimated to cover the yearly maintenance requirements of the network (Addo-Abedi, 1997). The act of Parliament allowed for an independent board. Control of the fund was shifted from the Ministry of Finance to the independent board improving releases for work carried out on maintenance projects.

It must be pointed out that the problem of delayed payments to the larger local contractors working on large reconstruction or rehabilitation projects still persists since these payments are made directly from central government funds. This may eventually have the effect of driving these relatively large enterprises out of business or at best restructuring the enterprises to be able to compete for small to medium sized maintenance works. The result would be that if this is not addressed no local enterprise would be able to compete for large projects and this section of contracting would be controlled totally by foreign contractors. It is therefore proposed that the road fund which was primarily set up to generate revenue for the maintenance of the road network should be re-examined after 2002 and probably expanded and the additional revenue used to support rehabilitation and reconstruction.

The Ministry of Roads and Transport recognises the problem of delayed payments to contractors and is working closely with the Ministry of Finance to ensure that only work that can be supported by the budget for any particular year is let out on contract. This is being done through the recently adopted Medium Term Expenditure Framework (MTEF). MTEF provides a three-year rolling budget which allows expenditures in subsequent years to be estimated, discussed and agreed on. The prompt payment of contractors at all levels for work done would go a long way to underpin the recommendations made for improved management and the right sizing of enterprises to ensure the growth of the local contracting capacity capable of providing services for small to large road/bridge projects.

SUMMARY

The Ghana Highway Authority, with the support of the Ministry of Roads and Transport, has since 1974 embarked on the development of the local construction industry to support their road maintenance and rehabilitation programs. These programs have been supported by the International Development Association (IDA) of the World Bank and other donors active in the sector.

The development of the industry has had a number of benefits. Among the benefits is the increased contracting capacity. This has resulted in a gradually improving network condition. The increased capacity has also allowed a shift from the use of direct labour in road maintenance to private sector contracting. The shift has helped the Ghana Highway Authority and the other road delivery agencies reduce staff and improve efficiency.

Despite these gains a number of issues need to be tackled if the growth of the industry is to be sustained. Among the problems confronting the sustained development of the industry is the management of the local companies. Other problems include the excessive number of contractors especially in the lower classes and delayed payments to contractors for work done. It is suggested that organisation and management studies be carried out for these local enterprises and the companies helped to restructure their organisations and managements. The introduction of non-executive directors for the companies is also recommended.

The need for a strong association of contractors in the short term and an independent construction industry development board in the medium to long term to regulate and promote the development of the industry is advocated. It is further recommended that the registration of contractors especially at the lower end of the scale be tightened to reduce the numbers to a level that can be sustained by the volume of work likely to be available over the medium term. It is also recommended that steps should be put in place to ensure the prompt payment to contractors at all levels for work carried out. It is believed that the growth of the industry can be sustained if these issues are addressed.

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Project Management Techniques and Procedures: A comparison of construction contracting and aircraft manufacture

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Abstract

Over recent years there has been a substantial growth in the number of industries employing project management methods (Chaffey, 1997), construction being one of the recognised first users of these techniques. Following the Latham (1994) and Egan (1998) reports in the UK, there appears to be a consensus that the construction industry could benefit by an examination of certain sectors of manufacturing industry, with a view to developing improved methods of working.

It was therefore decided to undertake a comparison of Project Management techniques in the construction contracting and aircraft manufacturing industries. The aircraft industry was chosen because of certain similarities with construction, such as the size and complexity of some of its large projects, and because it is an industry perceived to be at the cutting edge of technology.

This paper considers the reasons for differences between the two industries from both an evolutionary and environmental perspective. Initial findings would tend to endorse Egan's recommendations. Suggestions are made for best practices in managing projects that could be embraced by the construction industry in the move towards improved efficiency, both nationally and globally.

Keywords: *industry comparison; construction; aircraft manufacture; project management; tools and techniques.*

INTRODUCTION

The Industries

It is pertinent to open with some observations about the two industries considered in this paper. One of them, construction, is one of the oldest industries in existence. The other, aircraft manufacture, is one of the youngest. Impressive buildings were being constructed two thousand years ago, whereas the first powered flight took place less than 100 years ago. The Wright brothers' first flight was shorter than the wingspan of a Boeing 747, but within six or seven decades, the industry was designing and building rocket-powered craft to fly at speeds up to Mach 10 and altitudes of 35 miles. So we are comparing a technologically mature industry (construction) with a younger one where rapid technological progress (aircraft manufacture) has taken place. Projects are carried out within quite different environments; in construction, work is completed in the often chaotic conditions of a building site, whereas in aviation the work will be done within the more regulated environment of a modern factory.

On the other hand, there are significant similarities. Both industries are now very large, and they both routinely tackle very large projects. Both require liaison with a multitude of suppliers of goods and services and the co-ordination of activities on more than one site. A large building can easily cost £100 million; this price is of the same order as the price of a modern Jumbo Jet airliner. In construction, a large project would be the erection of a building such as Canary Wharf or the Greenwich Dome in the UK. In the aircraft industry, a large project would be the design and tooling up for a new airliner or military aircraft. In construction, the project manager’s final involvement might include the hand-over of the facilities to the client. In aviation, his responsibilities might end when the designs and tooling are taken over by the production engineers.

Project Management

Project management is increasingly being adopted by all sectors of industry because of the importance of delivering projects that meet predetermined objectives. It is now being seen as the most effective way of implementing changes in business, whatever their nature, whether marketing, manufacturing, the setting up of new services, and so on. Whilst the use of projects has been taken up by many business sectors over the last few decades it is interesting to note that its beginnings are generally regarded as being in the construction and engineering industries (Chaffey, 1997).

The UK Government, via the Egan Report (1998) has pointed out that over recent years, some sectors of the economy, particularly manufacturing, have made significant improvements in their productivity and ability to deliver high quality products at the right price to meet client's requirements. This is less apparent in the construction industry, which John Prescott, the Deputy Prime Minister, perceived as being stuck in some sort of ‘time warp’, unaffected by the great developments and forward march of other industries (Construction Industry Board, 1999).

The Egan Report makes specific reference to construction ‘improving the project process’. This study is concerned with the various project management techniques and procedures applied in industry today. It contrasts the use of project management methods in the aircraft building industry, a ‘member’ of the manufacturing sector, with those in the construction industry and considers whether the different technological and commercial constraints in aviation have resulted in significant differences in the way project management (PM) is utilised. More importantly, it considers whether there are any lessons to be learnt by the construction industry? Our findings would indicate that, despite evolutionary (and other) differences between the two industries, there are some PM methods used in aviation that are viable for adoption by, and could lead to enhanced performance of, the UK construction industry.

THE STUDY

Research Approach

The comparison was undertaken using a generic model of project management procedures, distilled from relevant literature. It was felt that this would provide a non-threatening platform from which to gather information and provide a framework for a comparative assessment of the application of project management tools and techniques.

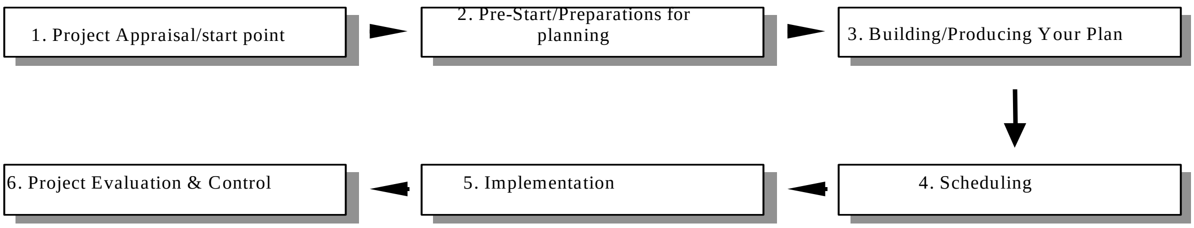
Project management techniques and procedures differ from one project to the next, dependant upon the project’s nature, complexity and cost. There was therefore a need to identify comparable projects in each of the industries. Initially, unstructured interviews were used to get a feel for the scale of aviation projects in the UK. The authors, being more closely involved with the construction industry, were more familiar with typical projects in this sector. Subsequently, detailed information was gathered using structured interviews based on a generic model of project management (discussed below). Participants, from both sectors, were selected on the basis of position and reputation within their sector. The intention was that the management of these projects undertaken by the respondents represented typical projects employing typical techniques and methods.

The Generic Model

In producing a generic model it was important to identify standard project management techniques and procedures. These procedures were established from various project management standards and textbooks. In particular, reference was made to the Association for Project Management's (formerly known as the Association of Project Managers) 'Body Of Knowledge' (APM, 1993) and the British Standards, BS6046 (1991) and BS6079 (1996).

It is well accepted that the overall project sequence can be broken down into stages which, together, constitute what is known as the "project life cycle" (see Healy, 1997). The project life cycle assists in the management of the sequence of tasks needed to complete the project and also in the identification of the work and when it is to be done. This process is often presented as a four-step model. Two examples are Objectives, Plan, Implement and Control (OPIC) and Plan, Do, Check, Act (PDCA) (Healy, 1997). The framework applied to this study was a six-step/stage model, the four-step model being modified to provide more detail. Briefly, 'control' was contained within 'implementation, 'objectives and planning' was expanded into 'preparations and scheduling' and 'project evaluation' was added as a discrete step. This modification was prompted by key areas from the 'body of knowledge' (APM, 1993). The overall six-stage model is shown in Figure 1.

Figure 1: Six stage generic model



The generic model developed for this study was not an exhaustive collection of the tools and techniques of project management, but included those techniques that were considered most appropriate. Furthermore, following on from their previous work examining the use of CAPM in the UK construction industry (Sturges *et al*, 1997), the authors were interested in an inter-industry comparison of 'hard' PM methods. The tools, techniques and procedures (including the 'hard' methods) relevant to each stage of the project model formed the basis of the structured interview.

<u>Results of Structured Interviews</u>

The analysis is broken down into the six stages shown described. The limitations of this paper mean that only the significant differences or similarities have been highlighted. The points are summarised in Table 1 and subsequently discussed.

Table 1: Summary of Similarities and Differences in Project Management Techniques

Stage	***Technique***	***Aircraft Manufacture***	***Construction***
1	Project/Work definition	Analysis of contract documents (detailed information already exists from previous projects)	Analysis of contract documents and study of proposed site
2	Select/assemble appropriate team members	Project team depends on type of work to be carried out	Project team depends on type of work to be carried out and by the availability of team members
3	Identify project tasks	Input from all project team and data from previous projects	Input from project team and involvement from subcontractor
	Work breakdown structures/develop detail	Detailed WBS and OBS carried out	No WBS or OBS carried out. Logistic plans carried out
	Identify durations/procurement periods/milestones	Involvement from project team, and specific data from previous assemblies.	Involvement from project team, suppliers and subcontractors. Experience on previous similar projects. Includes contingency for external site environment.
	Identify the project logic and produce networks	Specific data from previous assemblies. Network analysis carried out.	Logic established using experience and knowledge from previous similar projects.. Limited use of network analysis
4	Bar charts/CAPM	Detailed charts with precedence. Used to plan, report progress and as a control technique	Strategic charts with main activities and milestones, no precedence. Used to plan, report progress and for presentation
	Resource allocation	Implemented using CAPM. Internal resources or repeat external	Tender enquiry process. External resources
	Resource levelling/calculating plan	Implemented with CAPM	No resource levelling because resourcing is primarily external
	Risk/contingency plan	Identification, assessment, mitigation, contingency and control procedures all carried out	Method statements and risk assessments carried out.
	Resource plan/schedule	Predicted resource requirements for project in form of resource plan	Predicted resource requirement for project in form of subcontractor procurement schedule
	Procurement plan/schedule	Supplier management for procurement of materials	Supplier and design management in form of material and information schedules
	Financial plan	Expenditure profiles, sales plan and cash flow profiles all carried out.	‘S’ curve (receipts profile) and expenditure profiles carried out
5	Baseline project	Configuration freeze serves as the baseline for all operations	Baselining rarely carried out and contract programme is rarely revised
	Establishing reporting procedures	Project control system in place for monitoring, review, report and control.	Project control system in place for reporting and control
	Monitoring and tracking	Undertaken using CAPM. Monitor progress, assess remaining work and forecast performance	Carried out manually. Monitoring progress, progress assessment and forecasting.
	Problem solving/action planning	Undertaken using CAPM ‘what if scenarios’. Change management.	Subcontractor meetings used as essential control technique for action planning.
	Project performance/EVA	Earned value analysis undertaken.	No EVA. Based on variance only.
6	Post mortem procedures/project review	Post mortem procedures carried out. Lessons learnt recorded and fed into other projects	Performance reports on subcontractors and suppliers carried out and database updated.

Stage 1 - Project appraisal/start point

The understanding of the needs and purpose of the project are identified differently between the two industries. Here there is a substantial difference between the project environments. Construction contracting companies traditionally analyse detailed information within the contract documents and carry out comprehensive studies of site conditions to ascertain what factors may exist to influence the project which others are not obliged to bring to their notice. This is always a significant risk area in construction projects. By contrast, aviation often requires only generalised information to drive projects (for example,, the design of a wing to lift a certain load to specific drag criteria) as detailed information already exists within internal systems.

Stage 2 - Pre-start/preparations for planning

When establishing a project team within aviation, it is determined at the outset whether there is the capability to complete the project, the team is dependent largely on the type of work to be carried out and the methods and skills to be used. Although in construction the structure of the team depends on the type of contract, by comparison the team selection is often driven by the availability of the team members, recruitment options occasionally being considered if some shortages are apparent.

Stage 3 - Building/producing your plan

In aviation, identifying the project tasks is carried out by all the project team and is developed from experience and from lessons learnt from previous projects. Substantial detail is included in the plan. By contrast, construction projects tend to use substantial subcontracted elements and therefore often have plans, detailed solely by planners with little assistance from other members of the project team, with little detail of these packages. Interestingly, in previous work by the authors (Sturges *et al.*, 1997), certain subcontractors from the building services sector were frustrated by poor planning in the construction industry. In one situation, the services contractor was well-versed in using PM techniques, and could see clear opportunities for improving the planning of work on the contract job. However, the site manager resented and refused the offer of help with scheduling the work.

Aircraft manufacturers produce detailed work breakdown structures to allow their projects to be scheduled and resourced more effectively at work package level. Organisational breakdown structures are also used to allocate work packages. By contrast, construction contractors appeared to break down the project in the manner in which it was to be tackled, emphasising the logistics and the influence of the site upon the process. Not surprisingly, both sectors rely substantially on experience when assessing durations for elements in the project schedule.

The development of the plan in construction is more the identification of the activities and their juxtaposition with respect to time. Very rarely did the authors come across the employment of robust logic and task interdependencies leading to a detailed network and critical path analysis. Construction managers appeared to rely on judgement rather than techniques to establish critical interdependencies. By contrast, in aircraft manufacture, the use of networks was more apparent. Furthermore, these techniques and charts were used during the development to assess ‘what if scenarios’ in considering alternative options.

Stage 4 - Scheduling

Bar charts featured heavily in both sectors as a means of illustrating progress and monitoring activities. Construction bar charts were ‘activity’ based whilst aviation were ‘event’ based. This tallies with the findings of Graham (1999) who noted that in aviation the event is used to determine when assemblies must come together, whereas in construction the majority of assembly is on site and the focus is on the activity.

Aviation appeared to place greater emphasis on the automation of resource allocation and levelling than construction. Computers were seen to play a big part on aviation projects. In construction, the computer systems in place appeared to be used more as a presentation tool.

The approach to risk and financial planning appeared to be very similar between the two project areas. However, in terms of procurement, aviation appreciated that purchasing and supplier management is a vital element to the success or failure of a project. This is an area the construction industry is currently addressing. Both sectors appreciated that sound financial planning is essential to ensure the continued health of a project.

Stage 5 - Implementation

The reporting procedures within the aircraft industry appeared to be standardised and automated using CAPM, involving a systemised reporting arrangement. By contrast, construction used different reporting methods and forms did not appear to be standardised. Progress measuring in aviation appeared more objective given the existence of more measurable milestones and the greater experience gained through repetition. Accurate measuring in construction is harder to achieve and statements tended to be subjective. Construction frequently relied upon managers' judgement to assess progress.

Whilst the aircraft manufacturing industry has projects with very exacting performance standards, unexpected or 'out of sequence' work appeared to be an expensive reworking exercise. By contrast, changes in construction are commonplace and flexibility is expected. Clients changing specification during a project appears to be the norm. This operating culture in the UK, whilst appearing flexible and customer focused, can ultimately lead to problems when contrasted with the construction industry in other countries.

Project performance assessment using Earned Value Analysis (EVA) to give an integrated view of time and cost performance (in addition to forecasting trends) is employed in aviation, but was not found in construction. Its importance in aircraft manufacture was well articulated in a recent article (Anon, 1999). Effective use of EVA requires detailed breakdown of projects using a work breakdown structure, currently not seen in construction, as pointed out above.

Stage 6 - Project evaluation

Aviation carries out projects which have a formalised post-mortem feedback. This enables them to contrast project specific data with those of previous projects. Interestingly, respondents in aviation felt that there was substantial 'room for improvement' with their post-mortem procedures. In contrast, construction's post-mortem systems were rather limited in project-specific data and generally were not given a high priority. This concurs with the criticism levelled against the UK construction industry by Egan (1998) for its poor performance in undertaking effective post-mortems on completion of projects to allow reflection and consideration of best practice.

DISCUSSION

Many of the differences observed were undoubtedly due to the differing environments in which projects are carried out. In aviation, projects are nearly always carried through in the controlled conditions of a modern factory. In contrast, construction projects are undertaken in the rather chaotic conditions of a construction site. They are completed under physical conditions set by the client, and can be subject to variation while in progress. In aviation, project teams will probably work on many projects, and so team members will be quite well known to each other. In construction, teams are set up for each project, and then disbanded upon completion. Team members will usually not be known to each other. Many of the design team, suppliers and subcontractors will not previously have worked with each other and their relationship would be purely contractual. The aviation projects in comparison were larger and of longer duration. The design team appeared to be formed between internal functions and repeat external suppliers, operating closer as a single cohesive entity, becoming more formal over a period of time.

One major area of uncertainty in construction projects stems from the site conditions. Since adverse site conditions are discovered very early in site operations, projects can be subject to early delay, but such delays are frequently not allowed for in schedules. This can generate much (needless) time pressure later in the project.

The two industries have evolved differently, and one major area of difference is the way the various involved professions have developed. This has had an impact on communication mechanisms within each sector. Two hundred or more years ago, the mason was both designer and manager on a building site. Today, we have architects, quantity surveyors, engineers and construction managers; all these professions have well-documented inter-professional boundaries. Whilst there are departmental divides within aviation, the gaps between the different functions are less pronounced and concurrent engineering is facilitated by way of matrix organisations. One of the criticisms of construction made in the Egan Report is that there is too much of a divide between the design and construct functions. Certainly, in many cases, when the main construction contractor is engaged, a lot of the design work will have been carried out. The sub-contractors who will carry out much of the detail construction usually make no input to the design process. In the aircraft industry, the production engineers will make an input to the design process, to ensure that solutions are optimal from the manufacturing point of view. In construction, the second author has experience of design changes being faxed to site as construction was in progress.

However, as previously mentioned, there are definite similarities between the two industries, and the differing evolutions and project environments do not account for all of the variances seen. In aviation, there appears to be more use of the 'hard' tools and techniques of project management, such as:

- Network analysis
- Work Breakdown Structures
- Computer-Aided Project Management methods
- Formal Project Methodologies
- Performance measures such as Earned Value Analysis.

Do these techniques have little or no place in the management of construction projects? With the current pressure on the UK industry, it is suggested that this is not the case. Many leading edge organisations employ these techniques as well as aviation. So why are they not seen in construction?

Network analysis was quite popular in construction some years ago but it lost favour in the 1970s. The current use of CAPM is increasing, both in terms of the number of firms and the extent to which it is being used (Sturges *et al*, 1997). The current fashion for partnering and supply chain management, in conjunction with the increased customer focus and the desire to maintain competitive advantage, may be a useful catalyst in this process. Clients are demanding to be kept better informed of progress; suppliers and subcontractors would also prefer to be kept better informed of supply dates or start dates. The decreasing contract periods that we are currently witnessing are making increasing demands for improved co-ordination of the site-based processes. In the UK one is starting to hear of subcontractors having to supply programmes for the subcontract work. As computer literacy grows within the industry, smaller subcontracting firms are now producing their own CAPM-generated programmes. It would not be difficult to integrate these into the main contractor's programme. This increased information might stimulate the use of Work Breakdown Structures to organise the information and in turn, with some cost data attached, lead to the extraction of Earned Value Analysis and time and cost performance predictions. An additional indirect benefit of further use of these hard IT methods is that they lead to improvements in knowledge management processes within an organisation, less information being carried around in people's heads.

Another significant area with potential for adoption is that of improved customer focus. Considering its history in comparison to construction, the aircraft manufacturing industry has obviously been very innovative, open to new ideas and working practices, and has made impressive progress. It is in continuous contact with its customers - the military and the airlines - they feed back to it their future requirements. The airlines share their thinking on their services and how they would like to improve load factors, carry more passengers, fly further, etc and the military will require similar performance improvement criteria to be met. This means that there is usually an innovative element in aviation projects, and the acceptance of this constant drive for improvement has become part of the industry's *modus operandi*. Aviation is constantly and actively seeking greater efficiency and improved methods of working. Construction has tended to be more conservative, and has lagged behind in its adoption of new methods of working. This is only part of the picture; the aviation industry has undergone a huge rationalisation process, driven by the recognition that innovation carries a high price. Product value increases, and the necessary capital investment in technology and infrastructure creates pressure for firms to merge to survive. While there are just two major manufacturers of large passenger aircraft in the Western world, the UK construction industry consists of over 160,000 companies, most of which are very small. Perhaps this arrangement does little to foster innovation and continual improvement of service to customers.

CONCLUSIONS

The way in which two different industries, construction and aviation, undertake projects has been considered. Project similarities have been discussed along with the differing environments and historical development. Improved performance of the UK construction industry, as advocated by Egan, could be brought about by adoption of the following practices observed in aircraft manufacturing projects:

- greater use of hard techniques such as CAPM
- improved management of the supply chain
- greater interdisciplinary communication
- improvements in customer focus.

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Dealing with Alternative Construction Methods through Performance-Based Building Codes

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Abstract

In a world that is becoming more regulated and more aware of liability it is increasingly difficult to introduce radically new materials or to revive traditional methods of construction. As third world countries face increasing poverty, higher costs and demands for conservation of world resources, the use of alternative (i.e. non-mainstream) or revived traditional methods of construction to improve the housing of people in third world countries in the new millenium is becoming important. Performance-based building codes have the facility to accommodate diversity of construction methods, satisfying the regulators, conservationists and lawyers alike while providing improved cheaper buildings.

This paper will discuss the New Zealand experience of processing building consents for alternative methods of construction such as earth buildings, straw bale construction and log houses. The performance criteria of NEW ZEALAND Building Code clauses B1 “Structure”, B2 “Durability” and E2 “External moisture” and others are used to measure the adequacy of systems. The use of performance-based building codes to assess materials or systems that are not current standard construction can be used in any country taking local considerations into account.

Keywords: *alternative construction, durability, moisture, performance-based building codes, third-world country*.

INTRODUCTION

In *Appropriate Technology*, an English architect, Robert Barclay (1987), wrote:

> With some notable exceptions, most building regulations in the Third World are invariably restrictive, tend to inhibit the development of building materials, and to frustrate improvements in construction methods, including the important sector of alternative low-cost building materials.

and:

> Not the least of the problems is the urgent need for housing or shelter which uses appropriate technology to achieve the most at the least cost. Invariably, neither existing building regulations, nor the local building by-laws, are sufficiently receptive to the use of low-cost materials and technology, or, at best, attempts may be made to adapt or waive specific clauses as emergency measures to suit particular circumstances. Building regulations should be framed to facilitate the further development and use of appropriate materials and methods of construction consistent with health and safety requirements.

He concluded by saying that national building regulations based on a narrow concept of enforcement will be of very limited use. Regulations that are forward-looking and permit reasonable interpretation in their use are much more likely to achieve the desired result.

Has much changed since?

PERFORMANCE-BASED BUILDING CODES

Traditionally, building regulations have been prescriptive, saying what must be done and how to do it. By nature, such systems of governance are very restrictive because they cannot cover every foreseeable circumstance and certainly they cannot cover unforeseeable circumstances. In recent times, as regulatory authorities search for more flexible, less time consuming and cheaper methods of regulating building, they have been leaning towards performance-based building codes. Performance-based building codes simply state what must be achieved and are, therefore, by nature, very broad and versatile.

Performance-based building regulations can encourage the use of local materials and traditional construction methods, or new technology that results in cheaper construction, to improve the housing of the poorer people in third-world countries. The performance-based New Zealand Building Code has been in use for over 6 years now. As the New Zealand construction industry has become used to the system, its ability to be flexible and save costs is beginning to be demonstrated.

THE NEW ZEALAND STORY

The New Zealand Building Act 1991 set up the Building Regulations 1992 and a 6 months lead in period saw the full introduction of the New Zealand Building Code in January 1993. The Code has 37 clauses covering all aspects of a building code. These are divided into 8 sections, classified as General Provisions, Stability, Fire Safety, Access, Moisture, Safety of Users, Services and Facilities and Energy Efficiency. These are the mandatory clauses and are performance-based. Each clause has a 5-tiered system of sub-clauses. These tiers are as follows:

1. Objective - states the purpose of that clause, usually based on health, safety and accessibility.
2. Functional Requirement – states what has to be achieved.
3. Performance – states how to achieve the Objective in either a qualitative or quantitative form.

The next two tiers are of equal importance and are collectively called the Approved Documents. These are non-mandatory clauses and are prescriptive. They are a shortcut to proving compliance with the mandatory clauses above. They are not the only way to prove compliance, which can also be done by demonstrating that an alternative solution will comply with the Performance criteria. The Approved Documents consist of the following:

4. Verification Method – Calculations or test methods.
5. Acceptable Solution – Cookbook method.

It is in the alternative solutions that the flexibility of the performance-based code lies. Alternative solutions need to show that they achieve the relevant requirements of the mandatory clauses of the code.

Under the New Zealand Building Act, the regulatory authority (city council, district council, regional authority) administers applications for building consents. Section 34 of the Act requires that the regulatory authority shall grant the consent if it is satisfied on “reasonable grounds” that the provisions of the building code would be met if the building work was properly completed in accordance with the plans and specifications submitted with the application. Thus the applicant has to show documentary evidence that will give the Regulatory Authority reasonable grounds to be satisfied that the building code is met.

Compliance with the Approved Documents obviously constitutes reasonable grounds. When a building material or system does not comply with the relevant Approved Document the applicant must supply the regulatory authority with documentary evidence that provides reasonable grounds for being satisfied that the building will comply with the building code.

Proof of Compliance

A building does not have to be built in accordance with the Approved Documents, but if it is not, the owner, designer, builder or manufacturer has to show the regulatory authority that the design complies with the relevant clauses of the NZBC. One way of demonstrating compliance is "history-in-use", for example, a building system that has been in use for some time and proved satisfactory. Tests and standards other than those named in the Verification Methods and Acceptable Solutions may also be used, but the regulatory authority will need to know what relevance or standing they have. In working out what information is needed it helps to ask the following questions:

> "What is required by this clause?" and then
>
> "Does the design satisfy those requirements?"

When a material has been used locally for years, has a history-in-use and an established tradition of trade practice compliance is not difficult to prove. It is alternative systems from a different location or lapsed traditional local materials that cause difficulties. This is where the Performance criteria of clauses and the Durability requirements become very important because they provide the measure by which it can be shown that the building material or system is satisfactory.

Background to the New Zealand Building Industry

By world standards New Zealand does not have a long history of building construction. European settlement began only 150 years ago. The indigenous people (Maori) who settled in New Zealand from Polynesia in the 13^{th} century used a mixture of timber for the structure of their houses with raupo (reed) infill panels for walls and roofs with the occasional low earth structure. The country is geologically young and does not have large resources of building stone or much suitable material for brick manufacture. It was covered with forest including trees that supply superb building timbers. The frequency of earthquakes, the ability to grow exotic timbers (mainly Pinus Radiata) quickly and efficiently, and a small population, well dispersed, led to light timber construction becoming an obvious choice, particularly for housing and smaller commercial buildings. None of the examples used in this paper are traditional in New Zealand although there are links to materials used by both Maori and the early European settlers.

Alternative Construction

As the technical adviser for the Building Industry Authority (BIA) responsible for clauses E2 "External moisture" and B2 "Durability" the first uncommon building material that we were asked to deal with in day-to-day queries from both building officials and potential owners was earth building. This may surprise some people in other parts of the world but in New Zealand this is an unusual type of construction. Some earth buildings were constructed by the early settlers (a few are still in existence today, the most famous being Pompalier House, a rammed earth structure that has been restored to its former glory). Generally, however, timber structures were used, partly because of the problems experienced with earthquakes and partly because of their relatively low cost and ready accessibility.

Log houses were soon to follow as the subject of day-to-day queries. The latest material to appear on the scene is straw bale construction, an influence from the environment conservationist movement in the USA.

A pattern has emerged in dealing with the problem of obtaining a building consent. The owner/designer has to provide the regulatory authority with documentary evidence that the building would comply with the building code (Section 34 of the Building Act). Clauses that cover such factors as minimum hygiene are the same no matter the materials from which a building is constructed. For alternative construction methods, the main relevant factors to concentrate on are contained in the following code clauses:

- Structure
- External moisture
- Internal moisture
- Durability.

The New Zealand Building Code

To explain how the performance-based code deals with alternative construction, a detailed outline of how the above factors are dealt with by the New Zealand Building Code is now presented.

Structure

The strength of the structure can be demonstrated by recognisable methods of calculations. The performance-based clause for structure recognises all the likely loads to be imposed upon a structure. The Functional Requirement of NZBC clause B1 “Structure” requires buildings to *withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives.* The Performance criteria are qualitative, consisting of a list of likely loads and other factors that must be considered when assessing the stability of a building.

Resistance to those loads would have to allow for the strong horizontal forces experienced in New Zealand from both high winds (it is after all a couple of large islands in the middle of an ocean) and earthquake (New Zealand lies on the edge of the same belt of earthquake activities around the Pacific Rim that cuts through Japan). Clause B1, like all clauses within the building code, requires the same performance throughout the country. The variation in winds and probability of earthquakes changes from area to area depending on the forces experienced so it is the means of compliance that becomes the variable.

External moisture

Keeping the water out of buildings is dealt with by 3 clauses. Surface water is dealt with by the collection or prevention of entry of rainwater in clause E1. Penetration of the building envelope and floor structure is dealt with by clause E2, and internal moisture by clause E3. E2 “External moisture” is probably the most relevant clause of these three. E2’s Functional Requirement requires that *buildings shall be constructed to provide adequate resistance to penetration by, and the accumulation of, moisture from the outside.* The Performance criteria are again qualitative and deal with keeping out moisture that would cause undue dampness or damage to materials and includes moisture brought in from outside by building materials (such as concrete and timber).

Internal moisture

Internal moisture can be just as dangerous to health as rain from the outside. The moderate temperatures and high relative humidity experienced in New Zealand in conjunction with moisture emissions from the occupants result in condensation and thus growth of fungi and mould within houses. The Functional Requirement of NZBC clause E3 “Internal moisture” requires that *buildings shall be constructed to avoid the likelihood of fungal growth …and damage to building elements being caused by use of water*. The Performance criteria deal with causes of condensation, requiring a combination of ventilation and thermal insulation, and with overflow and water splash from sanitary facilities, requiring impervious and easily cleaned surfaces combined with floor wastes where appropriate.

Durability

The durability provisions of the building code are to ensure that a building continues to comply with the code after its date of completion. New Zealand, in deciding on the minimum period of time that a building material or total building should last, took into consideration not only people's expectations but also the national cost (a requirement in the Act under which the code is mandated). Various factors contributed to the decision that the life of a building should be not less than 50 years, including common construction methods, the youth of the country, rapidly changing technology, life styles and demographics. We recognised that the structure, as the mainstay of a building must have a durability equal to the life of the building. Other building elements having less importance could have a shorter durability period. Ease of access, replacement and detection of failure became the important factors. Based on concern for health and safety, and taking into consideration normal maintenance, building elements that are difficult to access <u>or</u> replace <u>or</u> the failure of which would not be detected during normal use or maintenance must have a durability of the life of the building being not less than 50 years. Building elements that are moderately difficult to access <u>or</u> replace, <u>or</u> for which failure would be detected during normal maintenance require a durability of at least 15 years. Only elements that are easy to access <u>and</u> replace, <u>and</u> for which failure would be detected during normal use require a durability of no more than 5 years.

The New Zealand Building Act, however, allows for the ability to nominate the intended life of a building. This is because some buildings (for example, temporary building, and semi-permanent marquees) may not always need to remain for a long period of time or because the life of experimental construction may not be known.

The durability clause not only relates to all the other clauses, it is the key clause. Compliance with other clauses must include the measurement of the durability of building elements or systems. The adequacy of construction to withstand structural forces such as wind and earthquakes are measured by the likely return of such events within the durability requirement. Thus, a building must be designed to withstand the force resulting from an earthquake likely to be experienced within a 50-year period. Similarly, the resistance to wind must be for the maximum likely strength of wind in 50 years. Structural materials in New Zealand must be able to withstand likely loads not just for one, two or ten years but for not less than 50 years. This means that some materials, for example those that are very flexible, may not be suitable, as they will fail within the life of the building (being not less than 50 years).

Prevention of surface flooding is measured in terms of return period of rainfall. New Zealand has made the decision that buildings other than housing must bear the cost by insurance or by calculating the risk, but that housing should be protected by law. Houses must be designed to prevent surface water from entering the building in the 50-year flood. This is required as a control of the cost to the country rather than inconvenience to people or a factor of health and safety.

The majority of failures of building elements are caused by water (Porteous, 1992). Thus, compliance with clauses for external and internal moisture can be greatly affected by the durability clause. The necessity of protective coatings or the ability of the construction to keep water out are vital to the assessment of the performance of those materials.

To explain further how the performance-based code and, in particular, the durability clause, assist in assessing alternative types of construction this paper considers earth buildings, log houses and straw bale construction. Each has its own idiosyncrasies but, as will be demonstrated, they are mostly dealt with in the same way, as can any other type of construction that is not commonly used, be it a traditional method that has lapsed or a new, hopefully cheap and efficient technology.

Case histories

a) Earth buildings

Earth buildings have the advantage of being able to be built from local materials with local labour. The skills can be taught quickly. What is more, the material does not consume vast amounts of energy to bake it in an oven, nor are noxious gases released in its manufacture. Usually, only a small amount of additional materials are required to stabilize the earth. Cement, lime or even dung can be used, depending on the type of soil, and sand may need to be added to clayey soils.

Earth is not a resilient material so there are structural problems involved in resisting the lateral forces imposed, particularly earthquakes. These have mainly been resolved by having steel reinforcement rods vertically and horizontally with a timber or concrete ring beam around the top of the walls to tie them together. Some experimental work is being done to find a way of using local fibres such as flax to strengthen the structures without the necessity for steel reinforcement.

Moisture is the other big problem with earth building. High rainfall and strong winds experienced in many parts of New Zealand mean that care must be taken in designing earth buildings to prevent dampness. Whatever the type of earth building, adobe or bricks, poured earth, or rammed earth or pisé, the following points need to be adequately dealt with in the application for a building consent if compliance is to be demonstrated to the regulatory authority:

- Careful testing of the soil to ensure that it will be sufficiently stabilised.
- Foundations and floor that have an efficient means of preventing dampness from rising.
- Location in a well-drained area or on a foundation of appropriate height to prevent flooding in the 50-year storm.
- Contraction and expansion joints in the plaster to prevent cracking.
- A protective coating that resists moisture but is permeable to vapour in order to seal the surface.
- Adequate flashings at all openings.
- Sloping window sills.
- Allowance for vertical shrinkage in all joinery.
- A roof that does not leak.
- Wide roof overhangs to shelter the walls below.

b) Log houses

Because trees grow well in New Zealand, a small group of people have been experimenting with log houses. We cannot go by the history in use in Canada and Russia, the main source of information about log buildings. The timber-damaging insects are different, we do not have the cold winters to kill them off and the rate of growth of trees is so much faster that our exotic trees have less hardwood than when grown in their native land.

Factors critical to the durability of a log building are the following:

- Design and detailing of the building (damp-proofing at floor level, width of overhangs, weatherproofing at windows and doors).
- Initial handling and drying of the logs.
- Exposure to the weather during construction (length of time under construction).
- Protective coating of logs, particularly cut ends, during and after construction.
- Continued maintenance including recoating of logs.

Because there is not enough information to be sure that a log house has a durability of not less than 50 years, regulatory authorities usually require a specified intended life from 15 to 30 years depending on the species of tree. When the specified intended life has been reached, those houses will be inspected to see if they should be demolished, repaired or if in good condition, have their specified intended life extended further. These will add information to the history of such buildings for future builders of log houses.

c) Straw Bale Construction

Straw bale construction is fairly new on the scene in New Zealand, influenced by an upsurge in California. It is understood that straw bales were first used by the early North American settlers who had slowly settled from the east to the west of America, building cob or turf buildings as they went, using the ample supply of this material on the plains. When they arrived at the sandhills of Nebraska, however, they found that the turf crumbled when dry and their shelters disintegrated. With no trees for timber or stone for solid walls they were obliged to use whatever other material they could find. At the same time the straw balers became commonplace. The bales were stacked up like giant bricks and plastered for protection against fire and the depredations of stray cattle (Welsch, 1972).

More recently, clean air laws have left farmers in California with waste rice straw, which they had previously burnt, causing large-scale air pollution. Straw bale construction has several advantages:

- It is made from a waste product.
- It is light and easy to handle.
- Its thermal resistance R-value of 6 to 8 is extremely high.
- Once plastered, it is very fire resistant.

Straw bale construction does not have much structural resilience so like earth buildings it must be tied together at the top of the walls to resist lateral forces, usually by timber beams connecting to vertical rods through the straw. Structural difficulties can be avoided by using the straw bales as infill panels to timber post and beam construction.

Because straw bales are very vulnerable to damage by moisture, the methods of keeping the water out must be carefully checked when assessing the adequacy of a straw bale. The durability requirement in New Zealand for straw bales when used as infill panels and not as a structural element is 15 years. If the straw bales are kept dry, a durability of 15 years is easily achieved and the straw will continue to act as a very good thermal insulation for that time. The essential requirement is to keep the straw dry. An useful analogy is to treat the building like a person who needs to have a good rain hat, coat and gumboots for protection against a storm.

The list of critical factors to show compliance is very much like the list for earth buildings with a few additions:

- Foundations that have an efficient damp proof membrane (DPM).
- A floor high enough out of the ground to prevent flooding in the 50-year storm.
- Low moisture content in the bales (this can be checked with a moisture meter using a long probe used by farmers when stacking hay).
- A good plaster system over the straw to protect it from wind blown rain and normal wear and tear, (NZS 4251:1998 is a good reference for specifying the proportions, mixing and curing of cement plaster even though it does not include straw bale construction).
- Contraction joints in the plaster to prevent cracking.
- A protective coating that resists moisture but is permeable to vapour in order to seal the surface and any small cracks that will occur in spite of all due care.
- Adequate flashings at all openings.
- Sloping window-sills (with a water proof membrane under the plaster to shed rainwater).
- A roof that does not leak.
- Wide overhangs to shelter the walls below.
- A good maintenance programme.

APPLICATION TO 3RD WORLD COUNTRIES

This paper has discussed alternative materials in terms of their use in New Zealand. The climate in New Zealand varies greatly from dry to wet, from snow and the terrain differs from sea level to mountains, from plains to rolling hills. There has not been a situation yet where the flexibility of the code cannot cope with the diversity of the climate or terrain. Even the diversity of our cultures can be catered for.

Some of the performance criteria are biased towards problems experienced in our climate and other requirements of our largely European-based society. Third-world countries would need to be aware of their own situations when writing performance-based codes. Because of the flexible nature of such codes, however, they are not likely to differ much from country to country. Performance-based building regulations are the appropriate framework for facilitating the further development and use of appropriate materials and methods of construction consistent with heath and safety. A durability clause within that framework provides a measure that can be relied on to ensure that the performance will be met.

In particular the durability period chosen by NEW ZEALAND will in all likelihood not be appropriate to other countries, based as it is on our particular types of construction and people's expectations. Local materials and customs may dictate shorter or longer durability requirements. The UK (building mostly in brick and other durable materials) standard, BS 7543:1992, categorises the design life of buildings into temporary, 10, 30, 60, and even 120 years for civic and other high quality buildings. Certain types of thatched roofs in Fiji have been shown to last 10 years if treated. Such factors could dictate the durability requirements. A third-world country, faced with large numbers of the population housed in conditions of poor hygiene and inadequate shelter could choose a short period in order to lower the cost and speed up the construction. A short-term durability period could be decided upon in order to clear up slums, refugee camps or disaster areas, while giving a breathing space for more lasting solutions to be designed, built and paid for.

There are existing projects that would have been more easily carried out in response to a performance-based regulation. There is also potential for as yet experimental systems to be used under performance-based regulations.

Earth Building in Fiji

An example of an existing project that could have been handled more easily with a performance-based code is the Rotacottage, commissioned by Rotary International for the Ba district in Fiji (Thomson, 1999). Land leased from the Fiji government designated for 'Shelter Housing' for the homeless and destitute families in the Ba District, a prototype was designed to use compressed earth bricks and to be made and erected by the local people from local earth.

Testing of soils done by engineers in NEW ZEALAND experienced in earth buildings showed that the soil, being volcanic, had little clay or fines and so required stabilising with 10% cement and 10% sand. The cottage was designed to encourage airflow through the building with cross ventilation and gable-end roof ventilation. All engineering calculations for the specification complied with the NEW ZEALAND Loadings Code NZS 4203, a verification method for the NZ Building Code structural requirements. Natural ventilation was provided by cross ventilation through openings in the walls, shuttered for shelter in storms, and with ventilation in each gable end of the roof, not only contributing to the ventilation and cooling but also having the effect of negating the wind pressure differential that is the major cause of damage in cyclones. This feature is, in effect, an alternative solution for fixing down of roofing material. The calculations on fixings used for that roof would be based on not only the strength of cyclones experienced but also the likelihood of the return event (Stuart 1999).

There may be some doubt about the durability of earth bricks in this area, although it is the dry side of the island, since the location experiences high humidity and torrential rain at certain times of the year. The points used in New Zealand to assess the durability of earth buildings would have been useful here and maintenance factors such as the ability to keep lush growth away from the walls become important.

Earth or mud buildings have traditionally been used on the Indian sub-continent, the Middle East, and most parts of Africa. With the right regulations we should be able to revive traditional methods where they have lapsed, and improve the standards in cases where poor practices have given them a bad reputation.

Other Traditional Materials

Underground buildings have been used in centuries past in countries such as Turkey and China. There are cave dwellings in the agricultural uplands of Tenerife in the Canary Islands. At the opal mine fields of Coober Pedy in Australia, underground caves are particularly pleasant to live in while avoiding the hostile surface environment. Modern earth shelters are now being used by energy conservationists to take advantage of the earth mass's moderation of climatic extremes of cold winters and hot summers in both North America and the UK.

New Materials

Rice straw and bamboo, materials that are abundant in some third-world countries and may even be waste products, could be reliably and quickly assessed for use under performance-based building regulations. Straw has been used in bales as mentioned before, both for infill and structural buildings. It has also been used for making sheet board materials (Hammer and Richert, 1999). With appropriate protection in order to achieve the required durability, such boarding could replace more expensive imported sheet board materials or could be used instead of less sustainable timbers that when felled could destroy the environment. Bamboo has similar, albeit lower, strength properties to steel. Could those properties not be harnessed as a quick growing renewable building resource?

Waste products of a different scale are those modern rejects of an affluent society. Refrigerated containers are such an example. Already insulated and waterproofed, they could be converted to modular housing. Stacked and locked together in various patterns to provide communities, they could have a measurable and cheap durability.

CONCLUSION

Barclay (1987) called for building regulations that can "facilitate the further development and use of appropriate materials and methods of construction consistent with health and safety requirements." Performance-based building codes, when used with a measuring stick such as the New Zealand durability clause, allow for the following:

- Flexibility;
- Encouragement of the development of building materials;
- Aiding improvements in construction methods;
- Using local materials and labour;
- Taking into account local conditions and customs; and
- Satisfying urgent demands for shelter.

Performance-based building regulations measured in terms of durability and combined with lateral thinking could be the solution. We think that we can tell a success story for performance-based building codes in NEW ZEALAND . As demonstrated in this paper, these controls could be adapted for use in third-world countries in the new millenium.

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The Danish experience from 10 years of productivity development

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Abstract

Over the last ten years a number of sector analyses and development programmes have been carried out in Denmark with an aim to increase productivity within the building sector. This has been undertaken in a continuous co-operation between the authorities, the research institutes and the industry itself.

This paper reviews this development and highlights positive as well as negative experiences. From the review, it appears that a systematic increase of productivity is possible. However, it is also apparent that there are barriers that have to be surmounted, if a successful change from craftsmanship into a modern industry shall take place. The experience gained is concluded in seven pre-conditions, which have to be fulfilled for a development programme to give permanent results.

Keywords: *productivity; development; re-engineering; Denmark; programme administration*.

INTRODUCTION

Since World War II, Denmark has established a widely recognised tradition for developing the building industry through a co-ordinated effort between the government, the building research environment, the customers through the social housing associations, and the industry itself (Nielsen and Bertelsen, 1997). In the 1960s this effort resulted in the Open Danish Building System, a highly efficient prefabricated and modular co-ordinated concrete slab system, capable of providing high quality housing at low cost. The system became an inspiration for the development of industrialised building systems over great parts of the world (Nissen, 1972).

In the 1970s the high rise dwellings went out of fashion and the Danish building sector had to introduce a complete new product almost overnight, and most of the processes on the construction site were transformed. Even if the modular co-ordination was still in operation, making it possible to keep the manufacturing of building components such as cupboards, windows and rafters as industry, productivity went down in accordance with the trades' return to the construction sites. Building went to some extent from industry back to craftsmanship.

Today, an understanding of the loss by this transition is growing in Denmark. Several initiatives have been taken to raise the building site productivity again but the road back is rough. Not only are the concrete high rises a scaring example of the architecture of yesterday – and few love their parents' ideals – but social problems in the 1960s' new urban areas add to the dislike too. Moreover, the efficient industrialised building systems are blamed for the problems. However, a new understanding seems to be on its way.

This paper reviews for the first time the more important productivity development programmes and sector analyses undertaken, in progress or planned, within the Danish building sector during the last fifteen years. Based upon this review it outlines some pre-conditions for the establishment of successful programmes for the development of the building sector. The paper is based mainly upon the authors' first hand experiences as participants in the work, as no formalised research in the subject has been undertaken as yet.

DANISH PROGRAMMES AND ANALYSES – A HISTORIC VIEW

Redevelopment of the multi-storey housing

This competition for Re-development of the Multi-storey Housing was launched 1983 by the Ministry of Housing. The idea was to give new life to industrialised building of high-rise dwellings by new structural systems allowing more flexible use of the buildings.

The winners proposed a plate-column system which combined with the prefabricated component production led to a substantial technical development in order to solve the structural problem with force transmission from the corners of the slabs to the columns.

The programme was reviewed 10 years after the competition at a time when 12 buildings had been erected (Boligministeriet, 1994). This unimpressive number indicates that the use of the principles met with some barriers. Most important were the technical and economical barriers. Due to size restrictions for components to be transported and need for structural strength at column-slab connection, the structures became too expensive, compared to the limited freedom obtained in the dwellings between the many columns.

However, the programme started close co-operation between companies interested in sector development.

The Ministry of Housing Development Quota

Since 1989, a portion of the government's social housing scheme has been reserved for experimental projects in either the area of product or process development. It was a deciding factor at the outset, that the industry participants in the experiments should play a major role to ensure the use of the results in their future building projects. At the same time the industry participants should carry the major part of the additional costs associated with the development. Priority was given to the testing of building systems or the building process as a whole, instead of the development of components or tools.

A wide range of ideas has been tested under this very broad programme making the target hazy. However, two projects stand out clearly as a basis for further productivity development. One was the development of the Building Logistic principles introducing a completely new approach to the materials management, inspired by the Japanese Just in Time philosophy (Bertelsen and Nielsen 1997). The ideas were successfully tried out in a series of six consecutive projects from 1992 to 1996 demonstrating a productivity gain of approximately 10 percent (Agapion et al, 1998).

The other project was the development in 1991of a new building system – ECO-byg – based on steel frames and gypsum panelling as an alternative to the prefabricated concrete structure normally used in the Danish housing projects. Besides being cost effective, this new system turned out to provide higher insulation, better indoor climate, as well as a reduction of noise transmission between apartments.

Even if these two projects were successful as experiments, they had very little impact on the building sector as such. The 'ownership' of the Building logistics principles was not clearly established, meaning that companies capable of, and willing to, utilise them were not identified wherefore all went back to normal practise once the experiments were completed. And the ECO-byg system did not find a commercial market outside the development quota. However, the two experiments were to become a major part of the basis for the later PPB-programme.

The Technological Counsel's Programme for the Data Exchange in the Building Sector

This programme, jointly financed by the Ministry of Industry and the building industry, was carried out in 1990 to 1994. It involved a great number of companies from the industry, who also undertook the management of the programme. Its objective was to establish standards, procedures and recommendations for the exchange of digital information in all phases of the building process.

The programme established the basic infrastructure for the use of information technology within the building sector, with a focus on the very important exchange of data between the participants. At the same time it caused the establishing of a Danish organisation for the users of Electronic Data Exchange (EDI) within the building sector. By this, the programme became the basis for the Ministry of Housing's recent recommendation for the data format of electronic as-build information. The programme was also a major prerequisite for the development of the inter-firm use of IT in the later PPB-programme.

Double Up

Between 1991 and 1993, the Danish Association of Consulting Engineers undertook a study of the development potential in the Danish building industry. The study was supported by the Ministry of Industry. The objective was to investigate ways and means to improve the productivity at least to the level reached during the industrialisation in 1960s without any loss in quality. The specific aim of the project was to exploit the booming German market (F.R.I, 1991).

Strongly inspired by the work of the American economist professor Michael E. Porter it was proposed that the building sector should be viewed as a whole, including the building materials manufacturers and whole-sale dealers in the sector (Porter, 1990). It was recommended that the domestic building projects to a great extent should be looked upon as vehicles for a further development to strengthen the industry's competitiveness. A demanding home market should be seen as the source of ongoing development of competitiveness.

It was further recommended that the building industry should establish permanent supply chains through vertical integration, making learning from past experiences and the development of new procedures easier. The analyses outlined a new role for the wholesale dealers as masters of logistics. It was found that this stronger co-operation could raise productivity dramatically, ease the usage of information technology and improve product quality. The study indicated potential productivity gains in the order of 20% and potential savings in the materials costs of the same magnitude (F.R.I, 1993).

Even though the project itself was abandoned before it turned to full-scale experiments, consecutive programmes and studies have been strongly inspired by the Double Up work.

The Cluster Analysis

In 1992 the Ministry for Industry launched a broad analysis of the entire Danish Industry divided into eight clusters inspired by Michael E. Porter's ideas as expressed in *The Competitiveness of Nations* (Porter, 1990). This study viewed for the first time Building and Domestic Housing as a whole, making manufacturers of building materials part of the industry. Up till then, these industries had been considered part of 'manufacturing based on wood, metals or stone' respectively. It was recognised that the export from the sector by this definition was surprisingly high, a fact explained as a result of early and systematic industrialisation (Erhvervsfremme Styrelsen, 1993).

The analysis suggested a number of initiatives aiming at increased productivity and competitiveness nationally and internationally. Three specific programmes were recommended. First, a systematic development of the building renovation process in order to reach the productivity level of new building – Project Renovation. Second, a development of the product and process with a focus on better product quality and a higher productivity, based upon long-term co-operation between leading firms within the industry – The PPB-programme. And third a long-term, overall programme – Project House – to rethink the whole industry.

With minor modifications these recommendations became the guiding light for the following developments.

Project Renovation

The European preference for preserving and renovating older buildings instead of demolishing and reconstructing has introduced new needs for the development of the building sector productivity. This is the background of the Project Renovation, launched by the Ministry of Housing in 1995.

Project Renovation is a major effort comprising more than a hundred individual projects. It looks into a wide range of problems covering the development of new components, new processes and new forms of co-operation, as well as new management tools. Most of the projects comprise development combined with full- scale testing in practice (Boligministeriet, undated).

The programme is near its end and it can be observed that a wide range of new and very useful experience will be gained. However, the programme was fairly broad in its scope and the individual initiatives only little co-ordinated. Also, the projects were selected on a competitive basis among ideas proposed by the industry with only a limited analysis of the needs. As projects and participants were selected on their creative merits mainly, lesser emphasis was put on how to transform the developed ideas into practice. At the end of the programme period this leaves a need for an extra effort to bring the results into daily use.

The broad scope with many participants has given the programme a firm foundation within the industry, and through a very professional communication of the results, the programme has put focus on the need for developing the renovation sector under its own programmes. On the other hand, the many and very different ideas combined with a programme period of five years only, has on very few occasions made it possible to try out the ideas in more than one case. By the end of the programme it was recognised that short series of experiments for each idea might give rise to an unforeseen problem: Who will carry on the development and, in particular, make sure the results are implemented in practice? This very important issue of the ‘ownership’, as it was named, has become very much the focus in the latest Danish development efforts.

The Process and Product Development Programme

The PPB-programme was initiated in 1994. It comprises four consortia consisting of at least an architect, a consulting engineer, a general contractor and a building society, that try out different strategies in developing a new approach to the building process. The target is mainly domestic housing but the results will be applicable to a wide range of projects.

The four consortia were selected through a competition where the participants’ different approaches demonstrated the wide range of possibilities. One of the winning consortia proposed to try out a completely new building system based on steel and gypsum. One consortium went even more off the road, proposing the usage of wood within domestic housing in buildings up to five floors. Unbelievable in Denmark where fire regulations up till then permit the usage of wood in single dwelling houses up to two floors only. The remaining two consortia tried the same new approach to the organisation of the building process: they divided the task in accordance with building parts and systems instead of the usual division into trades. One of these groups reorganised the trades into ‘process units’ i.e., groups comprising all the skills – including design capabilities – required for the building part in question, for instance the roof, the bathrooms or the heating system. The last group made the same division of the building but made contracts with existing manufacturers capable of supplying each of the subsystems in question under independent design, manufacture and install contracts. This approach is very much inspired by the Japanese car industry.

A common feature within the four consortia is vertical integration – i.e. partnering covering a number of projects. Also, the development programs for all four consortia include integrated use of IT, efficient logistics in the supply of building materials and up to date quality assurance programmes for work on the site (Erhvervsfremme Styrelsen 1995).

Even though the administration of social housing were transferred from the governmental agency to the local municipalities at the same time as the programme was launched, thereby hampering the market for the development, the programme is now well under way. By the middle of 1999 all four consortia had completed their first building projects and more were under construction. The groups have all experienced more trouble than expected, but it seems that at least three consortia will complete their development in accordance with the over all schedule. However, all four consortia have learned that making the building process more efficient is a long haul effort. None of the groups have so far reached their productivity targets as they envisaged them at the start of their effort, but they have indeed opened roads to a higher level of efficiency. This shows once again that the introduction of a new approach or new building system is very hard work, and it is doubtful whether more than one of the groups will benefit in the long run from the effort, if no further measures are taken. Initiatives to this end are discussed in the following section.

Also, all the groups have met difficulties in establishing a smooth co-operation because of the need for a changed behaviour by all the participants, a phenomenon often observed in partnering projects. In future programmes this problem should be envisaged and management involvement ensured from the very start in order to ease the problems in the day-to-day co-operation.

However, the PPB-programme has demonstrated the value of initiating a sequence of building projects over a number of years. This is of particular importance when the development involves a change in attitudes and a different behaviour by the participants, for instance in a partnering arrangement.

Using the Manufacturing Industry's Methods in the Building Industry

The Danish Academy of Technical Sciences – ATV – launched this study undertaken by a group of key persons from manufacturing industries and from companies within the building sector in 1997. Research in production methods at the technical universities was included in the work as well. The aim was to study to which extent the manufacturing industry's product development and manufacturing methods can be applied to the building sector. In some ways this is the approach of the Lean Construction Initiative, but the study is broader in its scope as it also considers manufacturing of buildings as a product. And it looks into the market conditions and the surrounding legal and administrative frameworks as well.

The study does not go into depth of the matter. Its objective – like other ATV studies – is to outline the potential, inspiring others to pursue the ideas (ATV, 1999). The study report shows that a lot of inspiration can be found in the manufacturing industry methods. The systematic planning of product, process, the logistics, delivery and service which is characteristic of the modern industry can beneficially be introduced in the building sector. The same goes for the industry's practice of long-term co-operation and redistribution of tasks in order to maximize the competitiveness.

The report recognises that such a transformation of the building sector can not be made solely by the sector itself, in particular not in a highly regulated market as the Danish. The client's behaviour must be changed as well and the legal framework governing building must be adjusted accordingly. The report presents a scenario for a 'marketplace' i.e. a procedure for choosing the supplier of a social housing scheme based upon a competition between a number of invited consortia. The process emphasises a new way of co-operation between client and supplier and makes other parameters than the offered price and product quality part of the selection of supplier. Past performance, process management and procedures are also important criteria.

The report also opens a number of key issues and through its review of the expected customer and authority requirements to the house of the 21st century, it clearly points to the need for a re-organisation of the building process based on industrialised components.

‘Project House’

Inspired by an earlier very successful development project: ‘Project Ship’, looking into the development potential within the traditional commercial vessel, the Danish Ministries of Trade and Housing, in 1999, launched a similar project looking into the development potential within the housing sector (Boligministeriet 1998).

The project is still in a very early phase, but is has been recognised that there is a great difference between the manufacturing of vessels and that of houses. Also the structure of the industries, as well as the business practices, are different. It has, therefore, been decided to look more into the building process in general in this programme – where ‘Project Ship’ focused upon some critical features, particularly cost of operation of the ship of the future. The objective of ‘Project House’ is: *To produce double value for half the cost*. This is a very ambitious goal to set and probably most of the participants in the programme committee will be happy if only a fair proportion of the target is reached.

The general approach is heavily inspired by the industrialisation of the building process, which took place in Denmark after World War II (Bertelsen, 1997). It is to get the leading companies in the building sector to co-operate in the development of a higher productivity, using methods taken from the manufacturing industry as well as lessons learned from the recent years’ development efforts within the sector itself.

A special focus within the programme is the needs of the customer. It has become evident that a potential increase in productivity is connected to a better fit to what the customers want and are ready to pay for. This puts the client into a key position within the programme as the representative for the coming users and as the critical buyer who can ask for and enforce an efficient production of his/her buildings.

Putting it all in Perspective

The Danish development effort over the last fifteen years seems to demonstrate the benefits derived from an alternation between analyses and experiments. But it also demonstrates the need for a long sequence of initiatives, and for the experiments to be stretched out for more than a few consecutive building projects.

The first experiments with Multi-storey Housing and the Development Quota were isolated projects where new methods were tested. Project Renovation was the first major programme that – loosely co-ordinated – put a number of players into action at the same time. The Double Up Study and the Cluster Analysis reviewed the results and put focus upon the importance of long-term co-operation and laid the groundwork for the following programmes.

The PPB programme had adequate continuity but comprised fewer participants. The development efforts were co-ordinated and the programme’s control system made the participants aware of their obligations to develop. Finally, the ATV study highlighted the results and, in particular, emphasised the importance of the client’s participation as well as the inspiration to be found in the manufacturing industry.

It may seem that there has been too many and widely spread experiments, not only in their content but also in the way the programmes have been arranged. However, it is the authors’ opinion that such a form is necessary when a whole but highly fragmented industry shall explore new ways of operating.

The upcoming Project House can be seen as the final block in this development process. Here a heavy involvement from a great proportion of the industry is expected, based upon the results from the previous fifteen years’ experiments. It looks like all parties agree that a new approach must be made. It has taken fifteen years to reach this understanding but that is probably the time frame one may expect when the objective is to change the industry behaviour.

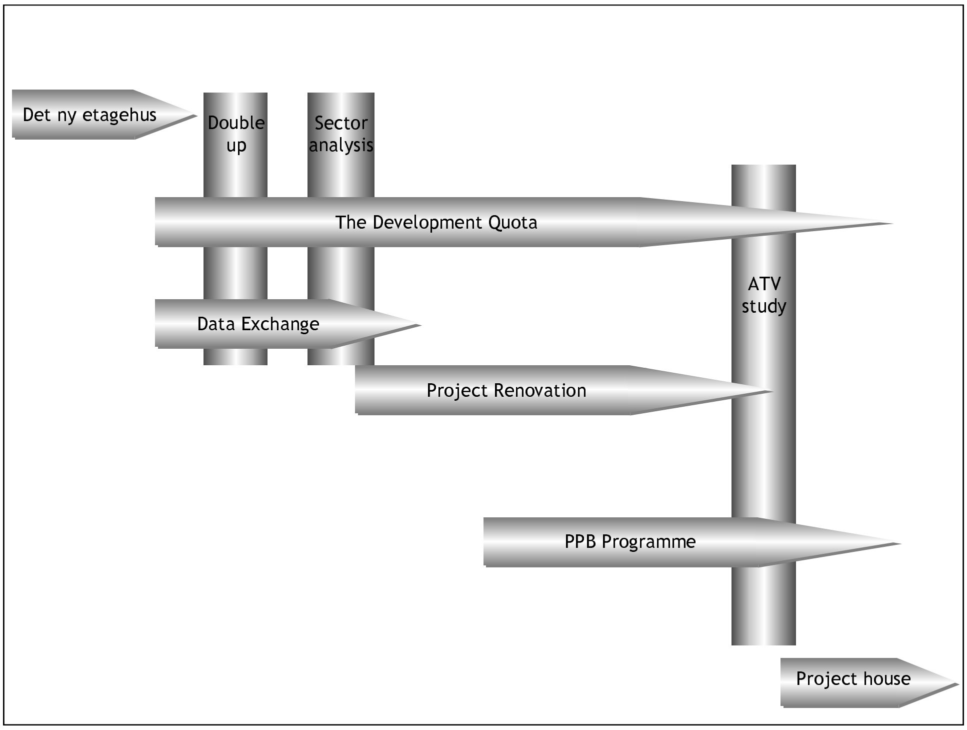

Figure 1. The relations between the programmes

DEVELOPING THE BUILDING SECTOR

Setting a Target

It is important to recognise that a fundamental change of the building sector with an aim to increasing productivity will call for a complete re-engineering of the industry to change its traditional behaviour. At the same time a significant number of customers must be asking for a changed delivery of its products. The entire framework guiding the sector must be changed accordingly. These pre-requisites will be dealt with in the following sections.

The actual choice of a national strategy is outside the scope of this paper. However, two different approaches seem possible when re-engineering of the construction industry as done within the PPB-programme. One is to industrialise the processes undertaken at the building site as tried out in the Building Logistics experiment and by one of the PPB-consortia. This strategy can be seen as an implementation of the lean construction principles (Howell and Ballard, 1998). The other is to look upon the building as a product to be manufactured and consequently making building an undertaking based mainly on prefabricated components, as tried out by another PPB-consortium. Both approaches have been investigated in praxis in the Danish development and as both seem to have their advantages, both should consequently be taken into serious consideration. The authors' expectation is indeed that the final outcome will be a mixture of the two.

However, it is of importance to stress the need for analyses before the start and during the process, particularly before the final strategy is chosen. These analyses should highlight the needs and evaluate the results and concentrate on the following development efforts trying out the ideas in full.

Firm but Flexible Programme Administration

The development of the building sector is a long process. The Danish experience from almost fifteen years' effort shows that it is possible but also that an effort of less than ten years duration will probably not result in permanent changes.

On the other hand, one should not establish one comprehensive programme aiming at changing the whole sector but rather a long line of initiatives. Some of these may be more successful than others. Indeed, some may even be considered fiascos while running, but must be seen as necessary mistakes in the global picture. However, it is important that all initiatives are based on all experiences gained up to their launch and that the evaluation of their results is based more upon the lessons learned than upon the expected results at the outset.

The programme administration must – jointly with the agents in the experiments – master the art of abandoning seemingly excellent ideas not working in practice, an art requiring deep understanding of the nature of the building sector. On the other hand, a lot of patience is needed. Ten to fifteen years to mature basically new ideas or to change the behaviour within the building sector is not a very long time.

Selection of the leading participants in the experiments is a matter of confidence, which cannot be undertaken by promises or by traditional tendering only. Past performance – be it good or bad – is probably the most important parameter. If the programme conditions are as favourable as they need to be, the temptation to promise a lot to obtain the associated construction contract may be high, and the penalty for not undertaking the experiment very hard to impose as the financial risks in the construction task itself are much higher. Therefore, a skilled and competent day-to-day programme management is of great importance to keep the agents reasonably on track. However, the programme administration must also, particularly when a programme comprises changing of the participants' behaviour, be flexible, giving the participant leeway to navigate as they deem best, as long as they move towards the over all target in a manner fair to the programme intentions.

The Danish PPB-programme has introduced a formal control system of monitors *ie,* persons with expertise within building practise who are assigned to follow the development effort closely to make sure the process is kept on track, but also to advise the programme administration whenever change in scope is necessary. This system seems to work fairly well, particularly when division of responsibility between the management of the experiment's building projects and the monitor is clarified from the very beginning.

Establishing Ownership

The very nature of the building sector and of its processes makes it mandatory for the programme administration to ensure ownership of results. By the term 'owner' we mean firms, institutions or authorities who are willing and capable of integrating the results in their operation, thereby becoming the acting agents in the sector transformation. Without such owners the programme will probably give a lot of positive experience, but also frustrations because seemingly good ideas are not used after the programme termination.

One of the major players in the Danish renovation process is the publicly owned Copenhagen Renovation Society, which acts as administrator for a great number of renovations projects. They are as owner continuing the work of Project Renovation through their own 5-years programme for the development of the productivity – the 'Toolbox'. The general idea is to develop and implement a new set of management tools, organisational and contractual arrangements as well as business procedures following the principles outlined above. This work will be undertaken in close co-operation with a number of their business partners as well as with the Danish Building Research Institute. It is foreseen that the main result in the first hand will be an increase in the contractors' earnings but it is envisaged that this later on will cause lower bids. In addition, higher quality, shorter project duration and more reliable scheduling are expected outcomes.

Catching the Results

A special topic to consider is how to measure the effects, particularly the short-term results. Building projects are generally unique so where is the basis for comparison? In the longer perspective general indicators from the national economy will probably show any increase of the sector's productivity, but this may not be sufficient for the programme administration or indeed for the participants. To this should be added that measuring detailed production figures and particularly establishing formalised benchmarking systems in not a normal practise within the building sector.

As the key issue is to improve the productivity and quality on the construction site, and as construction managers are very busy people indeed, the measuring they have to undertake should be engineered to be directly beneficial to their day-to-day work, for instance, by highlighting the indicators of good or bad practise. It may be systematic reporting on the number type of change orders and unforeseen events. It may be weekly evaluations of the order or disorder on the site – to be presented to the workers, or it may be systematic measurement of the amount of waste removed from the site. Also the deviations from production plans tell a lot about efficiency. Even if such measurements do not comply in accuracy with demands from research, they put focus on the actual problems.

Other than that, more ambitious methods may be implemented as a supplementary source of information, but undertaken by a third party in order not to disturb the daily operations. In the Toolbox programme outlined previously, three levels of measurements have been identified: The operational level as outlined above, the intermediate level where the measurements result in reporting while the job is on hand, for instance, frequency studies and performance measurements for whole parts of the building, and the final level where measurements are based upon analyses of the actual costs as reported by the end of the project. San Martin and Formoso (1998) outlines some more formalised methods, which may also be of interest to try out not only in individual projects, but integrated in wider programmes.

In any circumstance, a good piece of advise is to measure what can be measured, to count what can be counted, and to register the rest. This process in itself will give a lot of understanding of the nature of the problem.

Creating a Market Place for the Re-engineered Building Sector

A fundamental change in the building sector behaviour must probably arise from a demand from the customers. The client must still require a high product quality but he must at the same time organise his procurement process to stimulate the formation of a desired new kind of co-operation and the new division of responsibility. To this end it is important to understand the mechanisms guiding the behaviour of the participants in the building process as dealt with briefly later in this paper and in detail by Thomassen (1999). Once a traditional design and build contract is won, the contractor's prime interest turns toward maximising his own profit, leading him to seek the lowest bids from the subcontractors, a behaviour which not necessarily leads to a better co-operation and definitely not to long term alliances. New contractual arrangements must therefore be developed to suit the local contractors and their actual capabilities, as well as the need for change and development of new qualifications.

It might seem peculiar that the client in this way has to interfere with the organisation of the process giving him his desired product. But as long as building is mainly a service industry, where the services are provided in a divided form, this has to be the case. As building becomes more and more based upon prefabricated components, this situation might change, but in today's market this is not the normal situation.

The Danish Association of Social Housing Agencies has decided to try out in practise the principles outlined in the ATV-study. Their idea is to invite the four consortia formed under the PPB-programme to participate on a new market place, where they gradually over a five year period will establish a true competitive procurement process based upon a product delivery by firmly established teams. Over this five-year period not only the competition will be increased between the consortia, but the market place will also be opened up to further participants.

Changing the Frameworks

The building process is highly complex. The reason for it not ending up in total chaos is probably the frameworks guiding the process and thereby making it less complex in practice.

Talking about frameworks, we do not mean only legal and technical rules. We also think of mental, cultural and habitually structures that guide us through incalculable possibilities and problems. These frameworks have emerged as the product of a long history where we learnt from experience and – often without knowing it – changed our behaviour accordingly. In stable periods, this framework is very beneficial, and we could probably not live without it. But in re-engineering it causes problems, because the process no longer corresponds with the problems the old frameworks reflect. We do not, and are not supposed to think of these guiding structures in our daily routines. Actually, we only discover them when we try to change them. But then we certainly come to recognise the shape and magnitude of the frameworks in which the building project is embedded. This is an area which has not been scientifically addressed in the described programmes and which needs more research.

It would be obvious to point to the *legal framework*. One important aspect of the ATV-study's proposal is that it allows competition on past performance and not only on quality and price. However, the tender regulations in Denmark and EEC are created in order to ensure price competition mainly. This makes it hard to replace one-off price competition with long-term relations based on collaboration. Also the rules for arbitration and for the correction of defects reflect the traditional trade-based building process. Probably this will also be the case in most countries having a legal framework guiding the tender process in construction.

Administrative procedures are another framework that may conflict with the new ideas, for instance, the rules guiding social housing projects in Denmark. Also the piece rate system hinders a re-organisation of the building industry. Firstly, the rates are based on previous experience. When doing things in a new way, none of the parties know how high, or how low, the rates should be. Secondly, piece rate payments are based on the idea of specialisation – i.e. the work is divided into clearly distinct operations. Integrated manufacturing changes this approach and thereby makes the piece rate system useless.

However, the main barrier seems to be *the way we think*. The barrier formed by this mental framework is so important that it is dealt with in its own subsection, but it deserves its own papers based upon its own research.

But the worst thing about the frameworks is probably not their magnitude or the need for changing them, but the need for *changing them all simultaneously*. If just one of the frameworks is still there, the new system will become dysfunctional, and the logical strategy from the individual party's point of view will be to go back to the old well-known ways, making the whole effort of re-engineering futile.

Developing a New Culture

Thomassen (1999) characterises the co-operation within building project as being captured in the Prisoners' Dilemma: All the other participants must co-operate loyally if it shall be beneficial for me to do it. If the others cheat, it is better for me to cheat as well. Within the complex nature of the building project this dilemma leads to a situation where co-operation is almost non-existent. This must be seen in the light that a great deal of the obvious methods for productivity improvement require an effort from other parties than the one getting the benefit.

Going from tough price competition between trades to long-term co-operation between manufacturers requires a completely new way of thinking throughout the industry. Even if all the participants are aware of being in a partnership, it is very tempting for the individual to give some assignments to outsiders that appear to offer lower prices. Such behaviour completely ignores the benefits of the partnership, but seems logical from the traditional price competition framework's point of view. Correspondingly, experience from another – not yet reported – Danish innovation programme shows that the sub-contractors do not grasp the possibilities of affecting their building process. They are so used to a situation where the final responsibility for the detailed design and for the process organisation belongs to the professionals.

As mentioned earlier, development in itself will not suffice, an 'owner' for the results must be found. In the manufacturing industry the owner is normally obvious, but this is not the case in the process oriented building industry. Also clients being used to interfering with the building process may find it hard to accept that they more and more are buying products and not processes.

All these practises are so well established in the culture of the industry, that the radical change needed will call for a deep change in the mindsets or for complete new players – probably for both. This is not an organisational barrier only but a mental one. Barlow (1998) questions whether the existing contractors in the building industry will be able to manage this change in the sector's behaviour and how this process can take place. He further wonders whether a better solution would be to stimulate the establishing of a completely new kind of firm, capable of managing the whole building process and putting the customer satisfaction clearly in focus?

CONCLUSION

The Danish experience is that the development of the building sector productivity is possible but also difficult. It is basically a re-engineering effort calling for a change of behaviour, which must be undertaken as a long process. Close co-operation between authorities, programme administrators, owners, building researchers and the industry itself is mandatory.

Further, the issues listed below need to be addressed.

- The target must be clear and focused to suit local conditions. Also programme administrators must be firm in keeping to the objectives, but flexible in their programme administration.
- The 'Owners' of the results – i.e., companies, clients, authorities or institutes – who can, and want to adopt the results and use them, must be identified and involved from the very beginning.
- A number of competitive suppliers who are organised 'industrially' – i.e. organised in a way that allows 'organisational learning' – must exist.
- A market must be established – i.e., buyers who understand the need to support the development by 'buying' untraditionally.
- Business frameworks stimulating a changed behaviour must be ensured.
- In the course of the development a simultaneous motivation and involvement of individual persons in all the acting 'companies' must be established.
- A prolonged development process – i.e., more than 10 years – must be expected and the programme duration set accordingly, especially in connection with complex issues such as change of roles and processes.

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Partnering - an Experience of Nepal Engineering College

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Abstract

Construction projects are complex in nature because of generally long project duration and the use of many kinds of materials, equipment and manpower. Sometimes, the obvious errors in the contract document create ambiguities which lead to disputes. Such disputes consume lot of resources and time for both the employer and the contractor. Therefore, suggestions have been made to adopt contract documents which would ease contract administration. However, disputes are not minimized. Therefore, a concept of partnering on project management has emerged. Nepal Engineering College (NEC) adopted this concept for constructing its infrastructure at the Changunarayan Village Development Comittee, Bhaktapur, Nepal.

This paper reports on the development of the College. The project was completed in seven months and the college moved into its premises on July 16, 1997 from the rented property at Kupondol. The experience of the college is that there was no dispute, no claims, no time loss, hence overall gain in cost saving and increase in the level of confidence of employees and students.

Keywords: *construction management; contracts; disputes; delays; partnering*.

INTRODUCTION

Nepal Engineering College (NEC) was founded in July 1994 under the private sector but as a charity organization. It was housed in a rented property at Kupondole of Lalitpur, a town in Kathmandu valley. The academic programme started from September, 1994. In March 1996, almost 9 ha of land was donated to the college by Changunarayan VDC of Bhaktapur District, also in the Kathmandu valley, 20 km from Kupondole. The College also purchased about 1/2 ha of land nearby. The first phase of construction work started in December 1996 and was completed in July 1997. The college moved to its newly built premises at Bhaktapur in July 1997.

NEC COMPLEX

The development of the College's infrastructure was planned in a phased manner with the resource generated from the college - mainly students' fees. Low-cost building materials and technology were adopted. No grant is accepted to construct the buildings and other infrastructures mainly because NEC believes that grants will not help in sustaining the infrastructure. However, grants are accepted to establish scholarships for the students.

In the first phase, the following were constructed:

Administrative block	300 x 2 = 600 m^2

Class room blocks	500 x 3 = 1500 m^2
Laboratory blocks	240 x 4 = 960 m^2
Resource centre	430 x 1 = 430 m^2
Girls hostel	766 x 1 = 766 m^2
A basket ball court	
Deep well and pump house	
Generator house	

Total cost of first phase construction work is approximately US$ 800,000. Second phase of construction was scheduled to start in October 1999. Further expansion of the college is being planned.

NEC project is not a large project. But in a country where a project of the size of the NEC generally takes 2 years to develop, and are rife with disputes and litigations, Phase 1 of the NEC was completed in less than seven months and without any conflicts and problems with the contractor.

PROJECT ORGANISATION / PROCEDURE

NEC appointed its Research and Consultancy Division as the consultant for design and supervision work. After completing the design, a construction supervision team, consisting of a project manager and a supervisor, was tasked to complete the project in September 1997 when a new academic year would start. A class 'B' contractor was appointed through close bidding, whereby four reputable building contractors were invited to tender. The successful contractor's price was 18 % higher than the lowest bid. The capacity of the contractor was one of the main criteria for selection.

NEC gave the team leader all the necessary authority. It was comfortable with this because the team leader was a member of NEC (see organization chart in Fig 1). This paper was written based on the author's experience in this project, as the Principal of the College.

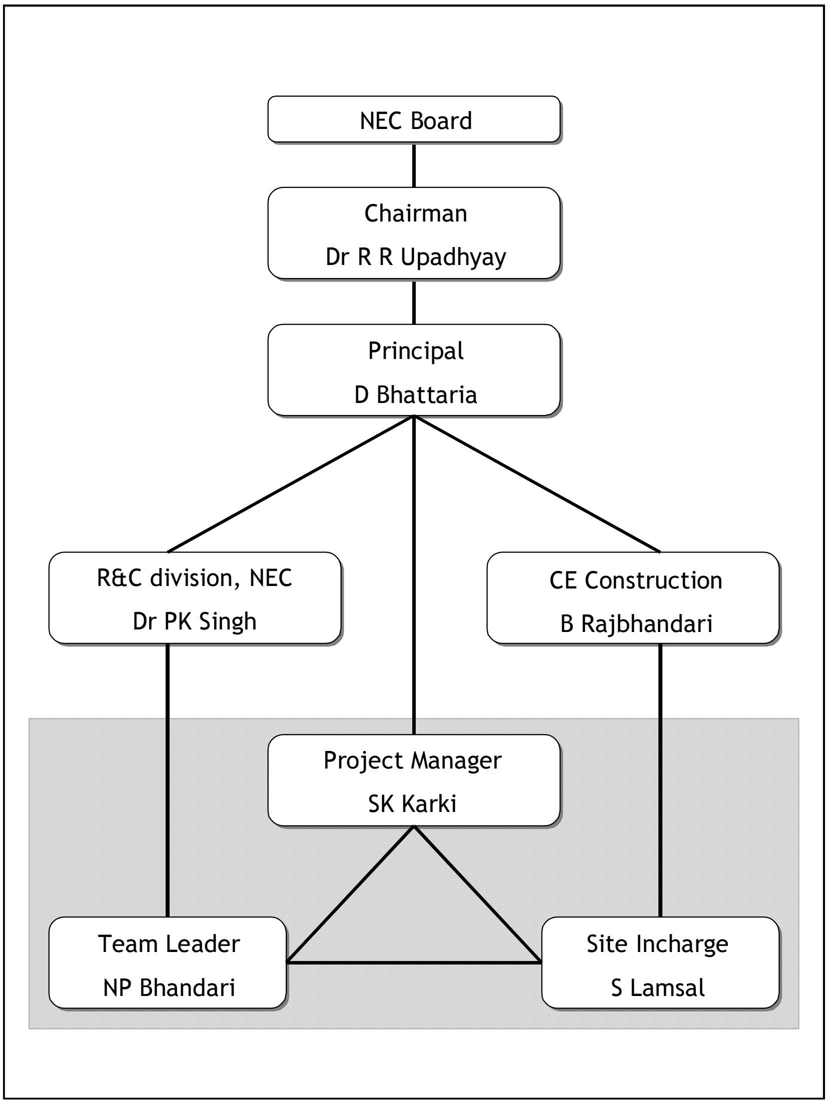


Fig 1: Organisation for project implementation.
All the authority was delegated at a level as shown by shaded portion of the organization chart.

PARTNERING CONCEPT

Partnering is not a new concept. In the US in late 1980's, arising out of the "design, construct and sue" experience of industry practitioners, a number of initiatives were taken that had as their essential feature, the construction of projects based on the development of shared objectives, achieved through open and trusting relationship. The concept of partnering was developed since many industry participants had concluded that the "hand-to-hand combat" which has been a feature of relationship between the industry stake-holders had in the end, benefited no one.

In Australia, the construction industry had recognized that it was suffering from an unacceptably high level of commercial disputes, and had recommended for a change, which was contained in the "*No Dispute*" report published in May 1990. Partnering in Australia received a boost from a series of seminars sponsored by Master Builders Australia (MBA) in 1992.

Partnering is a process to establish productive working relationships among all parties on a project. While the contract establishes the legal relationship, the partnering process establishes the working relationship among the parties through mutually developed strategy of commitment and communication. Partnering is a management strategy which offers a new way for the relationships among the owners, consultants and contractors. It may be defined as “a commitment between two or more organizations for the purpose of achieving specific business objective by maximizing the effectiveness of cooperation.

NEC OBJECTIVE

The objectives of NEC Infrastructure Development Project (necIDP) are listed below.

a) The project has to be completed on time.
b) The administrative and supervisory cost must be minimal.
c) There should be minimum conflict with the contractor.
d) Engineers and faculty members should be employed to undertake innovative work based on their capability.

NEC PROCEDURE

Selection of Contractor

NEC was committed to cooperate with the contractor to complete the project on time. This meant that the selection of contractor was important since it was essential that parties trust each other and understand the common goal. Therefore, tenders were invited from four building contractors. The successful contractor was selected based on his offer price, past performance in other projects and financial capacity. The successful contractor had worked with the author in a previous project. As such, there was a high level of trust for the contractor.

Contract Document

No contract document suitable for PARTNERING was available. The team therefore decided to use the FIDIC Conditions of Contract, and incorporated special conditions relevant to the project as part II of the document. General Specifications and Drawings were also provided. The contract was signed as any standard construction contract.

Partnering

There was a firm commitment from the top management of NEC for partnering. At the start of the project, the client’s project manager and team leader of the consultants were identified. The project manager was an experienced person. He was a senior faculty with a high level of moral and ethical values.

The team leader chosen was someone who did not believe in the conventional master-servant relationship between the client and the contractor. He was a top student when in the university, and had one year of teaching experience but without any construction experience. The contractor was also an academic but had extensive construction experience.

The project manager, team leader of the consultants, person responsible for supervising the contractor (site in-charge), and the contractor were trained in partnering through a one-day seminar. The participants were taught how to develop mutual trust, share experience and make decisions to achieve a common goal. They were also trained how to make timely decisions and be responsive, in order for the project to succeed.

At the Site

The NEC delegated all the authority to the project office. The team was told to do the following:

- Meet at site every day and have lunch together
- List any problem that need to be addressed within 24 hours of the problem surfacing
- Discuss the problem and make a decision at the site
- Allow the contractor to make small changes which would not increase project cost.
- Approve any extra item at the site
- Take measurement of any work which would be covered up, and sign off the measurement sheets
- Meet fortnightly with senior executive to evaluate performance.

RESULT OF PARTNERING

There were visible benefits from employing partnering concept in this project. Some of the benefits are listed below.

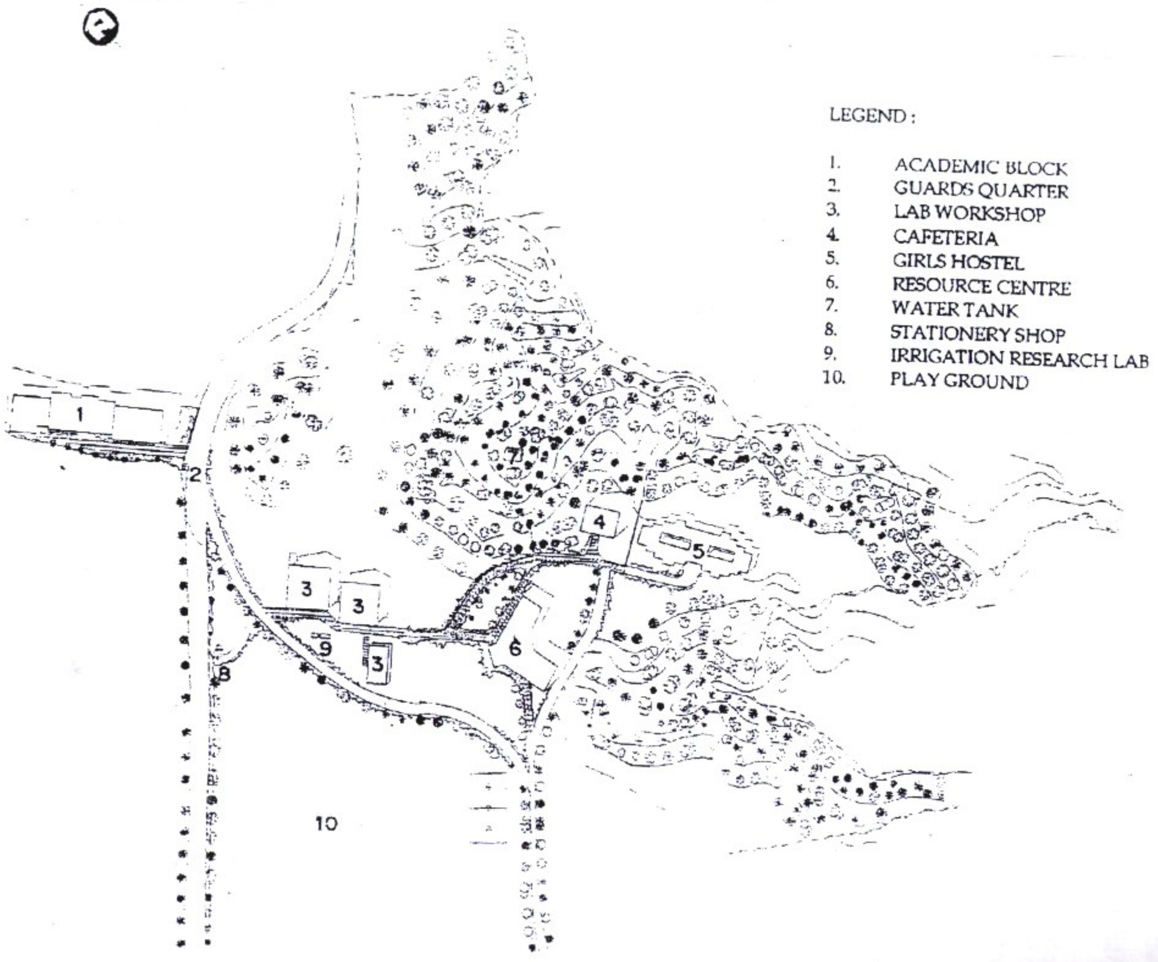
- The project was completed within seven months which is 2 months ahead of schedule.
- There was absolutely no problem during construction. The team was trained to work in new environment with joy and happiness. They were able to make decisions at the right time. A sense of responsibility and fair dealing was created among all persons involved.
- The project was managed with very little extra items.
- The project was completed at 5 % below the expected cost.
- Administrative and supervision cost was less than 1 % of the project cost.
- There was no claim from the contractor.
- There was no conflict with the contractor.
- The team had a very good relationship after the project was completed.
- The institutions developed greater level of confidence to work together in future.

CONCLUSION

Construction is a complicated process. Most of the projects in Nepal suffer time and cost overruns. It is very common for projects to cost twice its estimated cost when the project is completed. There are disputes and litigations. By employing the partnering concept, many problems can be solved. Projects can be completed on time. Most important of all, relationship among the parties involved remains cordial.

Partnering may be easily implemented in the private sector. The same spirit may not work in a public sector project, where there are many formalities and bureaucracy involved. Therefore a contract document incorporating the spirit of partnering should be developed to replace present contract documents.

Master Plan of
Nepal Engineering College
Changunarayan V.D.C., Bhaktapur



Construction CALS: Applications for Public Works

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Abstract

CALS (Commerce at Light Speed) is a global strategy to further enterprise integration through streamlining the business process and applying the standards and technologies for the development, management, exchange and use of business and technical information. CALS, first originated as Computer Aided Logistics Support, began as a US Department of Defense initiative in the 1980's to exchange technical data with the government in electronic format rather than in paper. But the scope of CALS has now extended far beyond its origins and covers almost all types of industry throughout the world. Research on the application of CALS to construction industry (Construction CALS) is going on in United States, Japan, Singapore, China, and some other countries. This paper sets forth the conception of Construction CALS and the merits of applying CALS to public works. Specifically, this paper presents a system model for electronic information exchange between the owner and the contractor, which includes the key technologies needed for applying CALS to public works.

Keywords: *CALS, construction CALS, electronic commerce, information sharing, system model.*

INTRODUCTION

It seems that every new technology or application of technology is destined to make great changes in almost every aspect of life. In this respect, CALS is no exception. CALS is considered as a revolution that will transform the face of business, industry, and manufacturing. CALS holds the promise of shortening time-to-market, reducing costs, and improving quality in business, industry, and manufacturing. Companies throughout the world are now watching closely the development of CALS. CALS is increasingly viewed as a business imperative (Eleen Massmer, 1995). Applying CALS to the construction industry (Construction CALS) is a new research field, and the research is going on in many countries.

CALS AND CONSTRUCTION CALS

What is CALS

CALS is a global strategy to further enterprise integration through the streamlining of business processes and the application of standards and technologies for the development, management, exchange and use of business and technical information.

CALS began in the mid-1980s as Computer Aided Logistics Support. It was originally developed by the US Department of Defense, which first converted manuals for weapons into the electronic media. It is said that in order to construct M-1 tanks, some 40,000 pages of technical data and 8,000 pieces of drawings were necessary. In other weapons systems, more documents were produced. In the mean time, there were large numbers of subcontractors who participated in a particular weapons system. Ensuring that these subcontractors are supplied with current information to achieve quality and timely delivery was difficult. CALS was developed to solve those problems.

With its scope broadened, the meaning of the acronym was changed three times:

- 1988—Computer-aided Acquisition and Logistics Support
- 1993—Continuous Acquisition and Life-cycle Support
- 1994—Commerce at Light Speed.

"CALS is synonymous with enterprise integration and electronic commerce," explains Aris Melissaratos, Vice-President in charge of science, technology, and quality, Westinghouse Electric Corporation, Pittsburgh, PA, and Chairman of the Executive Advisory Council for CALS. He notes that:

> It's a global information strategy, which may be viewed as the industrial or manufacturing lane on the Information Highway. CALS provides the framework for capturing product design, process design, development engineering, manufacturing, maintenance, and support data. CALS is a visionary, far-reaching concept.

What is Construction CALS

The information systems on public works for life-cycle support (generally called Construction CALS) is aimed at the introduction of CALS concepts to public works projects. Efforts will be made to reduce costs, improve quality, and enable efficient implementation on construction projects through information interchange, sharing and correlation among different organizations and in different phases of work. Construction CALS generally refers to the system which will enable information correlation over open communication such as the Internet as shown in Fig. 1.

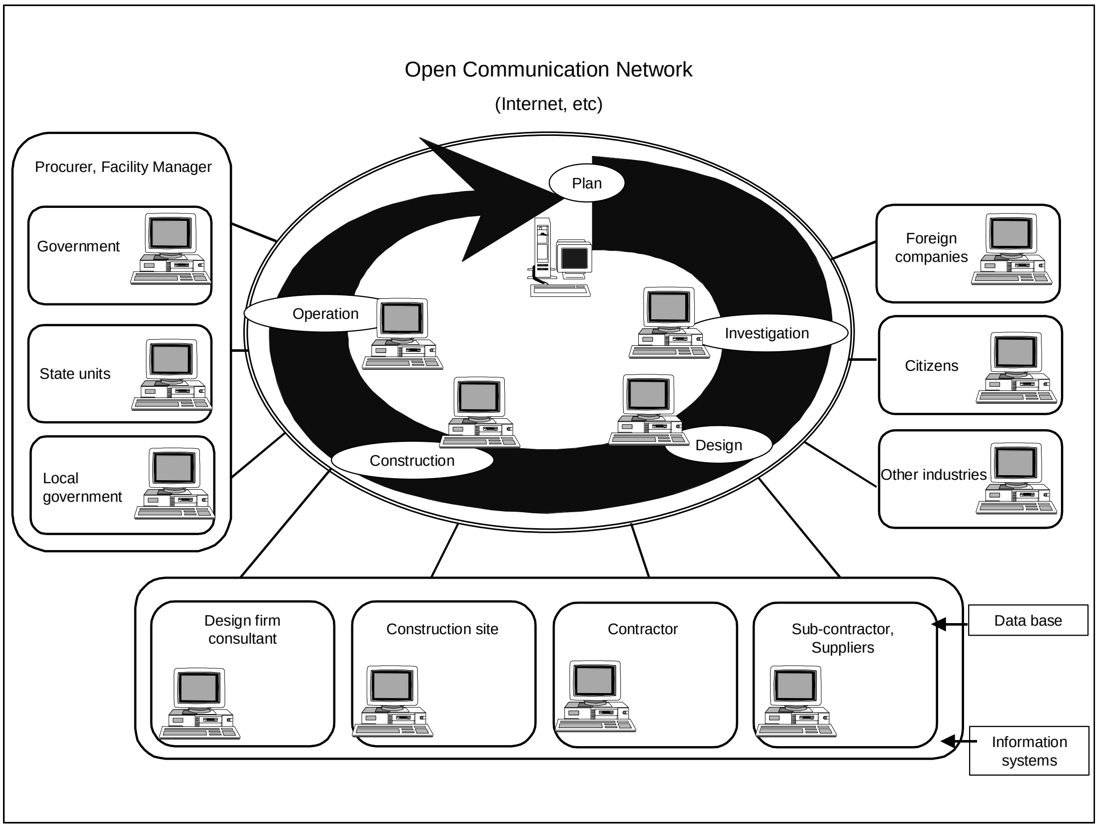

Figure1: Configuration of a construction CALS

Merits of CALS on public works (Construction CALS)

The electronic storage and sharing of common information means that a particular information prepared by one company or one division can be put to common usage by others. The purpose of Construction CALS is to improve the productivity and economic efficiency of the construction industry through information sharing between construction-related organizations throughout the life cycle of projects from design, procurement, construction, to maintenance management. Application of Construction CALS to public works projects will cause changes in the mode of business. The merits are now listed.

1. *Speedy Procurement*. With the introduction of Construction CALS, such information as notice can be gained directly from databases which are accessible from terminals. Tendering, co-ordinating and contracting can be implemented electronically. Therefore, the efficiency of procurement activities will be improved.
2. *Information Exchange Anytime and Anywhere*. Once Construction CALS has been introduced, information interchange will no longer be restricted by time and place as electronic-mail and teleconferencing become possible.
3. *Efficient Business Process by Information Sharing*. Permission and authorization procedures may be used as an example. After the introduction of Construction CALS, the applicant will send applications electronically while decision will be made electronically within the agency concerned. Thus, administration processes will be accelerated and documents will be reduced.
4. *Life-cycle Support for Products*. At present, information on the individual phases of a project, namely planning, design, construction, and maintenance, is transmitted via paper media. The integrated database introduced by Construction CALS will enable an effective use of information through uniform control of all the information generated in the life cycle from planning to maintenance.

A SYSTEM MODEL

As indicated above, Construction CALS is an electronic environment which consists of a number of information systems. In the bidding and contract awarding phase, information is frequently transmitted between public procurement agencies and the contractors. Owner agencies exchange information with the bidder via the clearing house, authentication office and bidding control office based on the Internet technology as shown in Fig. 2 (Japan Construction Information Center, 1997).

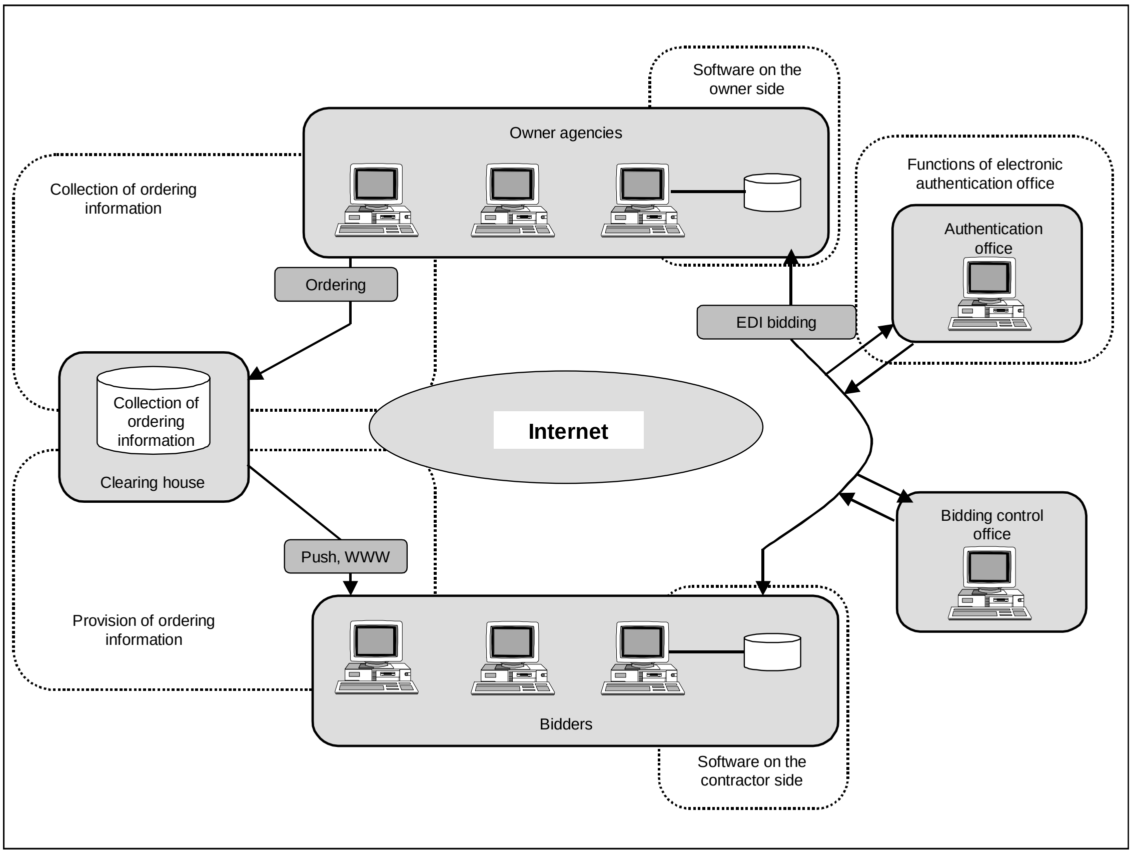

Figure 2: Construction CALS bidding model

In this model, some key technologies must be developed, including:

1. Technology that allows automatic gathering of ordering information scattered in a wide area.
2. Technology that allows the exclusive delivering of information corresponding to the project query specified by a potential contractor.
3. Electronic authentication technology to issue authentication certificate of the potential contractor to which information is sent.
4. Bid management technology to execute bid acceptance for enhanced fairness in the treatment of bidders.
5. A software package through which bidding information is released by public agencies and retrieved by potential contractors.

CONCLUSION

This paper first reviewed the basic concept of CALS and Construction CALS. An elaboration of merits of applying CALS to public works followed. The development of A systems model is the focal point, so a model for bidding and contract awarding in public works is presented. At the same time, the key technologies are listed.

The research on applying CALS to the construction industry is going on in United States, Japan, Singapore, China, and some other countries. However, it must be stressed that information sharing cannot be realized without uniform international standards for electronic data exchange. Efforts should be put into the development of international standards, including the information classification standards and technological standards such as STEP, EDI and SGML. It is believed that with further research and increasing broadening applications of CALS, Construction CALS would be implemented on all construction projects.

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Sub-contracting or Co-contracting: Construction Procurement in Perspective

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Abstract

The use of subcontract arrangements as part of the overall procurement strategy of the client is widespread within construction. Subcontracts in construction are often implemented in the spirit of adversarial relations that have traditionally characterised procurement in the industry.

The paper presents an overview of construction procurement and discusses several macro factors that are influencing business activity in construction, with attendant repercussions for contractor-subcontractor relationships and construction procurement in general. It proposes a co-contracting agenda as a means of engendering the same benefits that partnering has brought to the client -principal contractor relationship. The paper argues that a co-contracting agenda will be essential for achieving the levels of productivity that will be required in the intensifying competition that the industry will face in the future.

Keywords: *Construction, procurement, subcontract, co-contract, organisational relationship.*

INTRODUCTION

Over the last two decades the construction industry has been profoundly affected by economic and industrial change as a result of recession, changing markets, impact of new technologies and increasing competition arising from greater regional and global integration. In the context of these harsher operating conditions and the concomitant pressures imposed on companies that undertake business in construction, strategies that were relevant to the industry conditions of the 1960s and 1970s through to the early parts of the 1980s are no longer adequate for sustaining competitiveness. The pre-1990s strategies, which were predominantly growth-oriented, often resulted in rigid organisations and systems that take considerable time to respond to the changes within their business environment. Notably, the growth strategies, driven by large-scale economics and attended by vertical and horizontal integration strategies, have been replaced by new imperatives of the 1990s.

Faced by global and regional competition, the larger construction companies have responded by seeking greater flexibility. This trend in the 1990s, which will continue well into the future, involves a flexible response to the business environment and horizontal and vertical disintegration. The adoption of these strategies by construction companies has manifested itself in the disposal for peripheral business units and establishing closer and longer-term relationships with suppliers. These strategies have called for a greater reliance on outsourcing, externalisation, and subcontracting of several activities of the construction process by main contractors to their small and medium counterparts.

The paper examines the changing and emerging procurement strategies in construction against this background. In particular, it identifies and highlights the changes that are bringing about a shift from the traditional subcontractor arrangement to one of co-contracting. This emerging form will feature prominently in the procurement process within construction. Developing appropriate strategies to address such procurement forms will be essential for the future viability of construction companies.

CONSTRUCTION PROCUREMENT IN PERSPECTIVE

Construction procurement deals with the arrangements for acquiring construction goods and facilities by clients either as private individuals or corporate establishments or public institutions. Construction procurement from the 1960s has grown from situation whereby all public jobs and most private jobs were offered on just competitive tendering to having various alternatives. Currently there are several forms of procurement in use within the construction industry. The various forms of procurement can be loosely classified under the following four typologies proposed by Harris and McCaffer (1996): separated and co-operative arrangements, management-oriented procurement systems, integrated arrangements and discretionary systems. Figure 1 presents examples of the procurement categories adapted from Harris and McCaffer (1996) and Franks (1998).

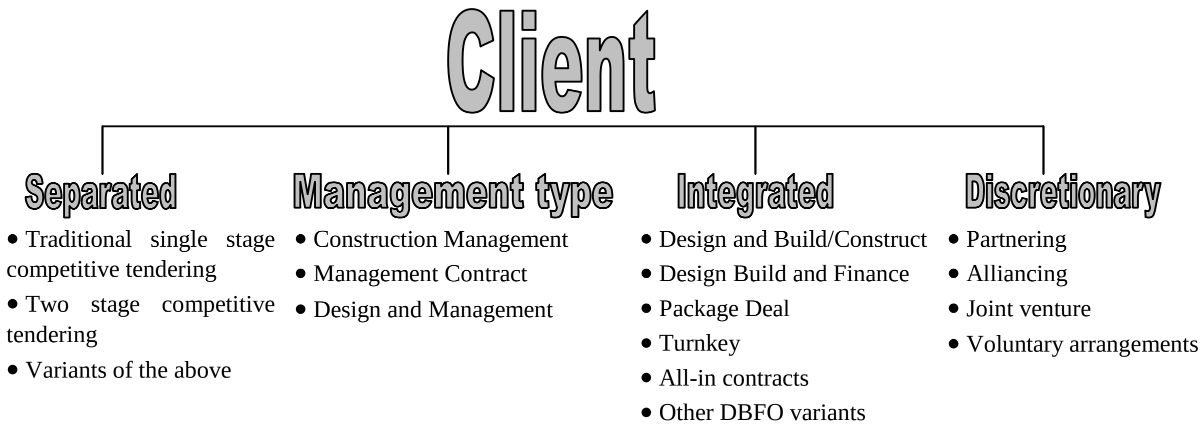

Figure 1: Alternative procurement routes for clients in the construction industry

The primary distinguishing features of all the different procurement systems in Figure 1 can be accounted for by defining three basic characteristics. First, the responsibility for design and construction of the facility, and whether this should be placed on separate organisations or on a single organisation. Second, whether the principal contractor should construct the works or manage the construction process. The third feature hat helps to distinguish between procurement systems is the basis of remuneration for any work done.

Examples of the above procurement systems in common use within construction include the traditional *competitive tendering* arrangement in which the principal contractor tenders for and constructs the works to a design that is previously prepared by the client's designers. In contrast to the traditional arrangement, *design and build* procurement places responsibility for both the design as well as the construction on the principal contractor. The principal contractor also constructs the facility. In a *management contracting* arrangement, the principal contractor is engaged in a management role for the construction process, while other contractors undertake the actual construction in a work package subcontract arrangement. Where such subcontract arrangements are held directly with the client, the procurement system is described as *construction management*.

The use of discretionary arrangements in construction is a direct response to a growing demand and interest shown in engendering the benefits of team working within the construction procurement process. *Partnering* particularly relies on such principles, which call for a high degree of confidence and trust, as well as commitment by all parties involved in the process to defined mutual benefits.

The procurement systems described above all rely on one or more subcontract arrangements outlined below.

Subcontract arrangements between the principal and subcontractors and on the initiative of the principal contractor, as is the case of *domestic subcontractors*.

- Subcontract arrangements between the principal and subcontractors and on the initiative of the client, as in the case of *nominated subcontractors* for specialist work.
- Subcontract arrangements between the client and subcontractor.
- Subcontract arrangements between subcontractors and sub-subcontractors on the initiative of the principal contractor.
- Subcontract arrangements between subcontractors and sub-subcontractors on the initiative of the subcontractor.

The widespread use of subcontract arrangements in construction is a result of the nature and structure of the construction industry. The industry's workload is highly diversified by type, size, function, form and method of production, and materials used. The execution of the works equally requires the services of many different trades and specialists. Since it is economically unsound for contractors to retain all the trades and specialisation of the industry, construction companies undertake only part of the full range of operations required. Companies of a relatively smaller size perform work that is not undertaken by the principal contractor as well as those of a specialist nature, through a sub-contract arrangement. The use of such subcontract arrangements enable the larger construction companies to maintain greater flexibility and to cope with the high variations in orders often associated with the industry (Hillebrandt and Cannon, 1990; Flanagan, 1995). For example, Thoburn and Takashima (1992) provide evidence of a growth in the use subcontract arrangements by UK firms in their attempt to develop greater flexibility to both competition and other market conditions. As a result, the construction industry is dominated by a large number of small companies that provide subcontract services to their larger counterparts. Hillebrandt and Cannon (1990) argued that in spite of many changes that had affected the industry from the early 1970s, the structure of the industry had remained largely unaltered.

THE CHANGING FORM OF PROCUREMENT IN CONSTRUCTION

The last decade of the 20th Century has presented significant changes for the way industry conducts business and particularly so for construction (Gomes-Casseres, 1996). There are a number of strategic factors that have come together to give rise to such unprecedented change affecting the construction industry. This section of the paper will give attention to some of these factors and how they are impacting and influencing the parties involved in the construction process. The relevance of the behaviour of these parties not only affects the degree of competition within construction, but is also contributing to defining a new agenda in construction procurement.

Changing clients and requirements

Construction clients are exposed to the same economic conditions as the contractors within the industry. Recent economic changes as a result of global economic downturns exposed these clients to cuts in development budgets, who, in turn, translated the impact of such cuts to the construction industry. In some cases, it meant a withdrawal from developments already commenced. As a result, construction clients have become astute in their requirement of value for money. The demand of value for money implies that construction companies need to attain unprecedented levels of productivity so as to continue to win orders.

Improving construction productivity

The construction industry witnessed considerable improvement in its productivity as a result of several initiatives and the deployment of concepts such as *lean construction*, *benchmarking*, and *total quality management*. The outcome of these productivity increases is reflected in the following benefits to the contractor:

- improved product quality- thus minimising re-working
- increased output
- reduced accidents
- increased motivation.

These potential benefits are passed on to the client as faster delivery times at a reduced cost and to a better quality for the products they procure. While it can be argued that there is still room for improvement in productivity within construction, the present levels of productivity attained in some economies such as the UK, Japan, and the USA, leave very little room for significant cost reduction in the actual construction operations. The ability of a construction contractor to achieve further productivity gains therefore lie in the effective alignment of all the parties involved in the construction process, and particularly so for the subcontractors it engages (Headley and Griffith, 1997).

Changing business in construction

Two decades ago it could be said that the fundamental business purpose of every construction contractor is to convert materials into a finished product. The industry since then has moved on from this scenario to a situation whereby some construction contractors only facilitate the process to one in which some contractors essentially provide managerial services. Effective construction is therefore hinged upon designing and implementing an integrated and systematic project organisation that consistently delivers a superior quality product and service at the best price and within the right time (Underhill, 1996). Construction contractors not only need to deliver these quality products and services – they must consistently do this with fewer resources if their clients are to receive the best possible value for money.

Widening economic and industry markets

The world is changing rapidly with markets turning global as information becomes a worldwide commodity and protectionism retreats in the face of deregulation and enlightened self-interest. Until the close of the 1980s and the beginning of the 1990s the construction industry’s traditional markets had remained largely a domestic one. Within the European Union, there are signs a gradual shift away from this traditional domestic-oriented market for construction as contractors explore options for improving their orders within an enlarged single market. The situation is not different for the ASEAN region and other trade blocs (Thoburn and Takashima, 1992). For those large construction contractors that venture outside their traditional markets, there is the need for forming local partnerships to take advantage of local knowledge and expertise, as well as minimise the high cost associated with labour transfers. The construction markets that will result from these enlarged trade blocs into the next century will require increased capacity in order to ensure competitive advantage. Equally the industry's employers are likely to develop capacities that will give them greater negotiating power. As a consequence, client organisations will be more discerning and are likely to demand higher quality and greater risk avoidance.

The requirements of this emerging enlarged market for construction and its attendant competitive forces demand a new approach to procurement for managing the project supply chain. Construction companies will have to pursue collaborative and co-operative arrangements not only to secure their long-term survival, but also to achieve a greater alignment between their organisations and the subcontractors they engage.

As a consequence of operating in such enlarged markets and also due to the current trend of increasing globalisation, smaller firms in construction are now exposed to greater competition. Once immune from overseas threats, these smaller construction companies now have to face up to accelerating domestic client demands as well as the reality of a new crop of competitors worldwide.

Electronic communication and IT

The impact of IT on the construction process has been considerable, although Thorpe et. al. (1998) argue that construction is yet to receive the full benefit of the information revolution. The widespread availability and use of IT is enabling many a small firm in construction to take on projects which until recent times had been the domain of only the large construction organisations. Many of these smaller companies can convert the latest knowledge to their needs, thus accelerating their ability to compete directly with their larger counterparts. The increasing access to technology by smaller construction companies, along with the continuing lower costs due in part to their small capacity, is changing the competitive market in ways yet to be fully grasped.

Technology and trade have traditionally been the main forces for change in the world economy. In recent years, new technologies, particularly information technologies, have intensified the pressure for change on industry structures and processes, and facilitated the development of global markets. Many new technologies are now applied widely and quickly, even in sectors previously regarded as *low-tech*. In many developed economies, these technologies have helped such sectors including construction to avoid decline, and are transforming these sectors into global competitors.

Current use of IT in construction, however, has facilitated virtual proximity for different business units of a construction company that are geographically dispersed, enabling what has become commonly known as electronic commerce. This has given rise to increasing use of tele-working in construction. Equally, the internet has eliminated any sense of geographical isolation or safety for construction companies. The possibilities with electronic communication with regard to the processes of construction are endless. Its impact on procurement within construction is likely to be considerable. This includes *electronic bidding and negotiation* for projects, and thus opening up a different way for doing business in construction. The need for synchronised communication systems to facilitate such electronic transactions cannot be overemphasised. This calls for a closer partnership approach for organisations engaged along the supply chain beyond existing practice.

Changing structure and form of the construction enterprise

According to Thorpe et. al. (1998), both academia and industry practitioners in recent years have suggested that the way companies organise themselves, do business, and undertake projects is inherently flawed.

As a result, traditional models of hierarchy, standardised procedures, functions, responsibility centres and performance measures for both the construction companies and projects have all come under scrutiny. So nothing short of organisational transformation has been advocated. Contemporary corporate activity such as downsizing, out-sourcing, de-layering, and re-engineering have found frequent use in the management of both the company and projects within construction (Thorpe et. al., 1998).

The resulting lean organisations have to rely on greater collaboration to achieve project and corporate goals, and have given rise to a growing trend in subcontracting and outsourcing (Gomes-Casseres, 1996).

In many construction companies, management structures are becoming flatter, with a greater focus on customer needs and on team working, including partnership with other firms. Firms are increasingly contracting out non-core functions to smaller external firms. Networks of operations, involving strategic alliances, are coming together.

CONSTRUCTION PROCUREMENT AND THE FUTURE

Partnering and other close organisational relationships have yielded considerable benefit to the client-principal contractor relationship. These benefits will be mirrored in contractor-subcontractor transactions within the construction procurement process as contractors explore options for achieving further productivity improvements. The viability of the large construction companies has become inextricably tied to the efficient performance of their smaller counterparts. It is imperative that these two categories of companies involved in the supply chain of the construction process should seek greater alignment of their organisations. Such a development takes on added urgency given the rate of growth in the number of small enterprises within the construction industry. For example, within the UK, 60% of construction jobs are in businesses with fewer than 10 employees, and there are now 1.2 million more small firms than in 1979 (DTI, 1995).

The *role* and *relationship* of the various players of the industry's value-creating chain will have to be re-examined to define new inter-linkages that facilitate the interest of all the participants in the industry. A co-contracting agenda where close association between major construction companies and smaller companies will provide one option for achieving the flexibility and capacities required for attaining the required to deal with present and future competitiveness. For the construction industry, this can best be achieved through a co-contracting agenda between the principal contractor and the subcontractors it relates to within the supply chain.

CO-CONTRACTING: AN OPTION FOR FURTHER COMPETITIVENESS

A co-contracting agenda involves effective alignment of management systems, operational processes, and information systems, to achieve harmonisation in procurement strategy such that the boundaries between different firms at various stages of the supply chain becomes blurred without reaching the point of actual merger (Cole et al., 1997; Gomes-Casseres, 1996). A co-contracting agenda is therefore a relationship between two firms that engenders an atmosphere of equal partners in which each partner's interests are taken care of (Smitka, 1991). For larger construction companies, achieving a good position in the international market is a matter of necessity. The only way the large companies can continue to succeed in an increasingly competitive world after considerable productivity gains in operational processes is to focus on such organisational relationships and interfaces. Within the UK, the ethos of such a co-contracting agenda is reflected in the various industry reports that focus on options for improving productivity within the construction industry (Technology Foresight, 1995; Latham, 1994; Egan, 1998). Naturally, such co-contracting arrangements have been taking place within the construction and manufacturing industries, albeit in an isolated fashion. Based on the advantages that have attended these limited uses of co-contracting, it is only logical to conclude that a widespread use of this arrangement will enhance the competitiveness of companies within construction industry. Its use within the construction procurement process should contribute to achieving the objectives of both Egan (1998) and Latham (1994).

SUMMARY

Subcontract arrangements within construction are employed in all the different procurement strategies in use. The widespread use of the subcontract in construction implies that any improvements achieved in this business transaction can yield considerable benefits to the industry. The paper has discussed several factors that have influenced operational improvements within construction. It has suggested that the next avenue for productivity gains within the industry lie in managing the relationships between companies that form the supply chain of the construction process. The use of co-contracting as an alternative to subcontracting is presented as one way forward for achieving further improvements in construction procurement.

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The Role of Construction Project Planning in Improving Project Delivery in Developing Countries: Case study of the Nigerian construction industry

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Abstract

This paper presents results from a study which examined the relationship between contractors' planning practices and the occurrence of delays in Nigerian construction projects. Data were collected using a structured questionnaire distributed to randomly selected construction firms operating in Nigeria. The prevalence of planning practices amongst Nigerian contractors was assessed. The relative significance of delay factors on projects undertaken by contractors who use quantitative management techniques for planning construction work and contractors who do not use quantitative planning techniques were also compared. The results of the study show that although the use of quantitative planning techniques contributes significantly to improving the project delivery process, limiting factors in the Nigerian construction industry discourage contractors from engaging in quantitative planning. The paper concludes by suggesting that if significant improvements in the delivery of construction projects in developing countries are to be achieved, specific frameworks for planning and managing construction projects in these countries which incorporate the identified limiting factors need to be developed.

Keywords: Nigeria; Developing Countries; Construction Industry; Project Management; Project Planning.

INTRODUCTION

In a developing country like Nigeria, which is still in the process of providing adequate social amenities such as educational and health care facilities as well as decent housing for its teeming populace, the construction industry has an important role to play. About 69% of the nation's fixed capital formation is produced by the construction industry (FOS, 1998). This implies that the construction industry represents nearly 70% of the capital base of the national economy and is an indication of the significance of the industry within the economy. However, despite its significant position within the national economy, its performance within the economy has been, and continues to be, very poor. Although studies undertaken by the World Bank have found that construction should normally account for between 3% and 8% of GDP in developing countries (World Bank 1984), the contribution of construction to Nigeria's GDP has hovered steadily at around 2% for the past 15 years (FOS, 1997). Similarly, although the contribution of the construction industry to employment has been found to average 3.2% in developing countries (World Bank, 1984), the Nigerian construction industry's contribution to employment has remained consistently at 1.0% over the last few years (FOS, 1998).

It is acknowledged that the poor performance of the Nigerian construction industry could be related in some way to the poor state of the overall economy. Nevertheless, the premise upon which the study reported in this paper is based is that notwithstanding the prevailing economic climate, the performance of the industry can be improved through the implementation of appropriate and relevant management practices by operators within the industry. The need to acquire competencies and capabilities necessary for managing projects efficiently is particularly important as the new millennium approaches. Increased competition due to a more global economy and improvements in information technology means that local operators within the construction industry in developing countries need to deliver projects as efficiently as possible.

Project planning has been found to be one of the most significant factors for the efficient and effective delivery of projects (Arditi 1985; Clayton 1989; Syal *et al* 1992). Since the planning function of management is responsible for defining the work to be managed, planning can be said to provide the basis for the performance of other management functions and can therefore be considered to be the most important management function. The study reported in this paper examined the relationship between the project planning practices of contractors operating within the Nigerian construction industry and the occurrence of project delays. The study also investigated factors within the operating environment of the Nigerian construction industry which affect project planning practices.

METHODOLOGY

Data for the study was collected using a structured questionnaire. The questionnaire was distributed to a sample of contractors operating in Ibadan, Oyo State, Nigeria. The questionnaires contained questions relating to the methods used by the contractors for planning construction projects. Respondents were asked to indicate whether their firm employed any quantitative techniques (such as bar charts, critical path networks, and probabilistic PERT analysis) in planning their projects and to describe their firm's planning process. The frequency distribution of the responses was used to assess the prevalence of planning practices. The questionnaires also contained a list of 11 factors considered to be responsible for the occurrence of delays on Nigerian construction projects. The following factors were included: weather, labour supply, material shortages, equipment failure, finance, off-site fabrication, construction errors, design changes, sub-contractors, contractual disputes, industrial disputes. The respondents were asked to indicate the relative importance of the factors in contributing to delays in their projects. Delay factors were classified as "very important", "important", "of minor importance" or "not significant". For each delay factor, a severity index was determined by calculating the total percentage of respondents giving the responses – "very important" or "important" (Baldwin *et al*, 1971). The severity indices were used to rank the delay factors in order of importance.

RESULTS AND DISCUSSION

The results indicate that a sizeable number of contractors operating within the Nigerian construction industry do not engage in any form of quantitative construction planning, but rather prefer to depend on "intuitive management" (acting on the basis of hunches or previous experience) for managing projects. Table 1 shows the proportion of respondents that use quantitative management techniques in planning their construction projects. 58% of respondent contractors indicated that they use some form of quantitative management technique (including bar charts, critical path networks, and probabilistic PERT analysis) for planning construction work, while 42% indicated that they do not use quantitative planning techniques.

Table 1: Extent of Use of Quantitative Planning Techniques

Use Quantitative Planning technique (Yes/No)	*Proportion of respondents*
Yes	58%
No	42%

Table 2 shows the distribution of the quantitative management techniques adopted by contractors who used quantitative techniques for planning their construction work. All respondents in this category use bar charts as a planning tool. However, only 28% use critical path networks and none uses probabilistic PERT analysis as a planning tool. A large majority of the contractors did not provide the average annual turnover of their firms as indicated on the questionnaire. This was meant to serve as an indication of the size of the firms. It was therefore not possible to relate the size of the construction firms to their project planning practices.

The preference of the contractors for “intuitive” management rather than the use of quantitative techniques to guide management decision-making is largely due to two major factors: (i) deficiencies in management skills; and (ii) the climate of uncertainty and unpredictability that generally pervades the Nigerian construction industry. A lot of domestic contractors are not familiar with quantitative management techniques such as bar charts, critical path analysis, probabilistic PERT analysis, resource planning, cost control, and management accounting. Lack of managerial skills has been highlighted as a major deficiency of local construction enterprises in developing countries (World Bank, 1984; Ofori, 1991). However, even those contractors that are familiar with quantitative management techniques are constrained in the extent to which they use these techniques by limiting factors such as political instability, excessive delays in payments, and unfavourable procurement and contracting procedures.

Table 2: Types of Quantitative Planning Techniques Used

Planning technique	*Proportion of respondents*
Bar Chart	100%
Critical Path Network	28%
PERT analysis	0%

Table 3 shows the severity index and ranking of delay factors for the entire sample. Table 4 shows the severity index and ranking of delay factors for contractors who use quantitative management techniques for planning construction work and contractors who do not use such techniques. An examination of the ranking of delay factors by contractors who use quantitative planning techniques shows that the delay factors ranked highest by this group (finance, weather, design changes, equipment failure and subcontractors) are factors that construction planning has little or no control over. On the other hand, delay factors ranked highest by contractors who do not use quantitative planning techniques include factors that can be managed effectively by appropriate construction planning techniques. Weather, material shortages, finance, labour supply, and equipment failure were ranked as the five most important delay factors by these contractors. Although project delays due to weather, finance and equipment failure might not be due to deficient planning practices, the use of quantitative planning techniques would be of immense value in eliminating, or at the very least, minimising delays that occur due to materials shortages and labour supply.

Spearman’s rho and Kendall’s tau-*b* rank-order correlation coefficients indicating the extent of agreement between the rankings of delay factors by contractors using quantitative planning techniques and contractors that do not use quantitative planning techniques are presented in Table 5. No statistically significant agreement (at 0.05 level of significance) in ranking was found between the two groups.

Table 3: Severity Index and Ranking of Delay Factors

Delay factor	*Ranking (SeverityIndex) for entire sample*
Finance	1 (83)
Materials Shortage	3 (75)
Equipment Failure	4 (67)
Design Changes	6 (58)
Weather	2 (83)
Labour Supply	7 (58)
Subcontractors	5 (66)
Construction Errors	8 (50)
Contractual Disputes	9 (42)
Industrial Disputes	10 (33)
Off-site Fabrication	11 (25)

It is evident from the results that have been presented that the project delivery process can be significantly improved through the use of appropriate quantitative techniques to plan projects. Quantitative planning techniques such as bar charts and critical path networks make it possible to know in advance periods during which specific activities take place on site. Arrangements can therefore be made in advance to ensure that the required material and labour resources are available on site when required, thereby averting possible delays due to material shortages or unavailability of labour.

Although there is an obvious need to develop project-planning skills in Nigerian contractors, cognisance taken of the practical situation prevailing in the operating environment of the Nigerian construction industry. For example, political instability due to the high turnover of government administrations results in frequent changes in government policy with incoming regimes terminating or abandoning contracts awarded by the preceding administration. In such situations, contractors often have to renegotiate existing project contracts, or even go through the entire tender process all over again. Excessive delays in payments are also a regular feature in contracts awarded by the government (the largest client of the construction industry). For contractors that depend on such payments to finance construction work and do not have access to alternative sources of funds, delays in payment disrupt carefully planned construction programmes. Similarly, government contract procurement procedures are mainly one-sided, focusing on the rights of the government as a client and the obligations of the contractors, with no compensation available to the contractor in the event of default by the government. These contract procedures are also excessively bureaucratic in nature and are characterised by overlapping authority of government agencies, excessive paperwork and requirements to comply with several different laws and regulations. All these conditions combine together to create an environment of uncertainty and unpredictability around construction projects which tends to frustrate planning efforts made by contractors.

Table 4: Severity Index and Ranking of Delay Factors: Contractors Using Quantitative Techniques versus those not Using Such Techniques

Delay Factor	*Ranking (Severity Index)*	
	Contractors using quantitative planning techniques	*Contractors not using quantitative planning techniques*
Finance	1 (100)	3 (60)
Weather	2 (85.7)	1 (80)
Design Changes	3 (71.5)	9 (40)
Equipment Failures	4 (71.5)	5 (60)
Subcontractors	5 (71.5)	6 (60)
Material Shortages	6 ((71.5)	2 (80)
Labour Supply	7 (57.2)	4 (60)
Contractual Disputes	8 (42.9)	11 (40)
Construction Errors	9 (42.9)	8 (40)
Industrial Disputes	10 (28.6)	7 (40)
Off-Site Fabrication	11 (14.3)	10 (40)

Table 5: Contractors Using Quantitative Techniques versus those not Using Such Techniques

		Kendall's tau-b coefficient		*Spearman's rho coefficient*	
		1	2	1	2
1	Contractors using quantitative planning techniques				
2	Contractors that do not use quantitative planning techniques	0.42		0.60	
3	(All Contractors)	(0.56*)	(0.49*)	(0.61*)	(0.67*)

*p<0.05

As the new millennium approaches, a challenge for researchers is the development of 'appropriate' management techniques and tools that are tailored to the operating environment of construction industries in developing countries. Training courses for local contractors in developing countries that are based on such 'appropriate' management techniques and tools will undoubtedly be of direct benefit because the concepts imparted in the courses will consider the practical situation prevailing in the local industry. Contractors in developing countries will then be able to acquire relevant skills that will be necessary for improving the efficiency of the project delivery process and consequently for remaining competitive in the construction industry of the next century.

CONCLUSION

The use of quantitative management techniques such as the bar chart and critical path networks for planning construction projects would assist significantly in reducing the occurrence of delays and minimising their impact when they do occur. This is because the use of quantitative planning techniques (as opposed to intuitive planning) makes it possible to know in advance when activities are due to take place. Arrangements can therefore be made early enough to ensure that required resources (for example, labour, materials and plant) are available at the appropriate time. Furthermore, whenever a delay does occur, its implications on the future performance of the project can be immediately determined and corrective action can be taken to minimise any negative impact on project performance. However, any programme developed for the purpose of enhancing the construction planning skills of Nigerian contractors must recognise the prevailing characteristics of the Nigerian construction industry if the programme is to succeed. Such characteristics include: frequent delays in payment, scarcity of construction materials, and poor operating conditions of available construction plant and equipment. As we approach the new millennium, there is therefore a need for researchers to develop a body of knowledge on tools and techniques for successful management of construction projects in developing countries, taking into account the operating conditions within the local industries.

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Construction Industry Development and Government: A Grounded Theory Approach

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Abstract

Taking a fresh look at a problem can often reveal new insights. The research reported here attempts to capture the key factors that influence construction industry development. It does so by the use of a grounded theory approach as developed in the social sciences. Through the data collected from a set of in-depth interviews with renowned international experts in the field, 42 factors are captured. Analysis of the data is developed in stages, and some key generic factors are identified. Many of the factors relate to the role of government. The results from the interviews are then used as a basis for searching the literature and the nature of government's role is more clearly revealed. Although the nature of this role has already been outlined in the literature, there is still an immaturity of knowledge in this field. What is not known is the full extent of this role and its relationship to other key factors. Based on this exploratory survey, the findings indicate that the government's role is the most important influence upon construction industry development. An additional finding is that two other generic factors are important. These are human behavioural factors and key resources.

Keywords: *Construction industry development, government, behavioural factors, grounded theory.*

INTRODUCTION

This paper addresses the issue of the role of government in developing the construction industry. It does so in an unconventional way by first reporting on the results of some interviews with experts in the field of construction industry development. Since the interviews were conducted without reference to any a priori theoretical model, the concepts of importance were expected to emerge from the interview data itself. This approach, called grounded theory, is well known in the social science field, having been developed by its principal proponents Glaser and Strauss (1967).

The paper first describes the procedures used to capture the respondents' main ideas relevant to construction industry development. It then describes how the many factors identified were synthesised into groups under more generic headings. Third, it highlights those generic factors that appear to be of significance and explains the rationale behind their selection. Fourth, it draws on the recent literature for comparison and validation of one of the generic factors that appears to be most dominant - the role of government. Finally the paper concludes with a discussion of the findings and their significance.

EMPIRICAL DATA COLLECTION

Sources and Framework

The impetus for the empirical work stemmed from two main needs. The first was the perceived currency of existing studies. The second was the paradigm within which those studies have been conducted.

Although the literature can provide a good overview of the main concepts and their relationships, many of the existing studies are becoming outdated. The solutions offered by those studies have by and large not met with success and there has also been a lack of research interest in recent years (Ofori 1993:40, 1994). Coupled with the lack of research interest is the need for a stronger theoretical base.

The existing studies have been written almost entirely by researchers with a background in economics or engineering. Much of the data used was secondary, originating from reports by United Nations, other international agencies or national governments. Good and sound as they are, these approaches have not solved the problems experienced and thus may be regarded as too conventional for breathing new life into the field.

In the circumstances where a fresh insight is needed, without relying on previous conceptual frameworks, a grounded theory approach is suitable (Glaser and Strauss 1967; Miles and Huberman 1994:147). This relies on collection of data without any preconceived framework. The theory or model and the concepts that it comprises are developed from the data itself. This approach is well established in the social science research disciplines and it has proven to be a valid and reliable way of formulating theory. There is little evidence of its application to the field of construction, especially construction industry development. In view of the claimed difficulties in conventional approaches to research in the field it was decided to attempt a fresh look at the construction industry's problems to capture key factors that may have been overlooked in previous studies.

An up-to-date picture of the key variables and relationships would be best achieved initially by some in-depth interviews with experts who were currently working in the field. The contributions by these individuals would provide a good overview of the problems and issues being experienced. This would, in turn, point the way to possible areas to investigate further, both from the literature and from empirical sources.

Interviews were conducted in the summer of 1995 with five experts in the field. The selection of questions was based on the premise that the development of a construction industry means deliberately engaging in a process of change for the better. It is an intervention process. For such a change to be successful, however that is defined, there is needed at least a basic understanding of the key factors involved and how they interact.

Respondents were asked their views on the key factors in developing a construction industry. Given the intention at the outset not to focus initially on developed or underdeveloped countries, it was expected that generic characteristics would emerge applicable to both. Responses would therefore highlight any differences, if relevant.

Respondent experts

The experts were chosen on the basis of their wide experience and knowledge of construction industry development. All of them have construction field experience in developed as well as less developed economies. Three of the five have predominantly a background of extensive industrial experience of over 20 years in countries in Africa and Southeast Asia (Respondents A, B and C). Respondent C has both field experience and academic achievements, having completed a doctoral degree and published research papers and textbooks throughout his professional life. The other two were with mainly an academic background, distinguished in the field. Both have published extensively in the form of research papers and textbooks over the past 20 years (Respondents D and E).

Data Collection Procedure

Respondents were invited to respond to a series of open-ended questions arranged in a semi-structured sequence. These elicited responses on the key factors in construction industry development, current issues, and experience of intervention strategies and policies. Since the identification of the key factors is so fundamental to everything that follows, an additional note needs to be written to explain the process of identification. This concerns the *description* of the factors. Different experts will use different words to express a factor that they have in mind. For example, one refers to government influence being crucial in supporting the activities of the private sector. Another refers to government influence in executing functions such as education, legislation, regulation, fiscal and monetary policy. Yet another refers to government influence in preparing national development plans. All three experts acknowledge the role of government, yet their illustration of it and descriptions vary considerably. Initially, the list was written using, where possible, the expert′s own words of description or characterisation of the factor.

The data were collected using a tape recorder together with field notes. The tapes were transcribed using a word processing software package. The transcripts were then used in two ways. The first was to go through them systematically and highlight the key factors using the technique of content analysis. The second approach was to introduce them into version 4.0 of a textual analysis software called NUD*IST (QSR 1997). The NUD*IST acronym stands for: NUD = Non-Numerical Unstructured Data (Qualitative Data) and the IST = Indexing Searching and Theorising (The ways in which the data is managed and then theory is developed). These two procedures helped to ensure more consistency in analysis and interpretation.

The data analysis and interpretation is structured under several headings, broadly in line with the emergence of the dominant themes.

RESULTS

First Stage Analysis: Identification of 42 Factors and Ranking

In the first compilation, this resulted in a list of 42 factors (Table 1). As an initial result, this is a large number, but an expected outcome in view of the previous indications from the literature. It confirms that there are many factors that are held to be important in construction industry development. Some of the factors occurred many times. Some were mentioned many times by each respondent, and the number of asterisks in the Table indicates this frequency. Other factors were mentioned by only one respondent.

From an analysis of the responses given by the five interviewees, four factors emerged as more important. These four factors (highlighted in Table 1) are:

- Government Influence;
- Training;
- Finance; and
- General Business Environment.

These are identified because they are mentioned by at least three out of the five experts as being important. Frequency of mention by different experts may not automatically mean that these factors are the most important. However at this stage in the research process, this is an indication that these factors are key items.

Second Stage Analysis and Synthesis: The Role of Government in Construction

The high number of factors which fell under the generic heading of ″Government Influence″ led to a second stage analysis of their meaning and nature. An inspection of their nature combined with reflection over the role which government plays, led to the decision to arrange them under three sub-headings. These three can be regarded as being in a hierarchy of levels, with, for example at the highest level, the government′s influences on the general environment. This influence is asserted and maintained through various policies affecting all areas of society. Examples of such policies are those affecting education, commerce, health and social welfare. Since these policies affect all industries, the effects on the construction industry are felt only indirectly. At the next level, closer to the construction industry, the government makes its influence felt in a direct way. Examples are building regulations and procedures written for the construction industry. Finally, as a client, government directly influences various workings of the industry.

Thus the interview data can be synthesised into three roles of government, namely:
(A) Government as a provider of the general environment;
(B) Government as a provider of the construction industry environment; and
(C) Government as a client.

The use of the term environment does not refer to physical facilities, but is intended to include social, political, economic and managerial linkages in the general and operating/task environments.

The list of forty-two factors in Table 1 was then reviewed to identify all those that come under the generic heading of ″Government Influence″. Of these, 17 (40%) were found to fit under this heading, and these were abstracted and re-arranged under the aforesaid three sub-headings.

A The government′s influence on the general environment

Of the forty-two factors cited by the interviewees, six fall under this highest level of government influence. All of them concern values held by the government, namely:
8 Government policy supporting private industry;
28 Government values concerning employment;
32 Corruption (ethical values);
35 Government political concerns (values) over employment;
36 Government values concerning intervention; and
37 Government values concerning its image.

B The government′s influence on the construction industry

At the next level down in the hierarchy, the government can have a direct influence on the construction industry by implementing policies that directly affect its task environment. There are eight factors that fall under this heading.
9 Good communication between government and contractors
18 Out-dated colonial rules
19 Government attitudes too rigid
20 Government dependence upon external aid
27 Good communication between government, contractors and unions (tri-partite agreement)
30 Inappropriate government systems and procedures
38 Performance measurement of construction operations
39 Institution-building and development for construction

C Governments influence as a client

At the lowest level of the hierarchy, the government has a major influence as a client. This is evident especially in those countries where of the total construction industry workload, the government contributes over half. The relevant factors at this level are:
17 Government bureaucracy in tendering
33 Public sector workload variable levels
41 Competition between contractors too high

Discussion on the Three Roles of Government

In placing the factors under these three sub-headings, some guidelines were used in order to ensure consistency in the approach. Four of the factors shown under the sub-heading of (B)"Government as a provider of construction industry environment", namely *18 Out-dated colonial rules, 19 Government attitudes too rigid, 20 Government dependence on external aid,* and *30 Inappropriate government systems and procedures,* could be regarded as falling under the sub-heading of (A) "Government as a provider of general environment". They were put under (B) because the respondents spoke of each factor as it arose in a construction industry context. For example, factor 18 "Out-dated colonial rules" would probably apply as a characteristic to the government as a whole. However the description arose in describing the characteristics of a government department which had construction industry responsibilities. The decision to classify it under (B) was more appropriate. In this example, whether the factors are classified under (A) or (B) is probably not important. The question of whether the factor applies or not is much more relevant.

Table 1: Factors Affecting Construction Industry Development

Factor		*Respondents*					
		A	*B*	*C*	*D*	*E*	*Frequency of Mention by Different Respondents*
1	**Training**	*	*	**	**		**4**
2	**Limited finance**	*		*****	*		**3**
3	Limited technical knowledge	*					1
4	Limited management skill	*					1
5	Limited communication (telephone)	*		**			2
6	Limited materials	*			*		2
7	Lack of entrepreneurial skills	*					1
8	**Government policy supporting private industry**	*			**	**	**3**
9	Good communication between Government and Contractors	*					1
10	Lack of plant			*			1
11	Lack of investment		*				1
12	Market influence of overseas contractors		*				1
13	Senior construction manager perception		*				1
14	Chronic skills shortage		*				1
15	Lack of confidence in indigenous skills		*				1
16	Uncertainty about intervention strategy		*				1
17	Government bureaucracy		*	*			2
18	Outdated colonial rules		*	*			2
19	Government attitudes too rigid		*				1
20	Dependence on external aid		*	*			2
21	Aid agency procedures too strict		*				1
22	Aid agency perceptions/attitudes		**				1
23	Only short term thinking of indigenous industry		*				1
24	Attitudes of international contracting staff		*				1
25	Union flexibility		*				1
26	The mentor system		*				1
27	Trio-partite agreements		*				1
28	Government values concerning employment		*				1
29	Contractor motivation through ladder of opportunity		**				1
30	Inappropriate government systems and procedures		*				1
31	**Business environment**			***	*	*	**3**
32	Corruption			**			1
33	Workload - variable levels			*			1
34	Contractors perceptions/attitudes/ culture			**			1
35	Government political concerns (values) over employment			*			1
36	**Government values concerning intervention**	*****		*****	*****		**3**
37	Government attitudes concerning its image			*			1
38	Performance measurement of the industry			*	*		2
39	Institution building/institutional development			**	*		2
40	Lack of power (electrical)				*		1
41	Competition between contractors too high				*		1
42	Fragmentation of organisations and functions					*	1

An overall picture of the role of government as presented by this analysis shows by the high number of factors that the government has a multi-faceted influence on the construction industry. By far the greater influence if the number of factors is counted is the combined sub-groups (A) and (B). There are a total of 14 factors that together influence the general environment or operating/task environment of the construction industry.

By contrast, there are only 3 factors that are classed under the sub-heading of (C) “Government as a client”. This is surprisingly small, especially when compared to the results of the literature. The latter seems to place great emphasis on the influence of the government as a client. The results of this empirical study contrasts with previous findings. A satisfactory explanation cannot be provided at this stage, but this is an area for further investigation.

Third Stage of Analysis: Generic Factors “Behavioural Factors” and “Key Resources”

The remaining factors in the list of 42 were also inspected to ascertain if there was any discernible pattern. A similar approach was taken to that used in abstracting and classifying the ″Government Influence″ factors.

Using this approach, two other main groups could be discerned. One, which contained all those factors relating to attitudes, values and perceptions of ″key actors″ in the industry, was labelled as shown below:

Behavioural Factors (Attitudes, Values and Perceptions of Key Actors)

13 Senior construction manager perception
15 Lack of confidence in indigenous skills
16 Uncertainty about intervention strategy
22 Aid agency perceptions/attitudes
23 Only short-term thinking of indigenous industry
24 Attitudes of international contracting staff
29 Contractor motivation through ladder of opportunity
34 Contractors perceptions/attitudes/culture

The second major group that fell out quite naturally was dealing with the key resources, both physical and human. These ″key resource″ factors have been placed in two sub-groups as shown below:

Key Resources

Physical Resources

2 Limited finance
11 Lack of investment
5 Limited communication (telephone)
6 Limited materials
10 Lack of plant
40 Lack of power (electrical)

Human Resources
1 Training
3 Limited technical knowledge
4 Limited management skills
7 Lack of entrepreneurial skills
14 Chronic skills shortage

The Residual Factors

The remaining factors were then inspected. They were
21 Aid agency procedures too strict
25 Union flexibility
26 The mentor system
42 Fragmentation of organisation and function

Upon reflection, factors 21 and 25 could be regarded as coming under the heading of “attitudes”. Strict agency procedures existed because of the prevailing values and perceptions of the surrounding conditions. Likewise, union flexibility can only be achieved through particular attitudes of those actors involved. Factor 26 “The mentor system” could also come under the same heading since it requires a positive and benevolent attitude of experienced actors. However, it was felt to be closer to the development of human resources, and therefore it was decided to place it under that heading. The remaining factor 42 Fragmentation of organisation and function did not fit under any of the generic group headings, and is therefore left as a residual.

The three groups that have emerged from this analysis and synthesis are thus the government influence, behavioural factors and key resources. It is not our intention to pursue the latter two in this paper. Therefore attention will focus on the most dominant influence; that of government.

SYNTHESIS OF GENERIC FACTORS AND DISCUSSION OF RESULTS

From the data presented and analysed in the previous sections, it is now possible to combine the factors together under the three generic headings as shown in Table 2. The frequency with which the factors have been mentioned by the five respondents under these headings is also shown. This can give an indication as to their relative strength.

Table 2: Generic Factors Affecting Construction Industry Development

	0.1.1.1.1.1.1 Respondents					
Generic Factor	*A*	*B*	*C*	*D*	*E*	*Total Scores*
GOVERNMENT ROLE	**3**	**6**	**10**	**6**	**3**	**28**
General Environment	2	1	5	3	2	13
Task Environment	1	4	4	2	1	12
Client	0	1	1	1	0	3
BEHAVIOURAL FACTORS	**0**	**10**	**1**	**0**	**0**	**11**
KEY RESOURCES	**7**	**5**	**4**	**4**	**0**	**20**
Physical Resources	3	2	3	3	0	11
Human Resources	4	3	1	1	0	9
TOTAL SCORES	**10**	**21**	**15**	**10**	**3**	**59**

It can be seen from the results in Table 2 that in terms of influence upon the construction industry, the government is the strongest (score of 28), with the key resources (score 20) and behavioural factors (score 11) of apparently less importance. As we stated earlier when considering the individual factors in Table 1, the number of times which a factor has been mentioned by respondents does not automatically establish its importance. However, from our knowledge of the data we believe it does give an indication of the relative importance. This argument becomes stronger when considering combining individual factors into generic factors as we have in Table 2. The relative strength of the generic factors is based upon a combination of sub factors and thus there is greater credibility that a numerical score can reflect their relativity.

A further observation can be made about the data in terms of the bias of the respondents. In looking at the composition of total scores of the three generic factors, Government's Role, Key Resources and Behavioural Factors it is apparent that the respondents would rank them differently. Respondent A would appear to place more emphasis on Key Resources (score 7) compared to Government Role (score 3) or Behavioural Factors (score nil). Respondent B appears to rank them according to Behavioural Factors (score 10), followed by Government Role (score 6) and Key Resources (score 5). Respondent C places Government Role (score 10) and Key Resources (score 4) well ahead of Behavioural Factors (score 1). The respondents were not asked specifically to rank the factors in the interviews, but this would appear to be the next logical step in any follow-up study.

Looking at the distribution of scores for the three generic factors across the five respondents, it is noticeable that for the factors of Government Role and Key Resources, the total scores have been made up from contributions from 5 or 4 of the respondents. For the Behavioural Factors, Respondent B has contributed 10 out of the total score of 11. This may indicate the particular orientation of Respondent B and his experience. If Respondent B had not been selected for interview this generic factor would have been insignificant amongst the other four respondents.

Having abstracted the role of government from the interview survey, the results from the previous research studies can be presented for comparison.

REVIEW OF LITERATURE AND COMMENTARY: ROLE OF GOVERNMENT IN DEVELOPING THE CONSTRUCTION INDUSTRY

In searching for the key factors influencing the development of the construction industry, the government is mentioned in all references in the mainstream literature of the field. The purpose of this review is to seek and present representative strands of the themes explored to date, rather than an exhaustive examination. The review here will therefore be confined to several key and established texts on the subject together with a selection of papers published since 1990.

Government's influence on the general environment

One of the most significant findings from the literature is the strong emphasis on the external environment of the industry. This arises through the use of a systems framework in explaining the nature of the construction industry. A systems view of the industry would normally place the construction firms within the industry boundary, whereas the government and clients would usually be external. Issues and problems experienced within the boundary, i.e. within the industry by contractors, may stem either internally from other parts of the construction industry, for example design consultants, or alternatively from external influences. Support for this view can be found in the paper by Aniekwu (1995) that reports problems experienced in the Nigerian construction industry. Out of 47 factors that adversely affect the industry 34 (72%) were from the industry business environment. Further evidence is provided by Wells (1996) who argues that industry problems are originating from its operating or task environment. Ofori (1994) and Betts and Ofori (1994) adopt the same theme in their use of Porter's framework (Porter 1990). From the viewpoint taken in all of these cases, the client is outside the boundary of the industry. According to this view, construction firms in the industry can be aided to secure a competitive advantage by government creating a conducive environment.

The decision by government to influence the construction industry through its environment rests upon its policy towards intervention. At this macro level, the role of government in creating suitable conditions for industry to thrive is characterised by two approaches. One is to centrally plan economic activity and intervene quite strongly. The other is to allow market forces to develop capacity organically. Even in the so-called free-market approaches adopted by developed nations, government plays a powerful role. For example, in a recent article (*The Economist*, 1997), there was a strong assertion that despite concerns about the need to reduce the intervention of the state and allow market forces to shape the economic destiny of nations, government continues to play a dominant part in industry. Werna (1993) carefully analyses the development of the Brazilian construction industry and demonstrates that although the government withdrawal from the building scene could be shown to bring benefits, this may be undesirable. In relation to construction, from the interviews, the involvement of government appears to be a major factor in the way and the speed with which industry can move forward in both developed and developing nations.

In their study of international contracting, Strassman and Wells (1988) identify five areas of government policy which influence construction:

(1) Trade promotion;
(2) Tax incentives;
(3) The provision of insurance and credit;
(4) Tied aid; and
(5) A variety of controls.

They conclude that areas of finance and research / technology are the most crucial areas of policy differences between countries. Government plays an important role in both of these areas.

Government’s influence on the construction industry

Publications by Ofori reveal the importance of government for construction industry development. He identifies at least six roles for government (1993). These are:

(1) At the level of state planning and budget to regulate the economy in both the public and private sectors;
(2) As a client by using bargaining power to influence the practices, technologies and materials used;
(3) By monitoring of contractors’ performance;
(4) By offering incentives for change, training and development;
(5) By fiscal rules for mechanisation; and
(6) By setting up firms to increase competition in selected markets.

In a later paper (Ofori 1994) a number of desirable measures are outlined. These include a role for government classed under two main headings:

(a) National strategy which includes a prioritised set of initiatives arranged in the form of rolling plans; and
(b) Executive administration in the form of a central body to spearhead the strategy and measures.

The six roles would be subsumed under this strategy and its implementation.

Government’s influence as a client

The importance of clients in the external environment, according to Wells (1996), is that in all countries improvements in the performance of the construction industry have invariably been brought about by client influence. She claims that it is as a client that the government can exert the greatest influence upon the industry. Wells emphasises this point in which she cites the success of government intervention in Singapore. Using this and other examples, she states that most countries which have successfully developed their construction industries have done so with a high degree of government intervention, particularly in government’s capacity as a major client The key role of government is even more evident in the poorest countries, since government is the major and most regular client. This view is strongly supported by Aniekwu (1995). In the developed world, improvement begins with clients and government must take the initiative (Latham 1994:3). Wells asserts that there is no need to debate this, and she suggests that research should focus on how those tasks which need to be done can be done more effectively.

Construction is different?

The final point that comes through from the literature, and one that applies at all levels of this analysis, is that the construction industry may need to be considered separately from other industries. Several experts have argued that the construction industry is distinct from the sector of manufacturing, and thus need its own way of assistance and nurture (Miles and Neale 1991; Rainbird and Syben 1991; Strassman and Wells 1988). For this argument to be fully accepted and acted upon by government, there needs to be a greater understanding amongst all parties, industry, government and clients, about the role which government can play.

SUMMARY AND CONCLUSIONS

On the basis of an in-depth survey of opinions of experts, the results indicate the influence of government is substantial in assisting the construction industry to develop. It is the most important factor. However, government influence does not appear to manifest itself through its role as client as strongly as suggested by previous studies. On the contrary, the governments role in creating and maintaining a conducive environment, whether that be defined in business, social, educational, economic or other terms, appears to be dominant. This influence applies both at the level of the general business environment as well as the specific task environment of the construction industry.

Through the Grounded Theory approach the empirical work used in this study has enabled a greater understanding of the hierarchy of factors important in developing the construction industry. After the influence of government, the Key Resources and Behavioural Factors, respectively, are the next most important. This finding goes beyond those of previous studies, in which these factors were identified only as ones of many. This should be important to government policy-makers and those concerned with industry development issues.

The direction for further work needs to consider two questions. In view of the contrasting picture revealed through this empirical work concerning the government’s role as client compared to the previous studies, there is a need to look deeper into this aspect. It is suggested that the use of a wider, more quantitative survey needs to investigate the hierarchy of factors more fully. Both of these could be undertaken through the same study.

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Builder Registration in Victoria, Australia - A Sign of Things to Come?

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Abstract

Builders have a long history of a public perception of poor image and low quality products. Political and administrative demands for builder registration and tighter control of entry into the industry have been seen to be the solution to these problems. However, progress towards registration and control has proved elusive. Recently, the state of Victoria in Australia introduced mandatory builder registration under its Building Control Act 1993. Further reform for the housing industry was introduced in 1996 through the Domestic Building Contracts and Tribunal Act 1995. As the first legislation of its kind in Australia, the Victorian experience provides a case study for similar developments elsewhere. This paper reviews the history of builder registration in Victoria and identifies the major provisions of the 1995 Act, including the organisations established to regulate and supervise the implementation of the legislation. The perceived drawbacks and benefits of the new system are also analysed in the short period since the introduction of the legislation.

Keywords: *Construction industry, builder registration, building control legislation.*

INTRODUCTION

The lack of attention to quality by house builders in the Victorian Housing Industry has been a contentious issue for more than two decades. In an attempt to improve the quality of housing, various mechanisms have been adopted and discarded by industry-based organisations and government legislation. While builders are admonished to improve construction quality, little is known and published about the quality of housing produced by owner builders. This paper provides a critical review of the history of builder registration in Victoria and identifies the major provisions of the 1993 Act, including the organizations established to regulate and supervise the implementation of the legislation. The perceived drawbacks and benefits of the new Victorian system are also analysed in the short period since the introduction of the legislation. It is suggested that builder registration may form part of the construction industry's strategies for reform in the next century for both developed and developing countries.

BACKGROUND

Builder registration in Victoria has evolved over a number of decades. First attempts proved to be inadequate, but from the experience more robust and practical schemes have emerged. This paper reviews the history of attempts at consumer protection and builder registration to the present day. The current system enjoys the benefits of a number of attempts to ensure the customers of domestic building get the same protection and quality of product as the consumer of any commodity in our community. Historically, builder registration has been perceived as the preferred method of ensuring that the industry provides the required levels of quality control and service the community and customers expect. Whilst developments in this area over the last twenty years have been more substantive, the first attempts at registration and regulation of builders date back as early as this century.

The oldest established building company representative organisation in Victoria, the Master Builders Association (MBA) has been the primary champion of builder registration. In fact, as early as 1911 and 1914 it is recorded that the MBA advocated the registration of builders through representations to government (Victorian Government, Hansard, 1973). The issue then appears to have been relegated in importance for many years, probably due to the First World War and the severe economic circumstances during the 1920's and early 1930's. However, during the 1930's, Keast, (1994) stated that, *'… registration of builders was an ongoing saga with more information from all over being gathered together from New South Wales, Ohio, New Zealand and Western Australia'.* Nonetheless, little progress towards its legislative introduction seems to be evident. Another failed attempt was made in 1941, when Second World War activities may have removed it from legislative view. However, with the end of the War the issue emerged again with the MBA approaching government in 1945. Subsequently in 1946 the state minister provided support and in 1947 it gained national prominence when, *' … the Prime Minister was reported as wishing to discuss at the Premiers' conference, the subject of registration of builders'* (Keast, 1994). Needless to say, registration of builders never eventuated.

Through the 1950's registration as an issue never quite disappeared and in 1958 the Building and Allied Trades Association (BATA) joined the chorus for the introduction of a builder registration scheme. Unfortunately, due to competition between BATA and the MBA, a scheme for comprehensive registration was lost. However, the two employer bodies continued their dialogue and by 1960 a joint proposal to government narrowly failed. A gap between the two employer bodies developed once again because BATA preferred voluntary registration whilst the MBA maintained its preference for legislated registration.

Meanwhile, the government and the community were concerned about the state of the building industry. The Statute Law Revision Committee prepared a report on the bonding of contractors and in handing down their report considered that registration was not a solution to the problems facing the industry (The Australian Builder, 1962).

The Committee believes that most of the building industry's difficulties arise more from financial instability and managerial incompetence rather than technical inability, and is accordingly of the opinion that the implementation of a registration scheme would do little to remedy these defects.

Thus, the *status quo* in this early part of the 1960's prevailed. It appears with hindsight that the major impediment to change was political ideology. The free enterprise system was considered to be of prime importance and any government intrusion was viewed as socialistic interference with free market philosophies of the time.

Certified Homes Scheme

Nevertheless, the MBA continued to pursue legislative registration as they considered it was the best way to improve the image of builders through the better quality control that registration would bring. Its plan was to introduce the 'Certified Homes Scheme' which offered a two years structural warranty. Modeled on a UK program (National House Building Council) based with an insurance company that would take responsibility for 'making good' only when a building company becomes insolvent. It was not a registration of builders, but a registration of houses constructed by builders to a standard that the MBA and the insurance company were prepared to accept. The scheme was introduced in 1961 with a great deal of enthusiasm and confidence. Within its first five years the scheme was in trouble and 1967 discontinued it. Approximately 1,110 houses were registered with this scheme over its six-year life. Coincidentally, the rival body, BATA, commenced its 'Certified Homes Scheme' in 1961, one-month after its competitor's scheme. Strangely, BATA (known as the Housing Industry Association from 1972) also had insurance problems, probably due to the fact that it used the same insurance company as the MBA. This scheme is also believed to have foundered in 1967.

The Certified Homes Scheme was the first concerted effort by the industry associations to address community concerns about the quality of house construction. The major reason for its failure is believed to be its voluntary nature. While there was a growing community perception of lower quality standards in house construction, it did not translate into greater demand for higher quality obtainable through the schemes on offer. In the absence of demand by consumers, builders did not see the need to continue the schemes, as they did not add to their business. Failure of both schemes focused attention on *builder* registration as distinct from *house* registration that these schemes incorporated.

The MBA favoured registration by government legislation with minimum educational and competency standards. The HIA championed registration administered by industry. Both industry bodies went their separate ways and lobbied government individually. Each body believed its voluntary registration approach would enhance the standing of its members.

In 1972, the HIA instituted its own voluntary registration scheme establishing the House Builders Registry Board (HBRB). This Board enabled its members to offer a six-year structural warranty. In contrast, the MBA remained committed to compulsory registration despite the introduction of the HIA's voluntary registration scheme. However, to avoid leakage of members to the HIA, the MBA also introduced its own voluntary scheme, The House Guarantee Scheme. The MBA did not promote the widespread use of the scheme, and recommended that it be used only if requested by clients. This guarantee was effective for a period of one year after the certificate of occupancy was issued. Other pressures were building up over the years. In retrospect, probably the greatest impetus to legislated protection for consumers came in 1964 with the introduction of the *Consumer Protection Act.* Inevitably, the building industry came in for its fair share of criticism. The governing body under the Act, the Consumer Protection Council, brought the industry into its targets in a number of its Annual Reports from 1967 onwards. This culminated in a firm recommendation in its Annual report of 1973.

The Council strongly recommends to the Government that it passes legislation requiring the licensing of all builders and companies engaged in building. It should also cover the establishment of an independent tribunal to deal with complaints by consumers against builders as to unsatisfactory workmanship and delays in completion under the terms of the agreement entered into by the consumer with the builder.

House Builders Liability Act

The Government was obviously influenced by community pressure, the industry bodies and the Consumer Council and responded by introducing an industry administered builder registration scheme known as The Local Government (House Builders Liability) Act, 1973. Despite the introduction of this mild form of builder registration, complaints to Consumer Affairs continued unabated. The main features of the new Act were:

- Suitability for registration was determined by the two funds (generally to be a member of the HIA or MBA).
- Only new homes were covered.
- Owner builders were exempt from registration if the house was not sold for one year.
- Period of guarantee was from date of certificate of occupancy.
- Protection for owners in case of bankruptcy by builder.
- Guarantee covered work to a maximum of $40,000.
- Provided for arbitration in case of disputes between parties.
- Notification of defects had to be in writing and made within three months of the complainant becoming aware of defects.

The Act may have been well intentioned, but it was doomed to failure. Both industry associations saw the Act as an opportunity to enhance the status of builders, but more importantly as a vehicle to increase membership. Unfortunately, the interests of the consumers seemed to be a minor consideration. In addition, the two bodies marketed their schemes differently. The HIA presented its scheme as straightforward insurance, which created the perception that once a house was completed it became the insurance company's responsibility. In contrast, the MBA maintained that the builder was always responsible for the quality of the house constructed. The fund would only meet its guarantee obligations in the event of default by the builder. From its introduction, the system of registration did not reduce the complaints. Many were due to poor practices in technical content and dubious contractual applications. A number of Ministry of Consumer Affairs annual reports cited several problem areas:

- Differing standards of workmanship;
- Dispute resolution mechanism was perceived as favouring builders; and
- Notification procedures for complaints were inadequate.

By 1983 it was evident that changes would need to be made. The government asked a committee consisting of representatives from the Ministry of Consumer Affairs, industry bodies, community and consumer bodies to review the Act. In 1984, the Act was amended and the two industry funds were merged to form the Housing Guarantee Fund administered by the Ministry of Consumer Affairs (see Figure 1).

Housing Guarantee Fund

Despite amalgamating the funds an undercurrent of consumer dissatisfaction remained. This culminated in more legislation, requiring tighter control of the industry, to be enacted with the introduction of the House Contracts Guarantee Act 1987 (operational in 1988). The main features of the Act were:

- A seven-year guarantee from the date of contract or building approval (whichever was earlier).
- Applies to new houses and for the first time to renovations, alterations, additions and repairs with a value in excess of $3,000.
- Contracts required to state financial arrangements such as deposits and progress payment schedules.
- Deposit set at 3% for work in excess of $20,000.
- Compulsory for all builders to be a member of the HIA or MBA (but this requirement was deleted in 1992).
- Variations had to be in writing, signed and dated by both parties.
- Guaranteed maximum coverage remained at $40,000.

Provisions of the new Act would be administered by the Housing Guarantee Fund Limited (HGFL), which was a private non-profit company. It derived its income from annual registration fees from builders and a registration fee for every house constructed. Needless to say, both industry bodies believed that a substantial bias in favour of consumers had taken place with this legislation. Consumers were not satisfied with the new arrangements either. Annual reports of the Ministry of Consumer Affairs continued to report similar difficulties with the new Act as existed previously. Whilst some of these could be attributed to the flow-on effect from the old Act, the trends were worrying. Consumers became more vocal and lobbied government and made submissions at a number of forums. Eventually, an investigation and review of the House Contracts Guarantee Act 1987 was conducted, which climaxed in the finding that the Act was inadequate. Specifically, the major problems (Kliger, 1991) of the housing industry were:

- *poor quality of finish* - differing opinions and expectations of builders and consumers.
- *delays and variations* - additional costs caused by delays in construction by items that could be reasonably foreseen.
- *poor workmanship and defects* - disputes about poor quality workmanship and defects resulting in delays and costs.
- *major and minor defects* - differing opinions of builders and consumers on the severity of the problem.
- *poor supervision* - insufficient supervision of sub-contractors.
- *practical completion* - disagreement about what constituted practical completion and completion of stages in construction. This had ramifications for progress payments.
- *ignorance by consumers* - consumers were unaware of their rights and obligations during the procurement and construction process.

The Housing Guarantee Fund attempted to address these issues, with mixed success. This period also coincided with considerations for uniform national regulations resulting in the National Model Building Act. The reform process in turn led to the Victorian Building Act 1993 based upon a national model. The initiatives in this Act ranged from privatisation and deregulation of the building approval process through to restricting some aspects of legal liability. But most importantly, it required all building practitioners to register with the Building Practitioners Board in the newly formed Building Control Commission.

BUILDING ACT 1993

The Building Practitioners Board was established under the Building Act 1993 to oversee the quality and standard of the professional services provided by building practitioners in terms of public health and safety.

The Regulations describe the various categories of building practitioner and the qualifications and experience required for a person to be legible to apply to the Board for registration as a building practitioner. The Act is a milestone in builder registration as it established a significant governing body, the Building Control Commission, to oversee the operation of the registration and regulations systems.

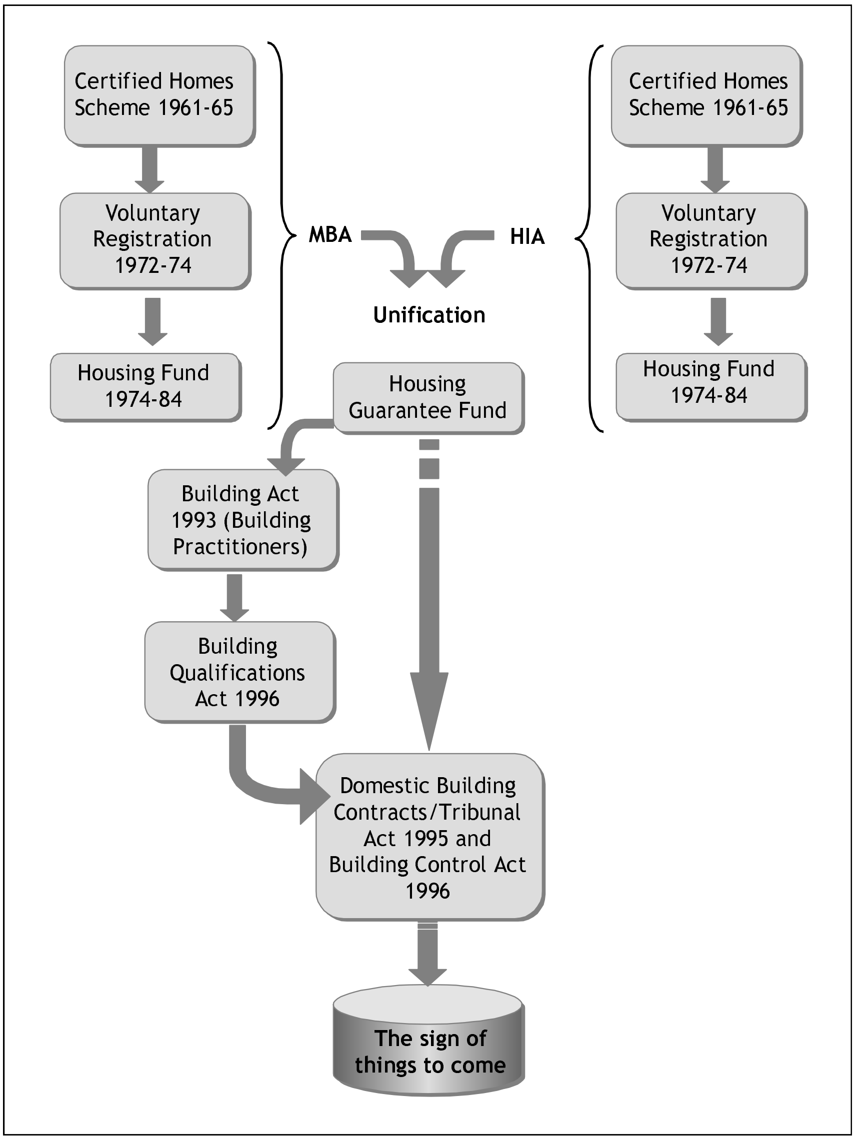

Figure 1 The Roadmap for Builder Registration Victoria

The main functions of the Building Practitioners Board are to administer the building practitioner registration system, report to the Minister on the qualifications requirements of building practitioners, monitor the conduct of building practitioners and deal with any other functions conferred by the Act or Regulations.

Building (Qualifications) Regulations 1996.

These regulations define building practitioners. Building practitioners include building surveyors, building inspectors, quantity surveyors, engineers, draftspersons who prepare plans for building work or prepare documentation relating to permits or permit applications, builders (commercial, domestic and demolition) and persons who erect or supervise the erection of temporary structures. The trades and on-site skill categories are also defined and regulated. Architects are covered separately under the provisions of the Architects Registration Act 1922 as administered by the Architects Registration Board of Victoria.

A significant departure from the past is that in these regulations it is the individual who is registered, *not a company*. This prevents the individual trading under a new company name, which was a problem encountered in previous legislation.

DOMESTIC BUILDING CONTRACTS AND TRIBUNAL ACT 1995 (DBC&T ACT)

From May 1996 the Housing Guarantee Fund Limited (HGFL) was no longer responsible for registering builders and building projects, and providing warranties. Each domestic builder was required to register with the Building Practitioners Board and, under the requirements of the DBC&T Act, to take out appropriate insurance in relation to all building work undertaken (see Figure 1).

The DBC&T Act operates under two main requirements to regulate the quality of domestic building. These are:

- Insurance of the works; and
- Registration of the builder as a building practitioner.

Insurance

In order to obtain a building permit from the planning authority or local council, a domestic builder will need to show proof to the building surveyor that they have the required insurance and they are registered as a building practitioner. The insurance must be validated by the Building Practitioners Board and be for a period of 6 years and 6 months, either with the name of the builder or the name of the building owner. During construction of the house a builder must also hold valid professional indemnity insurance. The lessons from previous experience again are evident, as the individual rather than a convenient *shelf company* must hold the insurance.

A builder carrying out domestic building work of more than $5,000 in value must be registered and this ensures that consumers are protected by a valid insurance policy. The project cannot be broken up into a series of small separate contracts below the $5,000 limit to avoid this protection. However, single trades such as electrical, glazing, floor covering, insulation, painting, plastering, plumbing and gasfitting are exempted from this requirement. Normally, when a domestic builder undertakes building work which involves more than one trade and the work includes structural work then they need to be registered and a building permit must be obtained for building work.

There are three classes of registration for domestic builders:

- A domestic builder (unlimited) being a person who has adequate knowledge and experience to carry out, manage or arrange to carry out all components of domestic building work;
- A domestic builder (limited), and
- A domestic builder (manager) being a person who has adequate knowledge and experience (including financial management) to manage or arrange the carrying out by a registered builder of the components of building work.

Qualifications for registration

These were originally defined in the Building Regulations 1993 and amended in the Building (Qualifications) Regulations 1996. In the 'unlimited' class the builder needs to possess an accredited degree, diploma or associate diploma and have three years of practical experience; or have completed a 'Course in Builder Registration (BPB)' together with three years practical experience. In the 'limited' and 'manager', a may certificate issued by the Building Practitioners Board, after examination of the applicant, which defines the components of domestic building work which that registrant may undertake. However, an existing builder could be exempt from these requirements if they had been registered in the previous scheme with the Housing Guarantee Fund before 1 May 1996.

ROLE OF BUILDING CONTROL COMMISSION

The Building Control Commission was established under the Building Act 1993 and it oversees the administration of building control in Victoria. The Commission is a self-funding corporate body subject to the direction and control of the Minister for Planning and Local Government. The role of the Commission is to develop and apply building law to provide for the design, construction and maintenance of healthy, safe, habitable and energy-efficient buildings. Another of the Commission's tasks is the role of promoting national regulation reform. It aims to increase the efficiency and cost-effectiveness of building regulations and improve their responsiveness to the needs of the construction industry and the community. The income of the Commission is provided by a statutory levy of 0.064 cents for every $100 of the cost of the project when it is more than $10,000 in value. The levy is paid to the relevant building surveyor before a building permit is issued.

Building Advisory Council

A Building Advisory Council was established under the Building Control Act (1993). The Commission provides administrative support to the Council. The Council advises the Minister on the administration and impact of the legislation and regulations on the building industry and the community. Its members consist of representatives of the industry and professions:

- Royal Australian Institute of Architects (Victorian Chapter)
- Master Builders Association of Victoria (MBAV)
- Housing Industry Association (HIA)
- Australian Property Council
- Australian Institute of Building Surveyors (Victorian Chapter).

Building Practitioners Board

This Board comprises building practitioners drawn from major professional organisations who are appointed upon the recommendation of the Minister. It administers the registration system of building practitioners and monitors their performance. It may also make recommendations to the Minister regarding qualification and on insurance matters.

Building Appeals Board

The Board's role is to hear applications for modifications to the building regulations, decide on any disputes or appeals arising from the Building Act and listen to appeals from the Building Practitioners Board.

Disputes and Complaints

If disputes cannot be resolved between the parties, they can be referred to the Domestic Builders Tribunal which is administered under the Domestic Building Contracts and Tribunal Act 1995. The Tribunal has unlimited monetary jurisdiction to hear and determine domestic building disputes, owners' insurance claims and insurers' decisions on such claims and requests to stop building work that does not comply with the contract. The Tribunal may advise mediation, order payment of money, vary a term of the contract, order rectification of defective work, and enforce any right of indemnity against a builder by an insurer.

Complaints about the conduct of Building Practitioners must be written and signed and lodged with the Commission. The Commission will investigate the complaint and may refer the matter under investigation to the Building Practitioners Board for its consideration and subsequent action.

Building Regulations Advisory Committee

This Committee advises the Minister on changes to the Building regulations. The Committee's membership comprises the Commissioner together with architects, builders, building surveyors, engineers and building owners as well as a representative from the fire authorities, state government and local government and the Melbourne City Council.

SUMMARY

The perceived drawbacks and benefits of the new system in the short period since the introduction of the legislation may be analysed. The perceived benefits of the builder registration are:

- The building practitioner must be insured to carry out the works and this protects the consumer.
- The commencement date for the liability period for insurance and disputes is fixed.
- Refusal of insurance for a building practitioner results in de-registration or non-registration by the Building Practitioners' Board. This has led to more individual responsibility being borne by practitioners.
- The registration requirements, taken with privatisation of building permits and approvals, has improved the speed of the system leading to cost and time savings.
- Consumers have greater protection.
- The building permit levy has generated funds that are being channelled back into the industry for research and education.

The possible drawbacks of the new system are:

- Consumers are paying more for building work and professional services because of the requirement for compulsory insurance for all practitioners and professionals.
- The building permit levy (0.064 cents per $100 construction costs) is added to the costs of projects and passed on to the consumer in higher building costs.
- Despite the insurance and qualifications requirements for building practitioners, there are still some disreputable individuals and firms whose quality of work and service is not up to standard. In these cases consumers will still not be satisfied with their work.
- When all builders registered with the HGF were automatically transferred across to the Building Practitioners' Board in 1996, the transfer included bad builders; for example, six bankrupt firms were registered.
- Some unregistered builders are still practising in the industry, illegally.

The system of builder registration in Victoria has evolved over a period of thirty years. Each step in the process has built upon the experience gained with the previous scheme, eliminating the obvious drawbacks with each stage. Registration has developed from voluntary arrangements, to registration of companies with insurance providing the means to protect consumers. The latest stage can be described as a scheme based on registration on the basis of the insurance of individual building practitioners with the necessary qualifications and experience to be insurable (see Figure 1).

It is too early to state categorically whether the most recent scheme described in this paper is a success. The authors' research on defects in houses constructed under the HGFL scheme indicated generally low levels of defects at an average of two defects per house (Georgiou, et al, 1998). Similar studies have not been carried out on houses under the present scheme. However, the early positive indications are that consumers appreciate the insurance protection it affords on an expenditure that is larger than most they commit themselves to during their lives. Statistics are not available to determine whether the level of disputes and defects have dropped as a result of the *policing* role conducted by the Building Control Commission and its various boards and tribunals. The registration arrangements in Victoria, Australia, (together with the organisations and bodies established in this important area) deserve close study by other administrations that grapple with similar problems in the construction industry. This form of consumer protection may be the most practical way forward in the new millennium.

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Changes in the European Large Scale Engineering Construction Industry

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Abstract

In recent years the Large Scale Engineering (LSE) construction sector in Europe has seen profound change. This is mainly due to increasing competitive pressures from the United States and the Asian Pacific countries which has led in turn to increased pressures to improve competitiveness, productivity and client satisfaction. Lack of understanding of clients' and contractors' requirements hinders achieving such goals especially with the increasing trends of executing LSE projects in a "virtual enterprise" environment. ICT (Information and Communications Technologies) vendors and developers also need to understand clients' and contractors' requirements of systems and to align their products to them. This paper reports on findings from studies undertaken within the eLSEwise (European Large Scale Engineering Wide Integration Support Effort) ESPRIT project to investigate the LSE construction industry requirements, and identifies gaps in the relationships of clients and contractors with other parties of the supply chain and in ICT provision.

Keywords: *Large scale engineering, information and communication technologies, construction, eLSEwise, virtual enterprise.*

INTRODUCTION

The European Large Scale Engineering (LSE) industry operates in a global market. In recent years it has seen profound change reflecting on the emerging political, social, economic and technological developments. Increasing competitive pressure globally, clients' demand for lower costs and better quality, coupled with new developments in information and communication technologies and deregulation and privatisation of utilities, have all come together to force players in the LSE sector to review their traditional ways of doing business. This is in line with the industry's commitment to improve its competitiveness, productivity and client satisfaction.

The studies presented in this paper were undertaken within the eLSEwise (European Large Scale Engineering Wide Integration Support Effort) project which is part of the European ESPRIT (European Union's information technologies research in technical developments) programme. eLSEwise is a user reference project which took a business led approach in identifying the European Large Scale Engineering (LSE) construction industry requirements for Information and Communication Technologies (ICT). eLSEwise aimed to reduce the fragmented nature of the current European LSE industry to improve competitiveness through integration of information and processes and enable it to collaborate more effectively in an increasing global market for LSE (Garas and Hunter, 1999).

Within the context of this paper, "Large Scale Engineering" refers to the complex multi-discipline engineering (both design and construction) which is encountered at the top-end of the construction industry's spectrum of activities (Watson, 1996). LSE includes complex buildings, process plant, infrastructure, significant civil engineering work and other major construction works. A LSE project has the following attributes (Watson, 1996; Brohn *et al*, 1997; Hunter *et al*, 1999):

- “High” capital cost
- Long duration but programme urgency
- Technologically and logistically demanding
- Requires multi-disciplinary inputs from many organisations.

Different parties to the construction process need to understand and fulfil clients' business and information requirements throughout the product life cycle from inception to operation, maintenance and decommissioning. However, it is also important that clients understand requirements and views of the contractors who undertake their projects. Information and Communication Technology (ICT) vendors and developers also need to understand clients' and contractors' requirements of ICT systems and to align their products to them.

The research described in this paper aims to identify clients' and contractors' business and ICT requirements of the LSE industry and presents their views of the LSE environment. This was achieved through a focused workshop supplemented by questionnaire surveys issued to LSE clients and contractors across Europe. The main requirements and views with regard to the LSE business environment were identified during the workshop and then ranked and prioritised through the questionnaires. In the same manner, the usage of the different means of information exchange was established, the degree of importance of different information systems within the LSE clients' organisation was identified, together with the areas where sharing information between different parties of the supply chain are necessary. The paper also outlines the vision developed by eLSEwise for future execution of LSE projects in a "virtual enterprise" environment. Finally, the paper concludes with a set of recommendations for the LSE industry and for ICT developers and vendors based on the eLSEwise findings.

THE CLIENTS’ ELECTRONIC WORKSHOP

The aim of the workshop was to gain clients’ views on current and future business and ICT requirements of the LSE industry across the different construction sectors, including complex buildings, process plant, infrastructure, and special large scale civil engineering projects. The objectives of the workshop were to:

- investigate clients' business drivers and objectives and the application of ICT to serve clients’ business needs currently and over the next 10 years; and
- investigate clients’ requirements from the supply chain to achieve their business objectives (also currently and over the next 10 years).

The participants in the workshop were senior representatives from large-scale engineering client organisations. Data elicitation during the workshop was undertaken partly electronically via a local computer network and partly manually via discussions and comments on initial results. The participants were divided into two groups and each participant was allocated a computer. The questions appeared on each participant’s screen and the facilitator explained each question in more detail. Discussions were generated among each group before each participant entered his or her answer. A separate window on each screen displayed the group answers. After all participants entered their answers for each question, the groups’ answers were printed and distributed for further comments and discussions. The electronic workshop enabled an equal participation of all the attendees, acquiring more ‘hard’ information in shorter time compared to traditional workshops and better time management for the workshop (Hassan *et al*, 1997).

LSE CLIENTS QUESTIONNAIRE

The objective of the clients' questionnaire was to investigate and prioritise the different factors and issues that were identified by the clients' electronic workshop. The questionnaire was issued to some 90 European clients. Although the response rate was disappointing (only 19%), covering the different LSE sectors, it did confirm one of the findings of the workshop which is that clients organisations are downsizing (and relying on more input from contractors) and there are increased time pressures on staff which reduced their participation in research activities (Hassan, 1998a).

LSE CONTRACTORS QUESTIONNAIRE

The objective of the contractors' questionnaire was to investigate the LSE industry's response to clients' views and requirements identified from the above mentioned workshop and questionnaire. In order to ensure a satisfactory response rate and geographical spread, the questionnaire was distributed through the eLSEwise project consortium. Each partner had to issue the questionnaire to LSE contractors in their countries (eight different European countries). Responses from a total of 34 LSE contractors were analysed (Hassan, 1998b).

The following sections describe the main findings from the workshop and questionnaires.

CLIENTS VIEWS AND PERCEPTIONS FOR CHANGES IN LSE BUSINESS ENVIRONMENT

The relationship between clients and contractors is changing with clients seeing a swing of responsibilities and risk from the client's side to the contractor. This is due to Clients out-sourcing their non-core activities to contractors and relying on more technical input from them. The result is a decrease in size of clients' organisations and loss of construction expertise.

Clients who responded to the questionnaire were asked to rank the importance of different factors which impact the LSE industry. These factors were identified by clients who attended the workshop as:

- Partnering/alliancing
- Private Finance Initiative
- Increasing regulations particularly Health and Safety
- More technical input from contractors
- More risk allocation to contractors
- Sharing expertise between clients
- Electronic information and documentation
- Increase in volume of information exchanged
- Change in size of clients' organisations
- Reduced time scale of projects
- Clients out-sourcing non-core activities.

Reduced time scale of projects, partnering/alliancing, reliance on more technical input from contractors and more risk allocation to contractors were found to be the most significant factors to impact the LSE industry currently and during the next 10 years. Electronic information and documentation, changing in size of clients' organisation and clients out-sourcing non-core activities will gain more importance in the future.

In a similar manner, different factors and issues, which have been identified during the workshop, were prioritised and further investigated through the questionnaire. The analysis of the results showed that there will be major shift in procurement routes during the next 10 years towards strategic alliances and integrated supply chains. Capital cost, quality, profitability and time scale of projects represent the most important factors considered by LSE clients in the business case of LSE products currently and in the future. However, in the next 10 years quality will be gaining more relative importance and the clients' cost focus is shifting from capital expenditure to total life cycle cost (Hassan *et al*, 1999).

Health and safety represents an important aspect in the clients' current and future view of the LSE industry. Clients envisaged growth in health and safety regulations and the use of information systems related to health and safety.

Although LSE clients maintained that their relationships with other parties of the supply chain are currently strong, they envisage a change in such relationships over the next 10 years as follows:

- Increased dependency on a small number of strategic alliances leading to an integrated supply chain.
- A greater role for regulatory bodies especially with regard to environmental issues. This may lead to a "tense" relationship with authorities.
- More technical dependency on contractors.
- Greater input from partners and funding bodies.
- More direct involvement with suppliers.
- Stronger relationships with consultants and funding bodies.
- Client/supply chain relationships will take the shape of a "private enterprise".
- Partnerships with other governmental bodies.

CLIENTS VIEWS AND PERCEPTIONS FOR CHANGES IN THE LSE ICT ENVIRONMENT

The analysis of the clients' questionnaire showed that the massive amount of information in paper format is being replaced by a massive amount of information in electronic format and there is a major shift in information exchange from paper, telephone and fax to e-mail and proprietary computer networks in the next 10 years as illustrated in Figures 1 and 2. However, managing such information remains a key issue. There is a growing need to train managers and executives in information management.

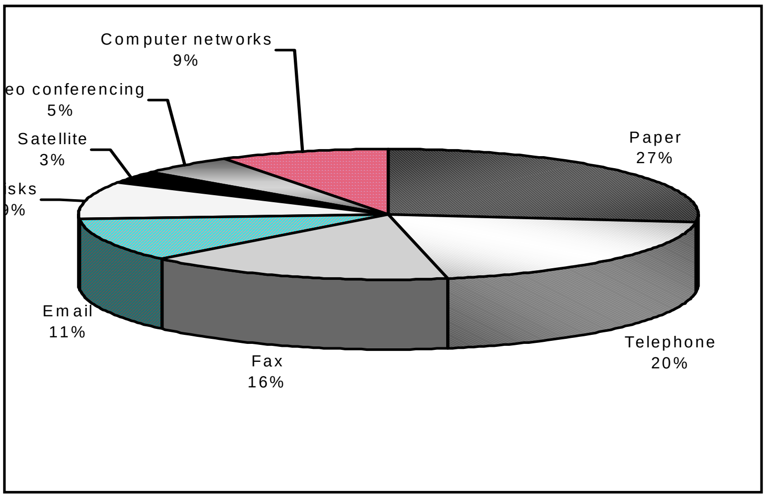

Figure 1

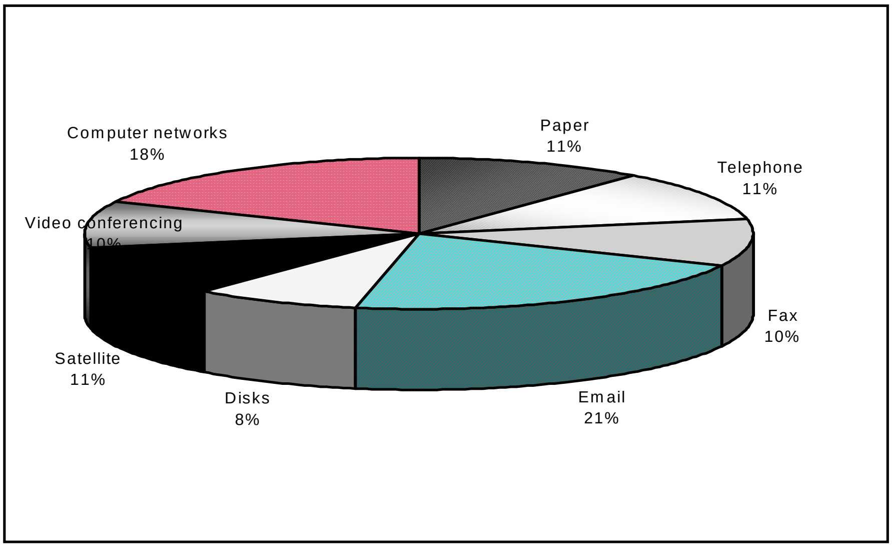

Figure 2

The most important systems for clients' organisations currently are finance and accounting, project planning and human resources. There is an increase in the importance of project planning, QA (Quality Assurance) systems and documents control; materials procurement, CAD systems and communications systems during the next 10 years.

There is a need for electronic sharing of information between clients information systems and those of:

- Contractors in the areas of CAD, project planning, materials procurement, QA systems & documents control, modelling and calculations and communications systems.
- Project Managers in the areas of project planning and QA systems and documents control.
- Funding bodies in the areas of finance and accounting.
- Consultants in the areas of modelling and calculations.
- Suppliers in the areas of materials procurement.

LSE Clients prefer to use proprietary ICT tools than bespoke ones as they want to focus on their core business not on IT development. They identified their requirements in ICT provision as:

- Systems to be developed to match business needs.
- Systems to be proprietary not to be bespoke.
- The ability for the system to be fully used by non-IT specialist with low level of training requirements.
- The ability to use the same system reasonably independent of computer hardware.
- The ability to be able to manage (track and control) electronic information within the system.
- Ease of information archiving, retrieval and updating throughout the whole product life cycle and not the life of the computer system.
- The ability to easily exchange digital information with other applications/ information systems using appropriate data exchange standards.

There is also a need for more integration not only between different systems within the client organisation and between the client's organisation and the supply chain, but also between different software of the same information system (a typical example is CAD systems).

CONTRACTORS VIEWS AND PERCEPTIONS FOR CHANGES IN LSE BUSINESS ENVIRONMENT

The responses to the contractors' questionnaire showed that LSE contractors are reacting to clients' views and requirements positively. They have also identified that 'partnering /strategic alliancing' and 'electronic documentation and information exchange' represent the most important factors having an impact on the LSE industry over the next 10 years. Contractors preferred a 'functional specification' type of brief from the clients as it allows them to innovate in the methods and technologies they apply for construction.

To respond to clients' requirements, LSE contractors have identified the following sources of competitive advantage for their organisations:

- The ability to generate sources of project funding and provide clients with better value for money.
- The ability to build partnerships/alliances.
- Reducing project time-scales which lead to increase of certainty.
- Technical expertise, experience and reputation.
- Capability to carry risks.
- Fostering a whole life cycle view for LSE projects/products.

In order to meet clients' requirements, and to achieve the identified sources of competitive advantage, LSE contractors have to extend their roles within LSE project delivery; moving from the traditional function of design or construction service provision, through that of project management of the design and construction, to one of developing a complete business. This requires extending the range of contractors' skills and knowledge base from pure construction, to design and construct, through working with clients to improve value-engineered design, construction and operation and latterly to become the complete sponsor and developer of complete businesses from concept to operation and maintenance. This is illustrated in Figure 3. This new role of business development was instigated by the needs of private funding of public sector projects, leading to the adoption of new contract forms such as BOT (Build-Operate-Transfer) and BOO (Build-Own-Operate) which require the constructor to operate the facility as part of his recovery of initial project finance. These aspects are reported in more detail in (Mitrovic *et al*, 1997; Hassan *et al*, 1998).

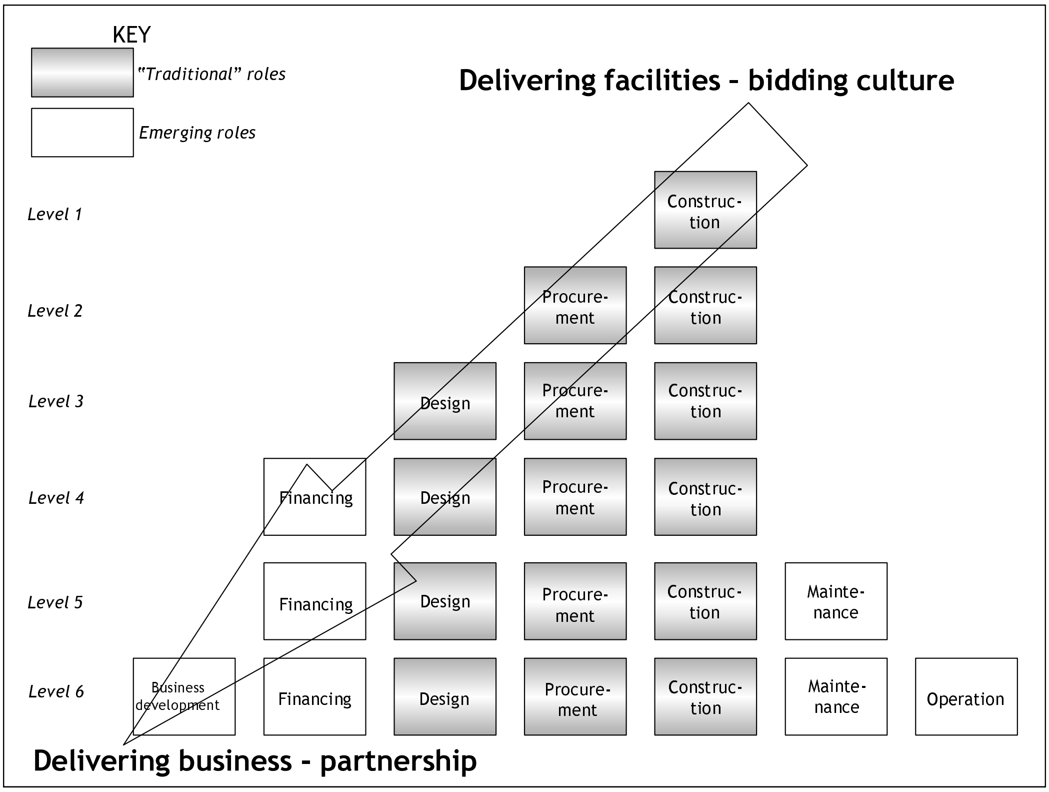

Figure 3

CONTRACTORS VIEWS AND PERCEPTIONS ON CHANGES IN LSE ICT ENVIRONMENT

LSE organisations will be increasingly turning to forms of applied ICT to assist with the understanding, planning and control of project information as well as the exploration of possible options to optimise proposed solutions.

The results of the contractors' questionnaire survey showed that the usage of e-mail for information exchange is anticipated to increase from 3% to 20% during the next 10 years and that the usage of external computer networks will increase from 2% to 16%. This shift is even more apparent in exchanging information between the contractors' offices and the site. This is undertaken currently via the traditional ways (paper, telephone and fax) 95% of the times. During the next 10 years it is anticipated that 60% of information exchange between office and site will be undertaken electronically.

It is expected to have a significant increase in the usage of the following information systems during the next 10 years:

- 3D Modelling
- Quality assurance/control systems
- Health and Safety
- Communications
- Procurement
- Logistics.

ICT tools should be able to exchange digital information with other applications/systems using appropriate data exchange standards. There is a need for more utilisation of existing data exchange standards such as

STEP and EDIFACT as currently contractors rely on exchanging information using neutral file formats and native file formats. Neutral file formats (for example, DXF, TIFF) are mainly used in exchanging information of drawings (CAD), invitations to tender, text processing and banking and accounting. Native file formats (for example, Microsoft Office products, DWG, HTML for web technology) are mainly used to exchange information of drawings (CAD), statistical calculations (spreadsheets), estimating and virtual reality (using web technology).

The lack of compatibility between different software applications / information systems results in a 'debate' at the start of each project on which information system will be used throughout the project (or sometimes the product) life cycle.

THE eLSEwise VISION

eLSEwise concluded that the required attributes for the LSE constructor to be competitive are best supported by the concept of a "Virtual Enterprise", where different companies with supportive skill sets, appropriate to meet the specific project demands, form into a cohesive team, but without the need for co-location of the team members. The Virtual Enterprise (VE) uses ICT tools to allow it to undertake such logistically complex projects whilst retaining the individual agility of the consortium members to undertake their own business operations and participate in other VE type projects simultaneously. The associated supply chains are also part of this networked enterprise (Hunter *et al*, 1999).

Various organisational models are represented diagrammatically in Figure 4. Although perhaps implied by the figure, these models are not entirely 'evolutionary' but do require greater degrees of pre-determined organisational and ICT skills moving in the direction of the arrows. The Integrated Enterprise may represent the 'departmentalised' view of a single organisation or a closely associated conglomerate group of companies. The Extended Enterprise reflects the current situation of certain manufacturing industry sectors, where a dominant partner has long-term supply relationships with associated providers of materials, components or resources such as design. The Virtual Enterprise is that model which eLSEwise believes best fits the LSE construction needs in the future. Here, a semi-transient central consortium provides the essential skills to formulate the solution to and spread the major risks of the project, but they will also involve various other supply chain members to execute the project. It is probable that one of the consortium, or a separately formed core team, will act as the "information and resources broker" to the project, involving other consortium member resources as required. However, communication and information flows between all members of the Virtual Enterprise (Hunter *et al*, 1999).

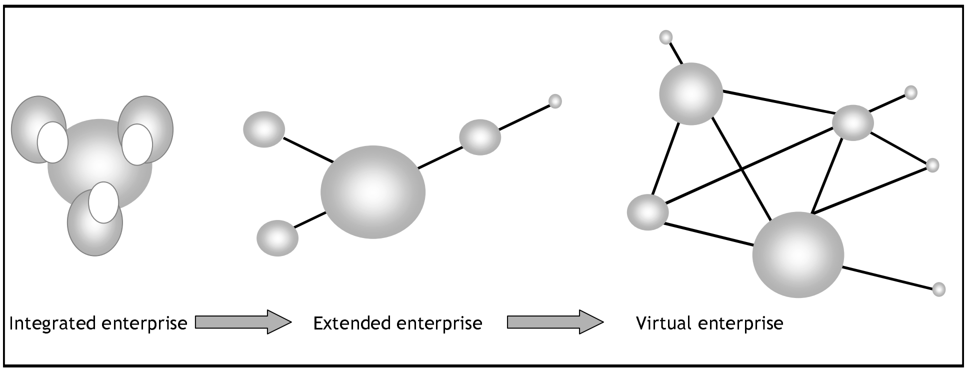

Figure 4

The LSE as an end user of the technology combines ICT with business drivers to work together to form the Virtual Enterprise that will deliver LSE projects. The ICT providers are developing the generic technologies and tools that can be used by LSE and other industries. The Research and Technical Developers are working to provide data models and data standards that can be uniformly adopted by industry and ideally are "open" in nature and hence independent of any particular ICT provider. The whole

Enterprise also has to operate within the wider conditions of regulations, standards and educational support provided by general society.

eLSEwise has devised simplified, pragmatic progression routes that are intended to assist LSE practitioners to prepare ICT and process development strategies that match to the overall future vision. The project has also suggested appropriate points of action to all parties that could influence the development of such a future vision. These development routes and points of action are reported in eLSEwise Consortium (1998) and Hunter *et al* (1999).

CONCLUSIONS AND RECOMMENDATIONS

The results of the studies presented in this paper which were undertaken within the eLSEwise ESPRIT project highlight clients' and contractors' requirements and views of the business and ICT aspects of the LSE construction industry. Understanding these requirements by all parties of the supply chain is crucial to ensure efficient and successful execution of LSE projects and operation of the final product. The studies provide also guidelines for ICT vendors who should consider the industry's requirements in their current and future provision for ICT systems and solutions.

The major ICT providers are already developing clear strategic thinking for many different businesses to enhance their working methods using current and near future ICT developments. What they lack from the LSE sector is a clear strategic development policy as at present the ICT developers do not perceive the LSE construction sector as a major user of ICT, nor do they fully understand the business requirements from this sector (Hannus *et al,* 1999).

It is this form of information and understanding that eLSEwise is trying to address, by providing some degree of business and process requirements for future LSE project delivery and also proposing some form of ICT strategy development. In this respect eLSEwise has proposed the following recommendations for the LSE industry and for ICT developers and vendors (Hunter *et al*, 1999).

Recommendations for the LSE Industry

- Foster Whole Lifecycle viewpoint
- Develop sector based Product Model Templates
- Define ICT policy that will support overall business needs
- Provide adequate network communications
- Define company wide data standards for project and company documentation
- Develop in-house company data libraries
- Define policy for company knowledge and learning.

Recommendations for ICT Developers and Vendors

- Work with LSE clients and practitioners to devise neutral format data models and use standard data representations such as STEP to allow inter-working between disciplines.
- Use neutral format based data management to hold, exchange and share data in a controlled manner.
- Link the data management needed for exchange and sharing to workflow requirements.

ACKNOWLEDGEMENT

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Choice of Technologies and Inputs for Construction in Developing Countries

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Abstract

In discussion of appropriate technologies there are, at one extreme, the advocates of the use of labour-intensive technology to generate employment in the economy and to enable small, and even informal, contractors to participate in the construction process. Such technology is usually associated with low capital intensity and lower labour productivity. At the other extreme are those who stress the need for the construction industry to modernise and to grow so that it can undertake work as carried out in developed countries and by foreign contractors in developing countries. The latter involves advanced technologies, higher capital intensity and higher labour productivity.

In this paper, the advantages and disadvantages of these two views are examined in relation to the economy and the construction industry. The conclusion is reached that most low- and middle-income countries should pursue a mixture of policies in separate segments of their industries.

Keywords: *Technology, labour productivity, growth, developing countries, employment generation.*

INTRODUCTION

There has long been advocacy by the International Labour Office (ILO) and others for the use of the construction industry to generate employment in the industry itself and also, through the operation of the multiplier, in the economy as a whole (for example, Edmonds and Miles, 1984; World Bank, 1984; Ofori, 1990 and Ganesan,1994) It is argued that projects should, for developing countries at least, be of simple technology, and make use of low levels of equipment and high levels of labour.

Another argument is that a country needs an efficient construction industry and that means aiming for low money costs and high productivity.

These two views appear at first sight to be incompatible. This is not so. A Habitat report (Habitat, 1996) states that 'A balance needs to be struck between the use of equipment and job creation, with a view to ensuring the efficient utilisation of resources available to each construction industry.' This paper attempts to identify some of the factors which determine the appropriate policy in countries with different circumstances.

THE ARGUMENT FOR LABOUR INTENSIVE TECHNOLOGIES

Unemployment and GDP

A major reason for using labour-intensive technologies lies in the economic concept known as the multiplier. The expenditure multiplier is the number by which a change in expenditure must be multiplied in order to determine the resulting change in total output or Gross Domestic Product (GDP) (Samuelson and Nordhaus, 1995). When a person is employed, he spends much of his wages on goods and services from other sectors of the economy which, in turn, generate employment and spending elsewhere, thus starting an upward spiral of increasing employment. There is therefore an employment multiplier as well. The employment multiplier may be defined as the number by which an initial change in employment must be multiplied in order to determine the resulting change in total employment in the economy as a whole.

Because construction in all countries is relatively labour-intensive, even with fairly sophisticated technologies, expenditure on construction generates a high level of employment, first in construction and then in the economy as a whole. If the technologies used in construction are labour-intensive, the employment multiplier will be even greater. Major studies of employment generation from construction activity in Sri Lanka have been undertaken by Ganesan (1979, 1982, 1994). He concludes that:

… a significant gain in total employment, of the order of 10-15%, can be realised through industrial restructuring alone to a more appropriate technology, --- A strategy to increase output through activities consuming more labour and less scarce resources is the only feasible way forward in most developing countries (Ganesan, 1994).

Similar conclusions have been promulgated by others (Edmonds and Miles, 1984; World Bank, 1984; Edmonds and De Veen, 1992; Gaude and Watzlawick (1992). However the South African Green Paper on construction (Department of Public Works, 1997), while acknowledging that the figures for employment generation by construction are higher than for other industries, warns that 'increased construction spending to create employment is counter-productive in the absence of improved productivity' (p11).

Information on the level of GDP and its growth is available from the World Bank (1999). It shows that there were 50 countries, out of the 130 for which data were available, where GDP per capita was less than US$785 in 1997. On a Purchasing Power Parity (PPP) basis their GDP was higher, but only 6 of the countries rose above $2000 on a PPP basis. Of these 50 countries, 31 were in Africa. The growth of GDP in the periods 1980 to 1990 and 1990 to 1997 was mostly positive, except for the countries of Eastern Europe and Central Asia. However, in about half the countries population rose faster than GDP, resulting in a fall of GDP per capita.

An oversupply of manpower may result in unemployment or under-employment, both common in developing countries. Statistical data on these problems is slight but there is little doubt that it is a serious problem in virtually all these very poor countries.

With their very low GDP per capita, growing only slowly or not at all, and their over-supply of manpower, there is little doubt that all these countries should consider using construction projects with a high labour input to boost growth in the economy.

The Balance of Payments

There are other potential advantages from the use of low-level technology in developing countries. Sophisticated technologies usually involve use of substantial capital equipment and, especially in the case of buildings, factory–made components. Both these are likely to have to be imported into developing countries, thus causing strain on the balance of payments and often using up supplies of hard currency.

Most developing countries have balance of payments problems. The World Bank (1999) shows that all except 5 of the low income countries had a current account deficit in 1996. Even more serious is the external debt. For over half the low income countries it was at least half their annual GNP but for 14 of them it was equal to, and in some cases 2, 3 or 4 times, their annual GNP.

Thus, the use of simple technologies, local materials and little capital equipment is appropriate where there is a need to reduce imports because of balance of payments or hard currency problems.

PROBLEMS OF IMPLEMENTATION

Finding the Right Projects

If a policy of low technology, labour-intensive construction is to be adopted, government needs to be able to control, or at least influence, the method of construction. If the government has a significant budget for construction, it should be able to ensure that the technology used is in the best interests of the country. Unfortunately, it is not always as simple as that. Vested interests may well be better off if more sophisticated construction methods are used. Then there is the matter of the public image of ministers. The late Professor Duccio Turin coined the word 'inaugurability' to describe the characteristics which politicians seek in selecting projects to approve. No minister will wish to open even ten public lavatories but would willingly inaugurate, say, a VIP lounge at the airport, even though its contribution to the common good is negligible.

However, opportunities are great, especially in rural areas, for fairly simple projects whose contribution to the standard of living of the local communities is potentially great. They can also contribute in urban environments, especially where there are run down areas and infrastructure (Gaude and Watzlawick, 1992). The mechanisms for undertaking labour-intensive projects, either in the community or on a larger, more impersonal scale, on a long-term continuing basis are very different from emergency programmes.

The proportion of construction projects funded solely by governments either central or local is not known. The World Bank (1999) figures show that on average about 65% of investment in the low income countries for which data are available is private. For projects which are privately funded it would be difficult to persuade clients to adopt labour-intensive methods unless it could be shown that they were cheaper or more able to provide the type of structure they required.

Then there are the projects funded from external sources. Gaude and Watzlawick (1992) state that the proportion of externally funded infrastructure projects in Less Developed Countries (LDCs) generally exceeds 50% and is as high as 70-90% in some of the poorest countries. Some of these would be government or international organisations but others would be private. Attempts to persuade international donors to arrange their aid or loans for projects in such a way that their construction can help the local construction industry, let alone act as a long-term boost to the economy and employment through the use of labour-intensive methods, have largely failed. Bilateral donors have much to gain from their funding of projects because it is accepted practice to tie the aid to the employment of contractors from the donor country. They, in turn, will favour high capital input and sophisticated materials, neither of which will greatly help the recipient country. International organisations are required by their rules to go out to tender for their projects. Local contractors do not have the ability to undertake such large and complex projects, and so are reduced to acting as junior partners or subcontractors. Lip service is paid to expatriate contractors transferring technology to local contractors but little is achieved in this direction, partly because time and effort spent in helping local contractors are expensive and may reduce already pared margins.

Unfortunately, the system is not only failing to improve the local industry and helping the local economy less than it should, but in some countries, such as Sri Lanka which had a reasonably well-trained and able industry, it is arguable that aid projects have taken away the ability of local firms to undertake large projects themselves and have certainly taken away their self confidence (Hillebrandt, 1997). There have been discussions with various aid agencies such as the Asian Development Bank(ADB) and the World Bank on improving this situation through, for example, splitting projects up into smaller contracts within the scope of local contractors. Progress is slow but the ADB has agreed to give local contractors a price advantage over foreign contractors in certain circumstances. On the other hand the World Bank's refusal to give contracts to state-run enterprises is a backward step.

Thus, the supply of projects which can easily be undertaken on a labour-intensive basis is limited because the government does not have control of the way in which construction is undertaken.

Money Cost of Alternative Methods

Some projects may be devised specifically to create employment. These projects should not be judged only on their money costs though it is clearly of relevance. The social benefits of employment creation have to be set against higher money costs. There are other projects, however, where the money cost is the major factor in determining what technology should be used. Economic theory uses iso-product curves, combined with price lines, to determine the optimum combination of two inputs.

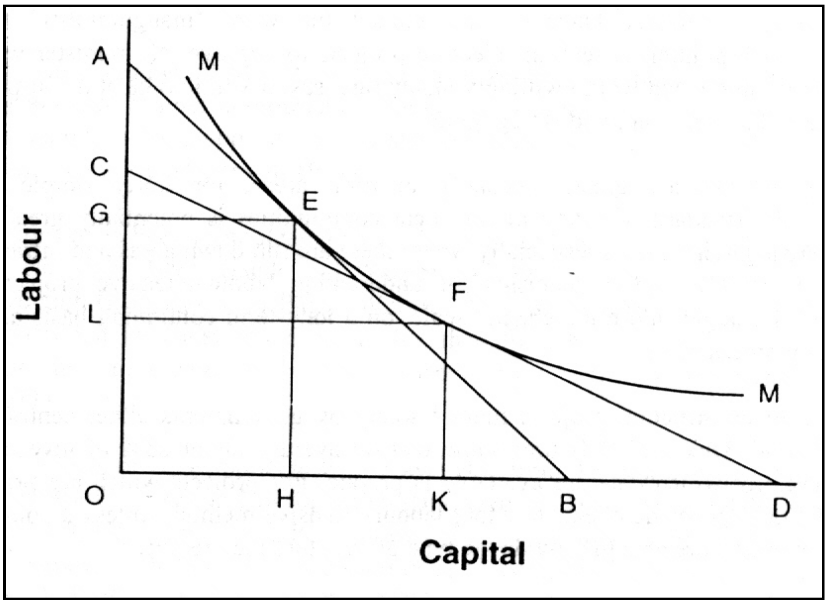

Figure1

In Figure 1, MM is an iso-product curve, that is, along its length it is technically possible to produce a given level of output with any of the different combinations of labour and capital. AB and CD are price lines whose slope shows the relative prices of labour and capital. AB shows a situation in which labour is relatively cheap, that is, one can buy a lot of labour for the same amount of money as a little capital. CD shows expensive labour relative to capital. The optimum combination is shown when the price line is tangential to the iso-product curve. Thus, when labour is cheap, the optimum point is at E using OG labour and OH capital. When labour is costly, the appropriate combination is OJ labour with OK capital. These arguments take into account only the amount of money to be paid out. They do not differentiate between hard and local currency nor take into account that the exchange rate may be artificial and not reflect the true costs of the inputs. Moreover, they do not include any indirect costs or benefits as discussed above. The optimum combinations are those which show rather a narrow, short-term and often selfish view, whereas the arguments above concentrate on the broad, long-term, community view.

Having taken into account all the distortions, it is very likely that a developing country, especially one with a high level of unemployment, will have cheap labour and that, at least for internally financed projects, the theory will support labour-intensive technology. For projects financed externally and undertaken by expatriate contractors, the other costs of using little capital and much labour (see below) will probably swamp the importance of the relative prices of labour and capital.

Other Costs of Labour-Intensive Projects

There are substantial costs of managing labour-intensive projects. These arise on site, in the contractor's office and in administration at the funding organisation. Man-management is more complex than the management of plant and equipment and many schemes have got into difficulties on that account. In many developing countries there is a shortage of managers which makes it more attractive to use plant and equipment to replace men. The situation is compounded for expatriate contractors. They, in any case, have difficulty in fully understanding the local operating conditions which are complicated by local customs. One of the major problems of operating internationally is the accurate assessment of risk and the need to minimise it. The risk of undertaking a labour-intensive project will almost certainly be greater than a capital-intensive one. This added risk will be priced heavily, thus increasing total project costs.

Administration costs of labour-intensive projects may be high. For community projects it will be necessary to arrange the supply of materials and tools to be at site at the right time and to have some managers available to sort out problems as they arise. Excellent schemes for self-build housing to settle squatters in Sri Lanka had to be discontinued because of the large amount of scarce management being used on the projects.

It is clear that a major problem in increasing the number of labour-intensive projects is the high requirement for management and, especially for overseas contractors, the high risk element.

The Usefulness of the Finished Product

So far, it has been assumed that the product constructed by labour-intensive methods is as useful as one where capital-intensive methods were used, or, at least, if they are different, that they give equal value for money. This may or may not be so. There is no way in which one can generalise on this matter but it clearly must be considered on a case by case by case basis.

THE ARGUMENT FOR CAPITAL-INTENSIVE TECHNOLOGIES

Employment and GDP

Where a country has a high level of GDP and low unemployment, there is clearly no need for the use of labour-intensive technology. Indeed, it can be positively damaging and lead to wage inflation. It has occasionally been used in developed countries for the alleviation of cyclical unemployment, using repair and maintenance expenditure as the catalyst.

There are 26 countries in the World Bank's tables (World Bank, 1999) which have a per capita income greater than $9695 including nearly all those in Western Europe.

Developed countries with a high level of GNP per capita, except in very unusual circumstances, have little use for labour-intensive technologies. There are a number of reasons for this, some of which have relevance to other countries.

The Need for an Industry to Meet Local Demand

A prime objective for the construction industry of any country should be to meet most of the demands put to it. In almost all countries there is demand for some sophisticated buildings or works. These are required by the private sector and sometimes by government. Their construction will require capital equipment and can use labour-intensive methods to only a limited extent. It is a sensible objective of government and industry policy, even in less well off countries, gradually to increase the ability of the local industry to undertake such projects. This has an added advantage that the drain on the balance of payments from the employment of foreign contractors would be reduced. In order to achieve this objective, at least a segment of the industry must be encouraged to raise its productivity, increase its stock of plant, understand how to utilise the plant to the best advantage, and above all, improve its management to deal with complicated projects. This need will occur in most countries including those where other policies are to concentrate on labour intensive projects for income and employment generation.

The Opportunity to Export

Some countries, even if themselves relatively poor, may wish to and be able to export their construction services. They may be able to do this because their potential markets have a poorly developed industry or because they have cheap skilled and unskilled labour. In the former case they will be wanted to work on the larger more complicated projects. In the latter case, the host country will probably construct only fairly high technology projects. Export opportunities will therefore also require familiarity with capital-intensive construction technology.

Need to Integrate Parts of the Construction Industry

Some countries have an industry which is partly sophisticated and partly at a very low level of operation. The prime example is that of South Africa, where the sophisticated part is run by white people and the other, at an early stage of development, consists of black-run firms. A major objective of government is to bring these two parts together, but to have any real integration, it is essential that some part of the black industry joins the high technology, high productivity category, even though there is also a need to use labour-intensive projects to boost GDP, reduce unemployment and provide some improvement in the physical infrastructure. The South African policy document (Department of Public Works, 1997) proposes both. A principle laid down is to ‘Maximise local employment through the optimal use of labour-based construction methods and target women and youth.’(p. 34). On the other hand, it does not lose sight of the broad social and economic objectives, including ‘sustainable economic growth and productivity of the sector’ (p2).

Although South Africa is the obvious example of this predicament, a similar less acute situation obtains in a number of ex colonies where colonists of the former ruling nations monopolise the top end of the construction industry. The need to integrate society may be a powerful reason to override purely economic arguments on the most appropriate construction.

The Influence of Recent History of the Industry

There are circumstances where history has given the construction industry in a particular country, characteristics which are out of keeping with the current state of the economy and the industry. The best current example of this is found in the former Soviet Union and to some extent in its former satellites. For very many years these countries had adopted a policy of very capital-intensive construction, in spite of having a good deal of hidden under-employment. They also had, and have, the advantage of a well-educated population. In spite of high current levels of unemployment, many obsolete factories and disastrously low levels of output, both in the economy and in the construction industry, it would be unwise to initiate measures to generate employment which would prejudge the long-term appropriate level of technology which may again be very capital intensive.

The Argument for a Mixture of Policies within a Country

It is apparent from the above that there is no reason why any country should opt wholly for labour-intensive technology or for capital-intensive construction. On the contrary, there are very good reasons to have a mixture and, in the case of some countries both policies may be pursued to their limits, simultaneously, but in separate segments of the industry.

This particularly applies to middle income countries. After concluding that the 50 low-income countries should almost certainly adopt policies for employment generation and that the high income countries had little need of such policies, this leaves 35 countries with an income per capita between $786 and $3125 and a further 19 countries with an income per capita of $3126 to $9655. These two groups include most South American countries, many in the Middle East and the majority of countries in Eastern Europe and Central Asia. These are the countries which may find it difficult to decide on their policy on appropriate technologies. They will need to consider all factors together. It is very likely that the conclusion should be that they should adopt labour-intensive projects for parts of their economy but sophisticated technologies in other parts. Even in the case of some low income economies, some segments of the industry might, with advantage, be developed to provide the vanguard for a more prosperous long-term future. Thus, the two extreme arguments for labour-based technology on the one hand, and capital-intensive high technology on the other, must, in most countries of the world, be used side by side to achieve the greatest benefit to the economy and to the construction industry.

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Preliminary Study on Contractor Success in Developing Countries

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Abstract

This paper provides preliminary strategies on achieving construction project success in developing countries from the contractor's perspective. Developing countries pose greater challenges for project management organizations due to inherent risks such as government instability, shortages of adequately trained craftsmen, difficulty in acquiring needed materials, and lack of adequate infrastructure such as roads, bridges, power plants, and water treatment facilities. For these reasons, it is anticipated that *more* effort will be required by these organizations to achieve outstanding project performance in developing countries. The research methodology involves identifying differences between contractor project management inputs for "average" and "outstanding" projects in both developed and developing countries. A total of 44 large multimillion dollar construction projects is included from a database collected from a previous study related to project success. Results are preliminary due to the relatively small sample of projects representing developing countries. They suggest that contractor project managers working on projects in developing countries have more experience compared to their counterparts working in developed countries. Additionally, greater effort is required by the contractor to control a construction project in a developing country especially in the areas of safety and quality. Further research in this area could provide contractors with additional information on how to consistently achieve high performance levels on construction projects in developing countries.

Keywords: *construction management, project success, developing countries.*

INTRODUCTION

Achieving construction project success is a challenging task for project managers on any construction project; but it can be even more challenging when the project is being constructed in a foreign environment such as a developing country where there is typically political and government instability, lower levels of worker productivity, strict importation requirements on equipment and materials, and harsher climates and terrain. For these reasons it is anticipated that *greater* effort will be required by the project management team to achieve success in developing countries. Success in this study is defined as a construction endeavour that is perceived by the project manager, and hence, by his organization, to have "outstanding" results for all parties involved in the project. The research methodology involves identifying differences in project management input between successful projects in developed countries and successful projects in developing countries. It is anticipated that additional management resources (such as planning and control effort) will be required to achieve outstanding project performance in the developing countries.

Several articles have been written pertaining to factors necessary for achieving construction project success in general. Many of the important success attributes relate to the project manager, project team, planning, control, and safety efforts. In particular, the project manager's capabilities, experience level, and commitment to the project seem to be important for success. The project team's commitment level is also perceived to be essential for achieving success. Furthermore, planning efforts during the design and construction phase are also considered essential for achieving success. Providing adequate control features to properly monitor cost, schedule, quality, and safety is also important. The following is a list of researchers who have provided insight into factors of importance for achieving overall project success (Murphy *et al.*, 1974; Cleland, 1986; de Wit, 1986; Jolivet, 1986; Morris, 1986;; Slevin, 1986; Ashley *et al*., 1987; Wearne, 1987; Baker *et al.*, 1988; Jaselskis, 1988; Pinto and Slevin, 1988; Sanvido, 1992; Chua, 1997).

Literature has also been written discussing the achievement of construction project success in developing countries. Israel (1978) presents past World Bank experience in the implementation of projects in developing countries and suggests ways in which they can be implemented more successfully. Wells (1986) states that the *inadequate capacity* in the construction sector is singled out as the major cause of failure on many projects in developing countries. Kharbanda and Stallworthy (1986) present experiences from various successful projects in developing countries. Palmer (1986) states that unless some aspects of the project are developed, clearly stated, controlled, and undertaken, construction project success will not be achieved. Coukis and Grimes (1980) present three factors identified to be critical for the achievement of success in labor-based construction projects. Austen and Neale (1984) describe the general principles of construction project management in developing countries, and emphasize many vital requirements for successful execution and completion of construction projects. Austin (1990) has written a comprehensive book related to managing business operations in developing countries, much of which is directly related to construction company success.

RESEARCH METHODOLOGY

Data for this study comes from previous research relating to achieving construction project success performed by Ashley and a research team at the University of Texas at Austin. These data were collected over a four-year period in phases: (1) pilot study (Ashley *et al*. 1987); (2) Second Phase – an objective evaluation of construction project success factors (Salimbene and Ashley 1986); and (3) Third Phase – development of predictive discrete choice models related to achieving construction project success (Jaselskis 1988). Factors linked to construction project success related to the project manager (such as years of construction experience), project team (for example, team turnover rate), planning effort (such as budgeted contingency), and control efforts (for example, number of formal quality inspections).

Characteristics of the data are summarized in Table 1. The database includes a total of 44 useable construction projects. About half of these projects are classified as "average" and half as "outstanding". 'Success' in this study is defined as a construction endeavor that is perceived by the project manager, and hence, by the project manager's organization, to have "outstanding" results for all parties involved in the project. "Average" projects were not considered failures. Most of the "outstanding" projects were completed under budget and ahead of schedule. All of the projects reflect the perspective of the contractor organization. Due to the small sample size representing developing countries, results should be considered preliminary at this point.

The research approach for this study involves identifying differences between these key project management inputs on successful projects located in developed countries and successful projects found in developing countries. Hypothesis testing is used as the statistical technique to indicate significant differences between these project resources. Due to the limited quantity of construction projects relating to developing countries, a student's t-distribution was used; the t-test is appropriate for analyzing statistical significance between two means when the sample size is small (<30 samples). The statistical significance for rejecting the null hypothesis is assumed to be ten percent. Other methods of analysis, such as modeling, will be considered when more project data are available.

The strategy for the hypothesis testing involves identifying differences between project management input for each single factor as follows: (1) average versus outstanding projects in developed countries; (2) outstanding developed versus outstanding developing country projects; and (3) combined average and outstanding developed country projects versus outstanding developing country projects (in the case where there is no statistical difference between average and outstanding projects in developed countries).

Table 1: Developed versus developing country project sample characteristics

PROJECT CHARACTERISTIC	**SAMPLE CHARACTERISTICS**		
	DEVELOPED COUNTRIES	**DEVELOPING COUNTRIES**	**TOTAL**
	(N=40)	(N=4)	(N=44)
Project Classification			
Average	50%	0%	45%
Outstanding	50%	100%	55%
Respondents Individual Role			
Project Manager	58%	25%	55%
Construction Manager	25%	0%	23%
Project Engineer	2%	0%	2%
Other	15%	75%	20%
Construction Industry Type			
Industrial	73%	75%	73%
Commercial	7%	0%	7%
Civil	20%	25%	20%
Residential	0%	0%	0%
Technology Type			
Process plant	53%	25%	50%
Manufacturing	12%	25%	14%
Office	5%	0%	4%
Power	8%	0%	7%
Pipeline	0%	25%	2%
Dam	8%	0%	7%
Tunnel	2%	0%	2%
Other	12%	25%	14%
Nature of Contractor Agreement			
Fixed price	55%	50%	55%
Reimbursable cost	34%	50%	35%
Unit price	11%	0%	10%
Project Cost (5mil)			
Mean	44	718[1]	95
Project Duration (mos)			
Mean	25	45	27

[1] One project was significantly higher than the others. Without this project, the mean project cost is $116 million

RESULTS

Results for this pilot study reveal differences in the amount of effort employed by the contractor's project management organization for achieving construction project success in developing countries. The most significant finding suggests that contractor project managers have more experience on the same type of project compared to their counterparts working in developed countries. Furthermore, greater effort is required to control a construction project in a developing country especially in the areas of quality and safety.

Figure 1 reveals several key factors related to construction project success. Shading is used to signify statistical differences or similarities between attributes of developed and developing country projects. Notice that contractor project managers working in developing countries seem to have more experience in some respects compared to their counterparts in more developed portions of the world. Managers in developing countries worked on more projects with the same technology type as a project manager compared to their project manager counterparts in developed countries as can be readily observed by the difference in shading scheme. These managers have worked on approximately six projects as a project manager with the same technology type prior to being assigned the "outstanding" project contributed to the database. Managers executing outstanding projects in developed countries had worked on approximately two projects as project manager with the same technology type prior to performing the contributed project.

Figure 1: Contractor Organization Success Profile

FACTORS RELATED TO CONSTRUCTION PROJECT SUCCESS	AVERAGE DEVELOPED COUNTRY PROJECTS	OUTSTANDING DEVELOPED COUNTRY PROJECTS	OUTSTANDING DEVELOPING COUNTRY PROJECTS
PROJECT MANAGER		8.4 / Month	
P.M. Formal Meetings			
P.M. Time Devoted to Project		95%	
P.M. Site Visits		21 / Month	
P.M. Subordinates	5.1 Subordinates	7.8	Subordinates
P.M. Levels to Craftsmen	3.6	Levels	7.5 Levels
P.M. Education Level (# Yrs. beyond High School)		3.7 Years	
P.M. Total Years of Construction Experience		19.5 Years	
P.M. Experience as a Project Manager		8.3 Years	
P.M. Experience as Project Manager on Projects of Similar Size and Duration		2.5 Projects	
P.M. Experience as a Project Manager on Project with Similar Technology Type	1.9	Projects	5.7 Projects
P.M. Experience other than as Project		5.3 Projects	

Manager on Projects of Similar Size and Duration			
P.M. Experience other than as Project Manager on Projects with Similar Technology Type		4.7 Projects	
PROJECT TEAM Project Team Turnover	14% / Year	7.1% / Year	
PLANNING EFFORT Number of Activities in Execution Plan (#)		11.4 Activities	
Budgeted Contingency (% Total Project Cost)		6.5% Project Cost	
Constructability Program (% of Projects with Constructability Programs)	43%	82%	Inconclusive Data
CONTROL EFFORTS Formal Progress Inspections		6.4 / Month	
Formal Quality Inspections	15.5 / Month	9.3 / Month	21 / Month
Formal Safety Inspections	11.4 / Month	5.4 / Month	21 / Month
Project Controls Budget (% of Total Project Cost)		2% Total Budget	
Formal Control Meetings During Engineering Phase		4 / Month	
Formal Control Meetings during Construction Phase	2.9 / Month	5.1 / Month	
Schedule Updates		7.2 / Year	
Budget Updates		13 / Year	

Project managers seem to possess similar traits on all projects whether they are average or outstanding projects located in developed or developing countries. These characteristics are listed as follows: Education Level (3.7 years beyond high school), Total Years of Construction Experience (19.5 years), Total years Experience as Project Manager (8.3 years), Experience as Project Manager on Projects with Similar Size and Duration (2.5 projects), Experience Other than as Project Manager on Projects of Similar Size and Duration (5.3 projects), and Experience Other than as Project Manager on Projects with Similar Technology Type (4.7 projects).

Furthermore, a greater amount of control effort appears necessary in order to achieve outstanding construction project performance in developing countries. Approximately twenty-one formal progress and safety inspections per month are performed on the outstanding projects in developing countries. This figure is significantly higher than that for outstanding projects in developed countries. It is interesting to note that there are fewer inspections performed on the outstanding projects in developed countries compared to the average projects in developed countries. A possible explanation for this outcome is that since the project is performing so well, not as many inspections are necessary. In developing countries, the additional inspections may be needed due to the lower confidence level in the quality of materials and workmanship of the local laborers. Moreover, outstanding projects in both types of countries require more formal control meetings during the construction phase. In fact, approximately five meetings are held per month on the outstanding projects compared to nearly three meeting on the average projects.

CORRELATION ANALYSIS

As was previously noted in Table 1, developing country projects were substantially larger on the average compared to developed country projects ($718 million versus $44 million). It may be possible that the size of the construction projects may directly influence the level of management-related inputs applied to a project. For example, larger projects may require greater amounts of effort by the project management team compared to smaller projects. This could be true for certain factors that are related to project size such as the number of subordinates directly reporting to the project manager; the number of levels between the project manager and the craftsmen; and the number of progress, quality, and safety inspections. As a means of exploring this possibility, a correlation analysis has been performed to measure the amount of correlation between the project size (measured in terms of construction manhours) and inputs that are perceived to be related to size. All correlation values (r) are less than 0.33 which means that a weak correlation exists between project size and management input. The stronger correlations related to the number of levels between the project manager and the craftsmen (0.258), project manager total years of experience (0.321), and project manager experience level as project manager on projects with similar technology type (0.308). Thus, the data used in this study does not reveal a strong trend between project size and management input; this may change, however, when additional data are available. One might conclude that successful construction projects in developing countries require additional resources because they are being built in more challenging environments and not because they are simply "larger" projects.

RECOMMENDATIONS FOR ACHIEVING SUCCESS IN DEVELOPING COUNTRIES

The preliminary analysis suggests that the experience level of the contractor's project manager plays an important role in achieving outstanding performance on projects in developing countries. It is highly recommended to use project managers with a significant amount of project experience in order to ensure outstanding results. Managers on the highly successful projects have significantly greater construction experience especially related to projects with the same technology type compared to their counterparts working on outstanding projects in developed countries. Furthermore, a greater amount of control effort appears to be expended by contractor organizations on outstanding projects in developing countries. Formal quality and safety inspections of the order of approximately one per day were performed on the highly successful developing country projects compared to one to two inspections per week on outstanding developed country projects. Other key success factors may emerge as research progresses in this area.

Future Research

This research has provided some useful insights into the challenges and management strategies required to achieve "outstanding" construction project performance in developing countries. More research should be applied specifically to understanding the determinants of construction project success in developing countries. Additional factors should be included that are unique to the developing country environment such as import restrictions, quality of in-country materials and labor, transportation infrastructure, political stability, and cultural characteristics. The original scope of this research investigated construction project success from a general standpoint and not specifically with the intention of achieving success in developing countries. It is the feeling of the authors that many of the factors related to success will be the same for both environments but there will be some additions that take into account the uniqueness of developing countries.

This study has been limited to investigating project success for large multi-million dollar construction projects related to the formal sector. Many of these projects involve multinational domestic contractors specializing in international projects primarily in the areas of industrial and commercial construction. Achieving construction project success on smaller projects in the informal sector is not considered in this study. This would be an interesting area to pursue in the future. Furthermore, it is recommended that additional data be collected to test the robustness of these preliminary findings and also test other hypotheses related to achieving construction project success in developing countries.

CONCLUSIONS

Achieving construction project success in a developing country can be a challenge for the project management organization because of the many obstacles it must overcome above and beyond what is commonly experienced on construction projects in the developed world. In many respects, these countries provide more challenges to the project management organization involved in completing a constructed facility due to the political and government instability, lower levels of worker productivity, lack of adequate materials and equipment, and harsher climates and terrain. For these reasons, more effort is anticipated in order to achieve outstanding construction project performance in a developing country environment

This preliminary study has demonstrated some interesting differences in management strategies for achieving construction project success in developed versus developing countries. Results from a statistical analysis of actual construction project data suggested that contractor project managers working on successful projects in a developing country have more experience than their counterparts working on projects in developed countries. Moreover, it was found that greater emphasis was applied to controlling the project especially in the areas of quality and safety. Further research could help provide a better understanding of the developing construction environment and the ability to consistently achieve outstanding project outcomes.

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An Alternative Data Entry System for Construction Site Information.

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Abstract

The need for good documentation in the field operations of a construction site will only become apparent and critical when a contractual dispute arises over claims for variation works and extensions of time. The systematic method of using standard forms to document the operations on construction sites is well established. Although software applications are also available for the purpose, computer literacy of construction field personnel is insufficiently widespread to take advantage of their availability. This paper addresses the issue with a prototype of a dual system where the fax machine is used as the data entry interface (in place of a keyboard) to a central computer. The system connects up fax machines in the construction site offices to a central computer in the head office via a modem/fax linkup. Hand-filled standard forms are faxed to this central computer where an Optical Character Reader/Intelligent Character Reader (OCR/ICR) engine translates the faxed handwriting images into computer-readable data. The Daily Site Report is used to prototype the system and the accuracy of the reading system is presented. Application of the system is also discussed.

Keywords: *Construction, documentation, computing, report, handwriting, recognition.*

INTRODUCTION

The need for maintaining good documentation of field operations in a construction site becomes apparent and critical when a contractor faces a contractual dispute or puts up a claim for variation charges and extension of time. Often, the contractor is not able to make full claims for the additional work and time for lack of proper records and supporting evidence. For the same reason, contractors are often also unable to negotiate from positions of strength during disputes. Abrahamson (1979) puts it aptly: “A party in a dispute, particularly if there is arbitration, will learn three lessons (often too late) - the importance of records, the importance of records, and the importance of records.”

The day-to-day records of many contractors tend to be limited to those fulfilling statutory requirements or contractual obligations even though the case for keeping good records and documentation throughout the project is compelling. Although record keeping in construction is a well established process, its practice is labor-intensive (Cushman, 1983), (Waier, 1990), (Grimes, 1989), (Fisk, 1997). In a tight labor market, the local contractor is likely to do away with this overhead item.

Information Technology (IT) is widely acknowledged or at least perceived to be the answer to the problem of tedious keeping of records and laborious storing of information. However, the use of IT in construction sites is low despite the availability of many computer software for such applications. These software contain useful features and functions to manage contracts, subcontracts, orders, budgets, correspondence, drawings, meetings, submissions, safety issues, quality assurance issues and even daily events. Few contractors take advantage of these tools because the computer skills required to use them are not present on the construction sites. Construction site staff such as supervisors, foremen, site agents and charge hands cannot be expected to be computer literate because they are trained in other abilities for achieving physical goals and tangible products. The seemingly abstract and symbolic jargon associated with computer usage is alien and even hostile to most of them.

In entering the new millennium, the construction industry needs to recognize the fact that computer literacy among construction site staff will continue to remain low and IT development can only make progress if provisions are made to befriend this group of users. This calls for novel ways of implementing IT on construction sites so that the interaction between humans and computers can be increased.

OBJECTIVE

This paper addresses the problem of incomplete documentation due to computer illiteracy by replacing the conventional keyboard-based data entry method with an alternative approach.

METHOD

This paper evaluates alternative data entry systems for capturing data in fieldwork. The key success factor is a system simple enough for the front-line worker to operate. Some examples of systems currently in use are hand held terminals used by:

- Waiters taking orders using hand held terminals with wireless data transfer.
- Postmen tracking registered mail using data loggers.
- Utilities meter-readers who enter meter readings into data loggers.
- Car park attendants issuing parking summons with a hand held terminals or printers.

The approach behind these systems can be adapted for capturing field documentation in construction projects.

This paper proposes using a fax machine to capture information written on paper forms by hand to replace the keyboard-based data entry system, data logger or hand held terminal. In effect, the fax machine is used for input, acting as a scanner to capture an image of the paper form, and transmitting the information as electronic data to a processing computer located away from the construction site. Instead of a keyboard, this method of data entry presents a familiar interface to the construction field staff i.e., the ubiquitous fax machine and paper forms. This unique form of interfacing with background computers sidesteps the issue of resistance towards the use of IT from the construction field staff. The conceptual model of the proposed system is illustrated in Figure 1.

Data Transmission

The system chosen can operate between the Head Office and several Site Offices. A fax machine at each Site Office is connected to the Head Office central computer through a modem linkup. The central computer services all the individual Site Offices. It receives all the standard forms that are faxed from the individual Site Offices through the fax-modem linkup. In the central computer, a handwriting recognition engine then translates the handwritten information on these forms into computer-readable data. All data are transferred into a Database Management System (DBMS) for storage and further processing.

Data Collation

The structure of the DBMS depends on the organization's operational process. It can be modified and customised specifically from off-the-shelf software packages to cover all documentation requirements such as purchases, accounting, budgeting, staff wages, overtime, change orders, submittals, transmittals, correspondence, log and other documents. Essentially, they store data obtained and consolidate or process them into various reports for different end-users in the organisation. The end-users could be management, personnel in administration, accounts and contracts, project managers and other parties in the contractor's organisation.

Periodic reports based on data consolidated by the DBMS are distributed by fax to the end-users using customised standard forms through the modem-fax linkup. End-users at the Head Office access the DBMS directly through computer terminals linked by a local area network to the central computer. End-users from the various Site Offices request for information from the DBMS by using standard query forms which are similarly channelled to the Head Office computer. The queries would be translated into electronic format and subsequently processed for appropriate responses. The responses are transmitted back through the modem-fax link to the Site Office using another standard form. Although the queries have limited flexibility because of its dependence on standard forms, this mode of communication allows the central computer to remotely manage and monitor the project documentation of several construction sites in different geographical locations.

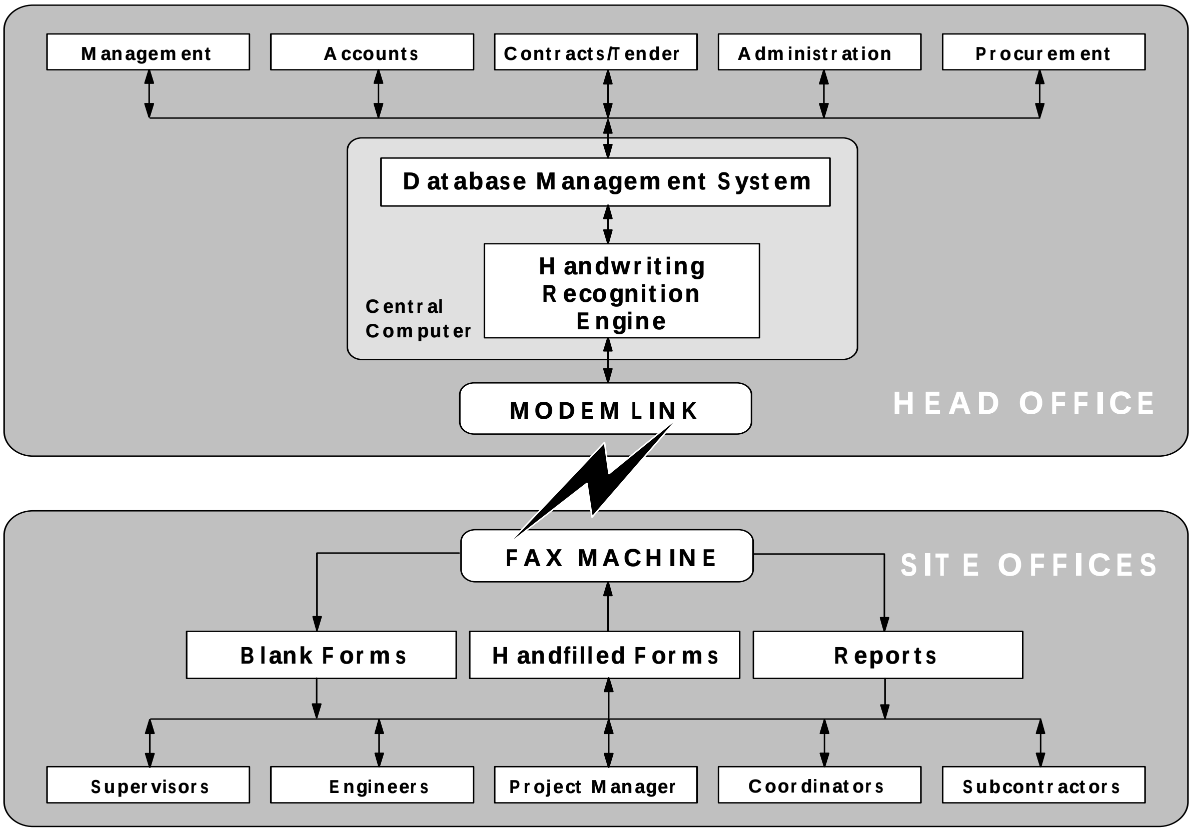


Figure 1: Conceptual Model of Remote Computing and Documentation System for Construction Sites

One critical feature of user-centric solutions is the presence of redundant information. Systems with apparent redundancy and secondary or parallel cues are more forgiving to the less computer literate personnel. These parallel cues assist users in disambiguating information (Alty and Bergan, 1992). Document imaging systems, such as the solution proposed here, are able to provide useful redundancies when the original paper document is duplicated into an electronic image. If the recognition technology is also deployed, then a second redundancy in the form of the translated electronic data becomes available. The presence of parallel sets of data helps both the office and field staff in handling information captured on the construction site. Office staff handling the electronic form of the information are assured of a backup from the original paper documents, while the field staff can retain their original paper documents which will allay their apprehension over losing information in the intangible electronic transmission.

DEVELOPMENT

A prototype has been developed to demonstrate proof-of-concept. This is to show whether handwriting recognition can be applied as an alternative data entry method for capturing construction site information. The prototype development requires several steps to demonstrate the feasibility of the proposed solution. They are to:

- develop a prototype form for recognizing handwriting from site records;
- use the prototype form to obtain samples of the different handwriting styles;
- scan the completed survey forms using a fax machine;
- transfer the image into a remotely located computer using the fax machine;
- translate the scanned images into electronic data;
- analyse the recognition yield from the translated handwriting; and
- use the recognition yield to gauge the feasibility of the concept.

Selection

The success of the study depends on selecting an appropriate application to prototype. The selected application should demonstrate an obvious and immediate benefit from implementing the full version of the proposed fax linkup system. The Daily Site Report stands out as a form commonly used by almost all construction companies. Its purpose and application are well documented and is therefore selected as the standard form for development of the prototype (Pogorilich, 1992).

Tests

The prototype has been developed over several stages and the final version has been implemented to test its recognition yields. 100 samples of different handwriting styles have been obtained from personnel working in the construction industry to test the prototype. Scanning the completed survey forms and transferring the images into a remotely located computer has been carried out in a simulated remote computing environment in which a fax machine has been linked by a telephone line to a central computer. The central computer used for this study is a Twinhead 9150TZ ™ notebook with the following configuration:

- 150 MHz Pentium CPU running on the Windows 95 operating system;
- 32 MB RAM, 1.35 GB hard disk; and
- 33.6 MHz built-in fax-modem.

The fax machine is hooked to a telephone line and the model used for the study is the Konica Konimail 200 ™. Data has been transmitted across standard telephone lines, the Public Switched Telephone Network (PSTN), from a fax machine to the fax-modem in the central computer. The transmission is based on international standards, CCIT Group 3 Protocol, using a maximum transmission rate of 9,600 baud. The resolution level is set to FINE which is 203 by 196 lines per inch.

Figure 2 shows an image of a completed form that has been faxed into the central computer. After transferring the scanned handwriting images, the images are translated into electronic data by a handwriting recognition engine and the results are stored into databases within the same computer. The handwriting recognition software application used to develop the prototype form and translate the images is Teleform ™. Its internal handwriting recognition engine translates the faxed handwriting images into electronic data.

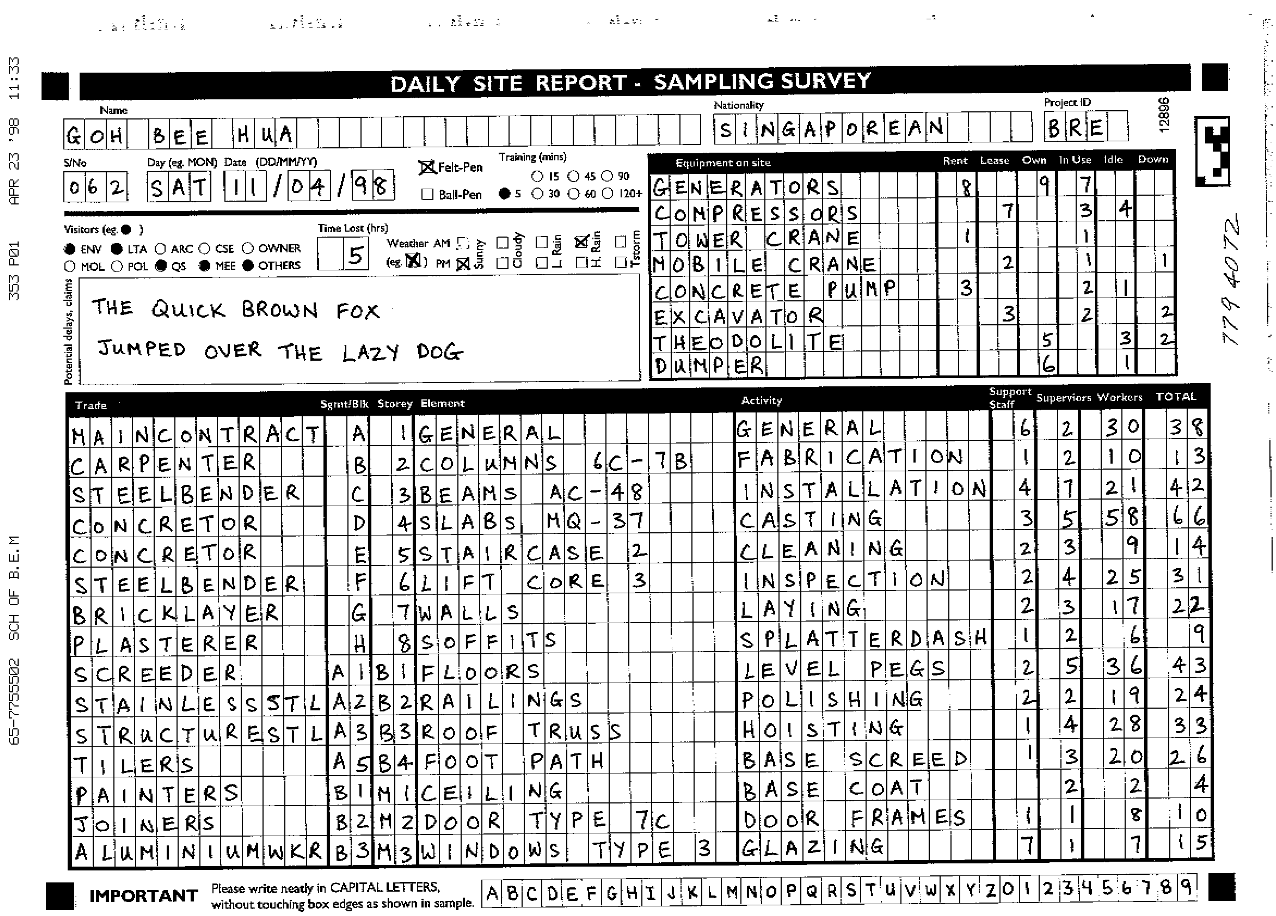
There are 3 types of text recognition engines:

- Optical Character Reader (OCR) for reading machine printed characters.
- Intelligent Character Reader (ICR) for reading hand-printed characters.
- Natural Handwriting Reader (NHR) for reading cursive handwriting.

The Teleform ™ engine is an Optical Character Reader/Intelligent Character Reader (OCR/ICR). This can read both machine and hand-printed characters. It is not designed to read cursive handwriting. Several recognition enhancement tools available in the system are therefore used. They are:

- Character enhancement using contextual boxes.
- Word enhancement using dictionary.
- Field enhancement using validation formula scripts.

A distinction is also made between constrained and unconstrained text, that is, whether each individual character space has been predefined using boxes or allowed to spill over.



APR 23 '98 11:33 353 P01 65-7755502 SCH OF B.E.M

DAILY SITE REPORT - SAMPLING SURVEY

Name: GOH BEE HUA
Nationality: SINGAPOREAN
Project ID: BRE
12896

S/No: 062 Day (eg. MON): SAT Date (DD/MM/YY): 11/04/98
☒ Felt-Pen ☐ Ball-Pen
Training (mins): ○ 15 ○ 45 ○ 90 ● 5 ○ 30 ○ 60 ○ 120+
Visitors (eg. ●): ● ENV ● LTA ○ ARC ○ CSE ○ OWNER ○ MOL ○ POL ● QS ● MEE ● OTHERS
Time Lost (hrs): 5
Weather AM / PM: Sunny, Cloudy, L. Rain, H. Rain, T.storm

Potential delays, claims: THE QUICK BROWN FOX JUMPED OVER THE LAZY DOG

Equipment on site	Rent	Lease	Own	In Use	Idle	Down
GENERATORS	8		9	7		
COMPRESSORS		7		3	4	
TOWER CRANE	1			1		
MOBILE CRANE		2		1		1
CONCRETE PUMP	3			2	1	
EXCAVATOR		3		2		2
THEODOLITE			5		3	2
DUMPER			6		1	

Trade	Sgmt/Blk	Storey	Element	Activity	Support Staff	Supervisors	Workers	TOTAL
MAINCONTRACT	A	1	GENERAL	GENERAL	6	2	30	38
CARPENTER	B	2	COLUMNS 6C-7B	FABRICATION	1	2	10	13
STEELBENDER	C	3	BEAMS AC-48	INSTALLATION	4	7	21	42
CONCRETOR	D	4	SLABS MQ-37	CASTING	3	5	58	66
CONCRETOR	E	5	STAIRCASE 2	CLEANING	2	3	9	14
STEELBENDER	F	6	LIFT CORE 3	INSPECTION	2	4	25	31
BRICKLAYER	G	7	WALLS	LAYING	2	3	17	22
PLASTERER	H	8	SOFFITS	SPLATTERDASH	1	2	6	9
SCREEDER	A1	B1	FLOORS	LEVEL PEGS	2	5	36	43
STAINLESSSTL	A2	B2	RAILINGS	POLISHING	2	2	19	24
STRUCTURESTL	A3	B3	ROOF TRUSS	HOISTING	1	4	28	33
TILERS	A5	B4	FOOT PATH	BASE SCREED	1	3	20	26
PAINTERS	B1	M1	CEILING	BASE COAT		2	2	4
JOINERS	B2	M2	DOOR TYPE 7C	DOOR FRAMES	1	1	8	10
ALUMINIUMWKR	B3	M3	WINDOWS TYPE 3	GLAZING	7	1	7	15

IMPORTANT Please write neatly in CAPITAL LETTERS, without touching box edges as shown in sample. ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

7794072

Figure 2: Sample of a Faxed Image of a Completed Form

RESULTS

Each form is filled by a different writer. All of these writers work in the construction industry. A standard set of data is provided for the writers to fill up in the sampling form. The results of the extent of recognition are then compared against this standard data set to obtain their accuracy. In order to optimise the recognition yield, the character sets are segregated into several categories. They are alphabetics, alphanumerics and numerics.

Table 1 shows the proportion (%) of forms differentiated between alphabetic, alphanumeric and numeric data types as well as the 5 ranges of recognition yields. Figure 3 presents the data in chart form.

Table 1: Ranking of Forms with the Best Recognition Yields

Recognition Yield	*Alphabetics*	*Alphanumerics*	*Numerics*	*Overall*
less than 80%	12%	47%	1%	9%
80% to 85%	15%	21%	2%	4%
85% to 90%	26%	17%	4%	18%
90% to 95%	28%	12%	15%	51%
more than 95%	19%	3%	78%	18%

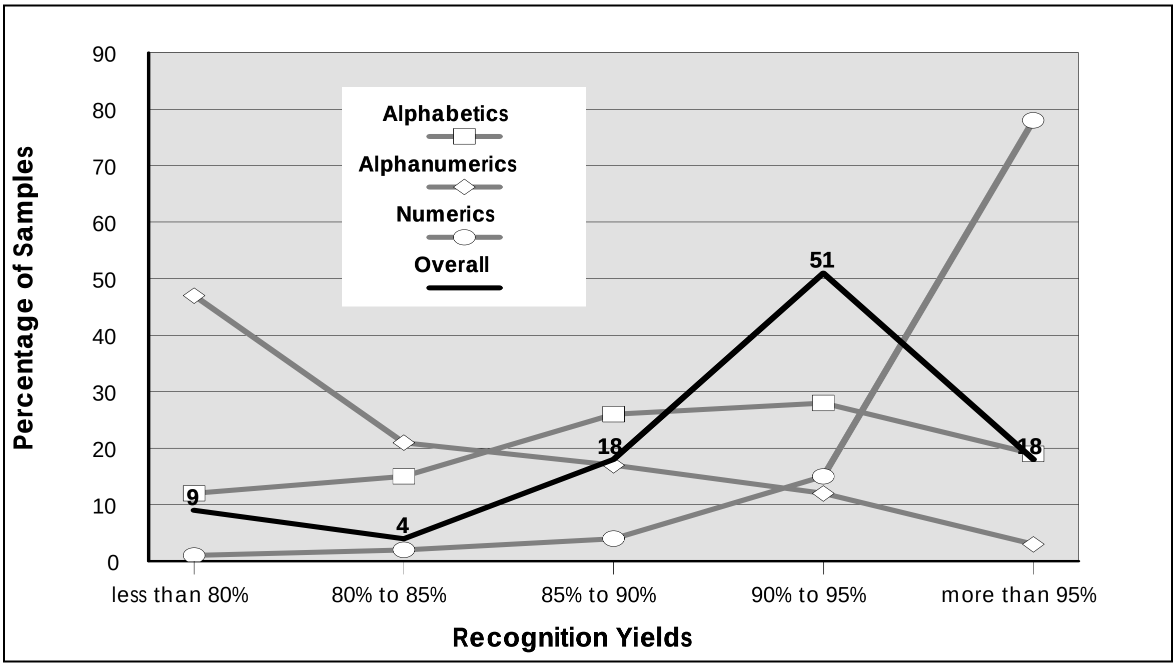


Figure 3: Overall Recognition Yields

Nearly half of the alphanumeric fields obtain recognition yields below 80% while more than three-quarters of the numeric fields obtain recognition yields above 95%. Slightly more than half the alphabetic fields obtain recognition yields between 85% and 95%. These results underscore the priority which should be accorded to the use of these fields, namely the numerics and alphabetics, and finally as a last resort, the alphanumeric fields.

The choice fields which are the optical marks using ticks, crosses and shades are not compared here because they are almost perfect and are regarded as the first choice of field types to be used. The overall recognition yield, regardless of field types, tends to converge around the 90 to 95 percentile range. Table 2 summarizes the results of the recognition accuracy.

Table 2: Average Recognition Yields of Data Field Types

No.	*Data types*	*Recognition yields*	*Remarks*
1	Numerics	97.1% word	Character sets 0, 1, 2, 4, 5, 6, 7, 8, 9
2	Alphabetics	91.9% word	Character sets “A” to “Z” and “a” to “z”
3	Alphanumerics	78.2% word	Comprises of all the above character sets
4	Choice fields	99.4% word	Optical marks eg ticks, crosses and shades etc
5	Day and Date	84% word	Validation script is applied to correlate the fields
6	Unconstrained alphanumeric fields	34.2% word 0% field	Individual characters are allowed to spill into the character space of the adjacent characters

These recognition yields are almost as good as those tested in commercial OCR packages. A review of OCR software by *PC Magazine* on 20 Jan 1998, rated the performances of commercial OCR software in Table 3.

Table 3: Comparative Evaluation of Commercial OCR Software

OCR Software (off-the-shelves)	*Word accuracy*	*Errors per page (500 words page)*	*Time per page (sec)*
Cuneiform OCR 3.0	96.8%	16.0	7.3
OCR Master	90.3%	48.5	46.0
OmniPage Pro 8.0	97.6%	12.0	19.2
Presto! OCR Pro 3.0	98.7%	6.5	23.5
Recognita Plus 3.2	97.2%	14.0	13.0
Textbridge Pro 98	98.8%	6.0	20.6
TypeReader Professional 4.0	98.1%	9.5	7.8

Although the recognition rates seem almost comparable, it is important to take note that the comparison is not absolutely fair. OCR software features multi-font and multi-document recognition capability while the prototype form developed requires many predefined information such as:

- the location and size of the individual field image; and
- the context of data expected in the field e.g. character sets, and dictionary.

The purpose of comparing commercial OCR with the prototype results is to provide a yardstick for gauging the practical utility of the proposed solution. The results from the prototype show that the proposed solution can provide the same level of utility as OCR packages if the types of character sets are restricted to numeric, alphabetic and choice fields only. Compared with OCR packages, a higher level of customisation is required to develop the proposed solution into practical applications.

CONCLUSION

Commercially, handwriting recognition applications are relatively new as consumer products. Throughout the early 1960s to the mid 1990s, this technology is available at a price suitable for large corporate users only. These applications are high performance reading machines which can process very high volumes of documents and are applied for highly specialized tasks such as check reading, tax forms processing and mail sorting (Downton and Impodovo, 1996; O'Gorman and Kasturi, 1995; Hunke and Wang, 1997).

This study shows that handwriting recognition application is a viable and practical solution for construction site documentation and can be adopted for projects of any size (Lee, 1998). One significant contribution the system can make for construction enterprises is in facilitating the implementation of ISO 9000 quality assurance procedures by addressing the most common complaint from site staff on ISO 9000 procedures - handling the volume of paperwork.

The solution proposed in this paper is attractive and practical for the following reasons:

- Only a simple computing infrastructure is required.
- The set up cost is low. The hardware set-up costs below US$10,000 for one host site and one remote site and software including customisation costs below US$20,000 depending on the scope of application.
- Maintenance and system upgrade costs are low and are confined to the host site.
- The simplicity of the system is amenable to frequent relocation which can occur in construction sites.
- Staff training is minimal as it consists of how to fill up the forms and how to operate a fax machine.

As the construction industry progresses into the new millennium, the issue of low IT literacy especially on the construction site will continue to be a problem. This is largely due to the type of staff employed on construction sites. Although IT training can help alleviate the problem, the site staff may not take to IT easily. After all, the main objective on construction sites is still to build structures and not to handle computers. Any IT application targeted at construction sites will have to confront the barrier of low IT acceptance. This study offers a unique direction for IT implementation. It is simply to replace the keyboard and monitor interface with alternative man-machine interfaces. The challenge in promoting IT on construction sites in the next millennium is not in building sophisticated applications but rather in providing arrangements that support simpler access to computing power.

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Introducing Quality Assurance in the Seychelles Construction Industry

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Abstract

In common with other developing countries, the construction industry in the Seychelles faces a major challenge in improving the quality of its output. The Quality Assurance (QA) framework, provided by the ISO 9000 standards, could be a driver and an agent for change of the current quality culture. Existing problems such as poor communication, inconsistent technology, lack of commitment and cultural resistance present barriers to QA implementation. The paper analyses and discusses quality related issues and speculates on the prospects for the successful implementation of QA in the Seychelles. The paper draws on the results of an extensive survey of the perceptions of building professionals and managers on issues relevant to QA implementation in the Seychelles construction industry.

Keywords: Quality assurance, Seychelles, implementation, problems, culture.

INTRODUCTION

Quality Assurance (QA) started in the construction industry around the 1980's in western countries such as the USA, UK, and Australia. ISO 9000 is the international standard for quality management. It is a combination of the different standards that were used in the past. It is used by many organisations in many countries around the world (Ashford, 1990). The Seychelles is one of these countries which is still developing and thus looking at ways to improve the construction business and may benefit by learning from developed countries which have experienced these new changes. Very little research has been carried out on the Seychelles construction industry and until recently, none on QA.

This paper reports on research on the applicability of introducing QA in the Seychelles' construction industry using a survey of building professionals and management of large construction companies'. Research issues explored include: interpretation of Quality Assurance; major problems in the Seychelles' construction industry; communication processes; technology used in the local construction industry; commitment of participants in the management of construction projects; culture and economic environments; and identifying a suitable organisation to first implement QA for industry-wide acceptance.

This research is limited geographically to the island of 'Mahe' which is the main island in the Seychelles. It is also where the capital city, Victoria, is located and where most of the companies' head offices are based. The study investigates the opinions of managers of major construction companies of over 100 staff members operating in the Seychelles.

Factors that influence QA Programme

The literature indicate that the following factors affect the implementation of a company's QA programme: (i) commitment; (ii) communication; (iii) contract disputes; (iv) rework; (v) technology; (vi) paperwork implications; (vii) training; and (viii) resistance to change.

SEYCHELLES CONSTRUCTION INDUSTRY

Population

The Seychelles population is only seventy-seven thousand *(77,000)* (Management and Information Systems Division MISD, 1998).

Clients

Since the Seychelles is progressing, with an increasing market share and an increasing number of overseas investors, it is just a matter of time before more clients will be asking for total quality in construction in terms of value for money. The Seychelles can learn from experiences in other countries that the government, as a client, will be the best body to enforce QA in the industry. McGeorge and Palmer (1997) indicate that Latham crudely states that clients have the power of the cheque book and therefore get what they want or they will not pay for it.

Importance of Construction Industry to Economy

The construction industry accounts directly for 7 to 9% of Gross National Product in most developed countries (DITAC Construction Forecaster Committee, 1997). In the Seychelles, the construction industry accounts for 9.4% of the Gross National Product (Management and Information Systems Division (MISD), Seychelles, 1998). An interesting aspect of these figures is that being a developing country, the Seychelles' construction industry contributes to approximately the same amount to its economy as a developed country. This is further proof that the industry is expanding and developing and should keep up with the changes within the construction industry world-wide to ensure that positive progress is maintained.

Seychelles Bureau of Standards

The Seychelles have an organisation responsible for quality in all sectors of the economy called the Seychelles Bureau of Standards (SBS) which was founded in 1987. SBS has been a correspondent member of ISO 9000 since December 1996 and is therefore recognised internationally. It has plans to assist firms in the implementation of the ISO 9000 standard but does not have the power to implement QA in the construction industry as yet unless they are projects related to environment and health issues (interview with Mr. Joseph, Director of SBS, 1998). SBS is one of the organisations in the Seychelles' construction industry which are most likely to provide a common yardstick in different aspects. Results of research in the UK suggest that QA provides a common yardstick for the contractors and the clients which, therefore, reduces claims and disputes, especially when certified by recognisable professional bodies (McCabe *et al.*, 1996). On the other hand, in the Seychelles, there are no professional bodies to give accreditation to any organisation for their achievements. Some companies or individuals have got international recognition or accreditation but this does not seem to be understood or appreciated in the Seychelles.

Number of Qualified People in the Industry

The percentage of employed expatriates in the construction industry is greater than in all the other employment sectors combined. In 1994, it was 52%, 1995 it was 33% and 1996 it was 23% (MISD, 1998). Although there has been a decline percentage-wise and number-wise as well due to the number of returning graduates, the number of expatriates is still high and is draining the country's foreign exchange. The government is attempting to alleviate the problem by sponsoring students to travel overseas to gain qualifications in order to decrease the country's dependence on expatriates.

RESEARCH METHOD

The main objective of this research is to analyse the QA in the Seychelles' construction industry. A qualitative approach was used to get the respondents to use their own terms in order to avoid influencing or constraining the issues. Research was limited only to the top management of construction companies with more than 100 staff. There were approximately 10 such companies on the island. All were contacted, and 7 responded to the structured questions. Content analysis (Patton, 1987) was used to analyse the responses.

The respondents may be described as follows:

Company A	Building Construction Company (*Government Related Company*)
Company B	Services Construction Company (*Government Related Company*)
Company C	Civil Engineering Construction Company (*Government Related Company*)
Company D	Residential Construction Company (*Government Related Company*)
Company E	Construction Company (*Private Company*)
Company F	Construction Company (*Private Company*)
Company G	Construction Company (*Private Company*).

SURVEY RESULTS AND DISCUSSION

Table 1: Summary of points under Issue 1

Issue 1 *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
Perception of a 'Quality Management' system								
Systematic process using resources to achieve objectives Team responsibility Overall package: safety, structure, communication, etc.	*	*	*	*				4
Construction materials and qualified people/ workmanship					*	*	*	3

The responses fell under two categories as illustrated above. It can be deduced that the management of government-related companies which are companies A to D have a broader and better understanding of a 'Quality Management' system which is an advantage as discussed under issue 9, because they are in a better position to have the power to gain industry-wide acceptance of a 'Quality Management' system and effect standardisation across the industry. These results do not mention clients at all, although it may have been implied, but this observation comes from the all-so-frequent response to a 'quality management system' in the related literature, that the benefits are passed on to the clients.

According to (Taylor and Hosker, 1992) and (Bailey, 1996) 'Quality' is the sum of: knowing the customers needs; fitness for purpose; designing to meet them; availability; exceeding customer expectations; safety; faultless construction; consistency; degree of excellence; value for money; reliable equipment and materials; aesthetics; good management co-ordination; reliability; getting it right first time; marketability; and conformance to requirements. The aim of a QA system is getting things right the first time and, by so doing, preventing errors. There is a growing realisation by some construction companies that a quality management system, when fully implemented, will not only raise their standards but also reduce their costs and hence increase their profits (Cornick, 1991).

Table 2: Summary of points under Issue 2

<u>*Issue 2*</u> *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
The construction industry's perception of a 'Quality Management' system								
Quality is seen on the surface only				*	*			2
Hesitant about it. Applicability problem If there is time and desire to become involved	*		*			*	*	4

The survey findings are supported by (McGeorge and Palmer, 1997) who state that the construction industry is an enormously complex one and it has barriers that appear to prevent the development of a quality culture. These barriers come in the form of people with diverse backgrounds working on the same project, the short-term nature of construction, and reliance on migrant labour that makes the integration of quality in the construction industry particularly weak (McCabe etc, 1996). Unfortunately, many of the people who are delivering the QA message tend to dwell on the clinical correctness of the technique rather than the understanding needed to develop a better management culture. This should be looked at carefully when delivering the message as it may add up to its resistance (Travis and Cusak, 1992).

The survey indicates that respondents are unclear about the benefits implementation may provide. Research in Australia shows that non-quality is adding between 10 to 20% to operating costs (Fox, 1991). Furthermore, results from research done in the UK construction industry have shown that a lack of commitment has been a major cause of unsuccessful QA programmes and that QA has a reputation for being unnecessary, and is an expensive distraction and little good often comes out of it (McCabe etc 1996). In contrast, (Chartered Building Professional, 1996) has identified that quality costs are due to our inability to get things right the first time.

There may not be a full understanding of a quality management system industry-wide in the Seychelles. This problem may be overcome with training as according to (Ashford, 1990) no matter how carefully devised and comprehensive a QA system is, people need to be trained to have knowledge and skills to operate it.

Table 3: Summary of points under Issue 3

<u>*Issue 3*</u> *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
The major problems in the Seychelles construction industry								
Lack of qualified people	*	*	*	*		*		5
Lack of foreign exchange and construction materials			*		*	*	*	4
Lack of proper monitoring at critical stages/ safety Planning time reduced	*	*	*	*				4
No common yardstick		*						1
Cracks and peeling causes rework and disputes				*				1

According to the results, the major problems of a lack of qualified people and foreign exchange and construction materials will have an influence on the effectiveness of QA. In relation to the results, the planning of a proper, applicable QA programme may help in the monitoring at critical stages of construction. However, the planning time cannot be controlled by QA. The problem of 'no common yardstick' should be overcome by a local organisation in the Seychelles' construction industry using ISO 9000 and modifying it to suit local conditions. Rework and disputes could be avoided if a QA system is implemented correctly and would therefore reduce the cracks and peelings that are the underlying cause.

The results are supported by current literature, as it becomes increasingly costly to redo a process as the project progresses. Therefore, it is better done right the first time (Ashford, 1990). Thorpe *et al*. (1996) also state that the major sources of cost-related error lie in either the design or the construction management team.

Quality does not have to be achieved through mountains of paper-work if there is commitment, honesty and trained and knowledgeable people with a common understanding of the quality management system involved in the procurement of the project (Cullen and Hollingum, 1987). The paperwork that is required provides formal records during the design and construction period which can have many benefits, such as providing proof for when disputes arise, and the results can also be analysed to be improved on in the next project. The sub-contractors tend to be slow in appreciating QA, seeing it as a lot of paperwork, perhaps because of their level of education. This is why training in QA is required.

Table 4: Summary of points under Issue 4

<u>*Issue 4*</u> *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
The communication processes in the construction industry								
Good		*			*	*	*	4
Bad	*							1
Varies			*	*				2

The responses fell under three categories as illustrated above. According to the results it can be deduced that the communication process in the industry is quite good and will allow a quality management system to be implemented successfully. Good communication processes in the Seychelles' construction industry will help greatly to have an effective quality management programme. This can be a result of the Seychelles' construction industry having smaller sites, hence more personal relationships compared to much larger sites in Australia. This is supported by (Thorpe etc 1996) who highlights poor communication as leading to poor operation. The most effective way to overcome communication problems in these cases is to formalise it. This can be seen mainly on large sites whereas on smaller sites there can be more personal relationships. As a result of poor communication there may be contract disputes.

Table 5: Summary of points under Issue 5

<u>*Issue 5*</u> *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
The kind of technology the Seychelles construction industry has								
Adequate office equipment but poor training	*	*	*	*	*	*	*	7
Equipment on sites is improving/adequate	*			*	*	*		4
Not enough equipment on site		*	*				*	3

According to the results it is clear that in terms of hardware and software, there is adequate technology which may not be fully exploited; but when it comes to equipment on site, nearly half of the respondents seem to think that there is enough, and half think there is not. Technology will also help reduce quality problems, especially in the design stage by using sophisticated design software packages which can solve some problems automatically, as it is where most of the problems occur (Cornick, 1991).

Table 6: Summary of points under Issue 6

Issue 6 *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
Commitment of management for pursuing the best for their clients and company industry-wide								
Big contractors yes and small contractors no	*	*		*				3
Lack of commitment industry-wide because there is more demand than supply and lack of qualified people					*	*		2
Committed but there are constraints			*				*	2

From the results it can be deduced that there is commitment in larger companies compared to smaller ones, and they also face some constraints such as lack of qualified people, and of foreign exchange, and hence construction materials. Only 2 out of the respondents believe there is a lack of commitment industry-wide due to the more-demand-than-supply situation and a lack of qualified people.

It has been identified that commitment from top management is the key to a successful QA programme. A number of companies have identified that having commitment and a long term vision were major factors in having a successful QA system. The main reason for disappointment in the implementation of a quality management system in the construction industry is the lack of management commitment, vision and planning amongst top management in a project or company-wise. Successful implementation can be achieved with proper training in an appreciation of QA and willingness to implement it in the appropriate way. Mathur and McGeorge (1991) state that "There is commitment to the industry, but each one seems to have set up their own priorities independently, and communication amongst them remains poor".

For a project to be successful, however, all the appropriate professionals should be involved at critical stages during the process. This can be supported by results from research done in the UK construction industry which found that teamwork and support at all levels to gain acceptance is required for a successful QA program (McCabe, 1996). To enable this to happen it is essential that there are well-defined interfaces, clear levels of responsibility and properly specified requirements, including those concerning work planning, resourcing, skills, acceptance criteria, records and so on (Thorpe *et al*., 1996). Commitment may be hindered as McCabe *et al*. (1996) state that QA has a reputation of being unnecessary, and is an expensive distraction and little good often comes out of it.

Table 7: Summary of points under Issue 7

Issue 7 *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
Competitive pressure to implement new management techniques for more successful tenders								
Yes, there is	*	*		*	*			4
Not a lot			*			*	*	3

The results indicate that the situation is quite neutral in terms of competitive pressure to implement new management techniques for more successful tenders. Competitive pressure in the industry must be provided to implement QA for more successful government tenders. It appears that there is little competitive pressure in the Seychelles construction industry to motivate the implementation of QA.

Table 8: Summary of points under Issue 8

Issue 8 *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
Whether there is favourable culture and economic environment for the implementation of a 'Quality Management' system in the construction industry								
Favourable culture	*			*		*		3
Not a favourable culture	*	*	*	*	*		*	6
Good economic environment	*		*	*		*	*	5
Not a favourable economic environment		*			*			2

The responses fell under four categories as illustrated in Table 8. There were a double the number of responses to a non-favourable culture as that for a favourable culture. On the other hand, there were more than double the responses to a good economic environment as opposed to a bad economic environment.

The importance of culture is supported by McGeorge and Palmer (1997) who suggested that there should be a shift from professional-based scenario to a project-based scenario in the construction industry to gain the most out of a project. This creates a challenge for the industry to provide 'a means of encouraging a cultural shift'. Although the culture of a society is not something that can readily be changed, it is not impossible to introduce new organisational structures into the work environment (McGeorge and Palmer, 1997). This is illustrated clearly from results of research done in the UK construction industry which suggested that ISO 9000 should be amended to suit the organisations' culture, it should not be imposed (McCabe *et al*., 1996).

The respondents indication of a good economic environment is further supported by recent literature stating that the construction industry in the Seychelles accounts for 9.4% of the Gross National Product (Management and Information Systems Division, 1998). An interesting aspect of these figures is that being a developing country, the Seychelles' construction industry contributes to approximately the same amount to its economy as a developed country. The GNP of most developed countries is between 7-9% (DITAC Construction Forecaster Committee, 1997). This is further proof that the industry is expanding and developing and should keep up with the changes within the construction industry world-wide ensuring that positive progress is maintained.

It can be concluded that the current situation is not entirely favourable for the implementation of a quality management systems in the Seychelles construction industry, as both environments need to exist alongside each other, therefore helping each other. On the other hand, it does not mean that QA cannot be implemented altogether in the Seychelles' construction industry.

Table 9: Summary of points under Issue 9

Issue 9 *Companies*	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*Totals*
The most suitable organisation to gain acceptance of a QA system and initiate industry standardisation								
Ministry of Land Use and Habitat (MLUH)	*			*	*			3
Seychelles Bureau of Standards (SBS)	*	*	*					3
Ministry of Industries						*	*	2

According to the tabulated results, all of the three organisations identified fall under that of government. The demand for quality will come from the customer. According to Beaumont and Amrik (1997), Australia has moved from a regulated economy to one in which market forces are allowed to hold greater sway, whereas, the Seychelles is still operating very much under a regulated economy. This is further supported from a different point of view by McCabe *et al.* (1996) who state that previously in Australia, clients have been concerned with their building being delivered in minimum time and to budget, at the cost of quality. Nowadays clients are using construction contractors with well-respected accreditation, thereby increasing the market share of these companies, because their clients are more satisfied.

It can therefore be concluded that the organisation(s) most likely to be chosen to have the power to gain industry-wide acceptance of a 'Quality Management' system and provide standardisation across the industry will be from a sector of the government.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Overall, amongst management and building professionals of major construction companies with 100 staff members or more on the island of Mahe in the Seychelles, there is a good understanding of quality, and hence quality management. This holds particularly true amongst government-related companies compared to other companies and the rest of the industry that may have a narrower understanding of such a system. There is an indication that the existing communication processes in the Seychelles construction industry are quite effective and that top management of major construction companies have more commitment in general than smaller companies, although there are constraints.

There is an indication that there is more competition amongst larger companies than smaller ones. The level of technology in the Seychelles construction industry seems to be very good in terms of hardware and software, but average in terms of equipment on site. This provides a relatively good environment for QA implementation. The major problems are a lack of qualified people and a lack of foreign exchange, hence construction materials which cannot be solved by QA, but monitoring at critical stages and reworks, and providing a common yardstick can be improved with QA. The best organisation to have the power to gain industry-wide acceptance and have standardisation across the industry is most likely to be government-related and they are SBS and MLUH. The cultural environment is not entirely favourable, but the economic environment is.

Following the above summary it is recommended that QA may be more successful if initiated by senior management of the larger construction companies in the Seychelles, which are government-related. Then by providing more awareness and training, which will involve propagating awareness of its benefits across the industry, gradually extend it into smaller companies. Competition amongst larger companies further strengthens the first recommendation to start QA in larger companies.

QA may solve the problem of monitoring at critical stages and reworks and using international standards such as ISO 9000 (amended to suit local conditions) will provide a common yardstick to start with in terms of quality management in the industry. The 3 companies that believe that there is a favourable culture and economic environment may provide a start for QA implementation. Quality management procedures can be prepared by the technical experts from SBS, and MLUH will provide the authority to request the application of the procedures on their projects. Thus, the two organisations can work in collaboration with each other.

In Australia, construction companies are obtaining quality certification, such as ISO 9000 certification, because of government and market pressure (MBA, 1998). The results of research done in the UK construction industry have indicated that construction companies are also getting certification with the main intention of being recommended for more jobs (McCabe etc, 1996). Furthermore Lloyd's Register Quality Assurance (LRQA, 1993) found that most of the benefits associated with ISO 9000 certification were external to an organisation's processes. 69% of the managers agreed that ISO 9000 certification enabled them to improve their business performance by allowing them to bid for more tenders (Hoyle 1994).

In contrast to these results, further work in the field has established that certification may not be the route to take and that possibly the most effective means of establishing a total quality culture and improving quality is for the company to develop its own quality improvement team (McGeorge and Palmer, 1997). Whoever initiates QA should believe that the way forward lies in gaining industry-wide acceptance for a practical action plan (Chartered Institute of Building, 1995).

RECOMMENDATIONS FOR FURTHER RESEARCH

The issues discussed in this study were broad because no research has been carried out on the topic. To gain a better understanding of the current situation in the local industry, a series of specific questions on each issue will allow an in depth analysis of the situation. Firstly, a study to identify the major problems, causes, and relationships would allow for a detailed understanding of the existing situation, and by using these results, implement a QA system that will work most effectively in this particular environment. Similarly, an in-depth study of the cultural and economic environment would give good indicators as to how the QA system should be implemented.

CONCLUSION

This study has attempted to analyse the applicability of QA in the Seychelles construction industry. The research has achieved its objectives which are illustrated as the major findings, and recommendation to practice. Overall, it can be deduced that QA can be implemented successfully in the Seychelles' construction industry, although there are a number of constraints. This can be achieved if the participants of the construction industry use the results of this research together with their experiences, in order to improve management decisions as to the most effective way of implementing a QA system, therefore improving the industry, which will ultimately benefit the community as a whole.

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The Role of HDB in Preparing Singapore's Construction Industry for the Challenges of the New Millennium

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INTRODUCTION

The Singapore Government, through the Construction 21 initiative, has adopted a vision for the construction industry to meet the challenges of the new millennium. The vision is set for the construction industry to be a *World Class Builder in the Knowledge Age.*

Currently, the local construction industry is troubled by many concerns which may prove to be the stumbling blocks obstructing the attainment of the vision. The most pressing ones must be its low or even negative productivity growth and its poor safety records. The industry is also highly fragmented with little co-ordination and interaction amongst the various key industry players.

As the public housing authority of Singapore, and arguably the nation's biggest construction client, the Housing and Development Board (HDB), through its various quality and productivity initiatives, plays a significant role in addressing these critical issues. This paper discusses some of the initiatives which the HDB has undertaken which can assist the industry in the critical areas of *productivity, safety and integration of key industry players*.

STRIVING FOR HIGHER PRODUCTIVITY

The productivity of the industry in Singapore lags behind those in countries like Hong Kong, Japan, Australia and the United States. There is an overwhelming myriad of inter-related reasons which have been put forth to explain this situation. These range from inherent industry practices like extensive sub-contracting and labour-intensive work methods to the abundance of cheap unskilled foreign workers. These problems require no less than an industry-wide integrated approach to resolve.

We will focus on what HDB has done and can do, as an organisation, to help raise productivity in the industry. Specifically, we will examine HDB's initiatives in the areas of construction productivity and construction resource management.

CONSTRUCTION PRODUCTIVITY

We firmly believe that the key to higher construction productivity lies in the use of labour-efficient construction methods. As construction methods are, to a large extent, determined by the design, we place great emphasis during the design stage to produce highly **buildable designs** for our public housing construction and upgrading projects. Increasingly, our buildable designs are brought to form through the use of industrialised construction methods which have enabled us to achieve higher productivity levels in recent years. To sustain our high productivity growth, we have cultivated a culture of **innovation** to seek out new breakthroughs in design, material and construction technology through our various quality initiatives.

Buildable Designs

Buildable design is about ease of construction and is characterised by simplicity, standardisation and integrated elements. HDB had been promoting buildable design long before "buildability" became an industry buzzword. HDB's initiatives to promote buildable design began with the use of modular co-ordination and standardisation of elements, and more recently through the greater use of prefabrication.

Since the early seventies, HDB has placed great emphasis on standardisation and modular co-ordination of its public housing designs. Standardisation was prevalent at all levels of planning and design, from building block type and unit layout to architectural and structural components. The main structural systems are also standardised to a large extent to allow repetition of column, beam, slab and wall designs. Architectural components like windows and doors are also modularised and standardised. These design features greatly simplify and facilitate the construction process which resulted in high construction productivity. We note that this is one area of considerable productivity potential which have yet to be fully exploited by the industry, especially the private sector.

A milestone in our effort to promote buildable design was reached in the early eighties when we started our prefabrication programme through the engagement of French, Japanese, Korean and Australian contractors to design and build several of our major public housing projects. The transfer of prefabrication technologies as a result of these collaborations served as a platform for HDB to further develop its prefabrication programme.

Over the last decade, we had developed and implemented our own semi- prefabrication systems which accelerated the use of standardised precast components and industrialised construction methods. The standardised precast components include precast floor planks, facades, parapet walls, staircases, refuse chutes, water tanks and lightweight partitions, etc.

The level of precast content in our public housing construction had increased from 15% in 1988 to 30% this year, which tremendously enhanced the buildability of our public housing designs. The average buildable score of HDB public housing projects was 78 in 1998, which was relatively high compared with the average score of 53 for private sector residential projects. This, to some extent, reflects the low precast content in private sector construction which currently stands at 7%. There is plenty of scope for increased use of prefabrication in the private sector.

With the maturity of HDB's prefabrication programme, our contractors can expect even greater use of industrialised construction. An increasing amount of work will be prefabricated in the factory, leaving the worksite neater and safer. Site installation of the finished products will be highly mechanised. This will motivate our contractors to equip themselves with advanced construction technologies which require multi-skilled workers in considerable smaller numbers. In time, they will become more self-reliant and will be able to reduce their dependency on sub-contractors who are mostly small timers entrenched in traditional work methods.

This vision has already taken form in our projects, especially in the upgrading of existing housing blocks where the Precast Volumetric Concept is adopted to construct additional floor space in existing housing blocks which are occupied by residents. The premise of the Precast Volumetric Concept, which is a core concept of prefabrication technology, is the fusion of precast walls, slab and façade elements into a single box structure. The large precast volumetrics are prefabricated in the factory using stainless steel moulds and installed on site using a combination of mobile or tower cranes. This method is chosen over conventional method because of its fast construction turnaround time and minimal generation of noise and dust, which are important factors for construction in very congested environment with lived-in residents.

With the use of this highly industrialised method, one floor of additional space can be completed by six workers in one day. In contrast, the conventional method would have taken twelve workers five days to complete the same job.

The variety of space adding items which can be constructed using this concept range from the very popular utility room to the balcony, bedroom or kitchen extension. In densely built urban Singapore, we are confident that there will be even wider applications of the precast volumetric concept beyond the upgrading of existing HDB housing blocks. In fact, we have already applied this concept successfully in some parts of our new housing construction such as lift shafts and stairwells, raising the productivity of such construction activities by five to six times.

Our drive towards greater prefabrication and industrialised construction will revolutionise the way contractors work, and hopefully see a corresponding positive impact on productivity in the industry. However, it is noteworthy that certain pre-conditions must be met before buildable designs can become an industry norm. As we have shown, highly buildable designs would, in many instances, require a substantial level of prefabrication of standardised precast components. This means there must first be wide acceptance and innovation in creative precast designs. This will create a sustainable demand for precast components to make them cost competitive.

The current industry demand for precast components is limited due to perceptions prevalent in the private sector that prefabrication methods hamper creativity and are costly. This in turn limits the current number of precasters who tend to only offer a limited range of precast components in response to the poor demand. The limited precast options seriously curtail the scope of design and further dampen the desire to use buildable designs.

HDB has played a significant role to facilitate meeting these pre-conditions. Because of our high construction volume, we can help to stimulate demand for a wide range of standardised precast components mentioned earlier. We have shown that through the repetitive use of precast components on a large scale in our public housing projects, the cost competitiveness of precast construction can be on par with that of cast-in-situ construction. If we consider the cost savings resulting from the huge productivity gains achieved through prefabrication, the actual cost of using this method could be lower than that of conventional methods.

On the supply side, we are also able to assist the precast sector by setting aside land to ensure adequate capacity. In this regard, we have identified 40 hectares of land in Tampines for precasting purposes. HDB is also involved in periodic dialogues with representations from precasters and contractors to ensure that the precast industry can plan and schedule their resources with more certainty.

On the innovation front, through extensive research and collaboration with the private sector, HDB is able to amass expertise in prefabrication technology. We produce results which prove that buildable designs do not constrain creativity. For example, precast concrete can achieve a wide variety of colours, forms and textures making it very versatile and suitable for facades. It gives our architects considerable freedom of architectural expression in the form of aesthetically pleasing precast facades which adorn HDB towns across the island. These facades are highly buildable with a quality of finish far superior to cast-in-situ construction. By taking the lead in this area, HDB hopes that the private sector will take note of the potential and versatility of precast construction and be encouraged to embrace buildability.

Innovations

As the largest developer in Singapore, we are committed to bring about change and progress in the industry through innovations in design, material and construction technology. This is apparent through the various research and development projects and other quality initiatives undertaken by us.

We will give an overview of some of the major innovations which we have developed and introduced in our construction projects.

(a) **Ferrocement cladding systems** - ferrocement, which is made of high grade mortar reinforced with layers of galvanised fine wire meshes, has good thermal and shrinkage cracking resistance and is also extremely impervious to water penetration. This material therefore has great potential as a thinner and lighter building cladding element with greater strength than normal concrete. We started applying this material in the form of thin secondary roof slabs which serve to insulate the main roof from intense heat and to drain away rain water. This new roofing system simplifies the overall roof construction process and reduces maintenance costs by eliminating the need for waterproofing membranes.

We have also pioneered the use of this versatile material as a more durable alternative to conventional lightweight cladding materials. Our architects have made creative use of ferrocement as attractive façade features in many of our upgrading projects. Its use has since been extended to cladding of service ducts.

(b) **Prefabricated bathroom system** - we have worked closely with our suppliers to produce a fully integrated bathroom system which incorporates a built-in vanity top basin and water closet with a full range of bathroom accessories as well as light fitting. It uses a shallow floor trap or P-trap for its waste discharge which saves space and is easy to maintain. Our pilot projects have shown that this integrated system, which is entirely prefabricated in the factory and assembled on site, has doubled the productivity in the construction of bathrooms.

(c) **Precast prestressed composite floor system** - this system was imported from the USA and had been re-engineered in-house for use in all structural floors of our projects, ranging from public housing flats, multi-storey car parks to commercial and industrial buildings. This method of construction has eliminated the use of formwork for floor construction and has achieved a 40% increase in labour productivity.

(d) **Open-space car parking** - our new generation of multi-storey car parks have a simple and efficient design where the columns have been moved to the periphery in order to achieve a more spacious and open feel.

(e) **Information technology** - we have invested heavily in computer systems like the Computer Aided Design and Drafting System which greatly stepped up productivity and improved on drawings. In collaboration with the China Academy of Building Research, we have developed a software which integrates the functions of analysis, design and detailing of structural elements. This software enables the sharing of common input data for the various different functions, hence greatly reduces the chances of error.

(f) **Architectural precast facades** - a fusion of architectural creativity with prefabrication technology. We have proven that precast facades can be creatively designed and take on a sophisticated appearance by designing attractive precast façades which have given many HDB blocks a unique look and identity. Our newest innovation in precast façade design is based on the "patchwork" theme which will see the use of undulating panels for the first time. This new design will feature twin patchwork panels running down prominently the front of the apartment blocks, adding depth and texture to the "face" of flats. It will be piloted in 14 apartment blocks this year.

(g) **Pre-cut and pre-bend reinforcement bars** - we have worked with steel suppliers to provide this service to our contractors. All steel bars required on our sites, except for mild steel bars and links, are cut and bend in the factory and delivered to site just-in-time for use. This arrangement eliminates site manual works associated with reinforcement bars such as bar bending, hence reduces wastes and improves productivity.

Sharing with and transferring to the industry our innovations have always been a part of our R&D philosophy. We do this through regular training, workshops, seminars and exhibitions conducted by our technical professionals. We believe our innovations can be adopted for wider applications by the industry and serve as the impetus for greater use of technology to improve the quality and productivity of construction in Singapore.

We will step up collaborations with key industry players as well as local and overseas research institutions to develop more innovations which are relevant to the local construction industry, especially in the area of construction information technology.

Construction Resource Management

In the early years of the HDB Building Programme, our contractors had to contend with several materials cartels who manipulated the supply and prices of essential building materials. There were frequent price escalations and supply disruptions which resulted in cost overrun and severely affected site productivity. To arrest the problem of price escalation, HDB formulated a price fluctuation protection mechanism in our building contracts to absorb the additional costs of the price hikes from the contractors.

HDB also started managing the procurement and supply of basic building materials to ensure undisrupted supply to our contractors. In 1969 we started our granite quarrying operations at Mandai. We also engaged operators to quarry sand from HDB land and supply it to our projects. In the seventies we started our Mechanised Sand Quarry at Tampines, the first of such type in Asia, called term contracts for cement supply and entered into a long-term supply arrangement with the local steel mill. The selective stockpiling of essential products was also implemented to circumvent any supply disruption.

Our large construction volume enables us to establish new suppliers and open up new supply sources. We are also able to introduce new products at lower costs and implement productivity enhancement measures like the supply of factory based cut and bent steel reinforcement bars and size modularisation of tiles and bricks to reduce cutting and wastage on site.

However, in the intense competition for land use in Singapore, the use of land for materials production has to give way to other higher value-added uses. As such, our Mechanised Sand Quarry in Tampines was phased out in 1992 and production at HDB Brickworks ceased in 1998. To circumvent any supply disruption, we started procuring through long term supply contracts to establish more supply sources and build up contingency stockpiles.

Besides the direct supply of building materials, the HDB also manages the quality of building products used in our projects through a List of Approved Materials and Suppliers. Our technical departments screen products and suppliers to meet stringent technical quality standards before inclusion into this list. Each product or supplier approval is reviewed periodically. With this pre-approval system, contractors and suppliers need not subject listed products through the entire approval process each time the product is used in a new project. This reduces duplication while raising productivity. Currently there are about 270 different product categories covered under this approved system.

We have also established the Certified Workers and Foremen Scheme to upgrade the skills of the construction workforce used in HDB projects. This scheme stipulates the minimum number of workers who must possess the relevant skills or supervisory certificate in each public housing project. This was necessary to arrest the problem of poor workmanship and low productivity, which had resulted from the use of cheap unskilled workers.

Due to the sheer volume of our construction, our initiatives in construction resources management have helped to maintain stability in material prices and supply not just in our public housing projects, but in the industry as a whole. Through our initiatives, we have also upgraded the skills of construction workers and built up the pool of local skilled workers.

TOWARDS A SAFER CONSTRUCTION INDUSTRY

Safety performance in the industry has been poor. There has also been an increase in the frequency and severity of accidents. This trend is both alarming and unacceptable. The high accident rates could be attributed to the general lack of safety provisions, inadequate safety supervision and precautions at worksites, inadequate safety education for workers, poor construction techniques and that most foreign workers are inexperienced and unskilled.

We have constantly strived to make our worksites safer. Consistent with our productivity initiatives, we adopt a total approach in ensuring as high as possible a safety level at our worksites. This approach addresses all the reasons of high accident rates in the industry.

We begin by ensuring that our worksites employ good construction techniques with a high level of mechanisation. This simplifies the work processes which reduces our workers' exposure to dangerous situations. Through industrialisation of construction, we have shifted substantial amount of work to the factory, leaving our worksites tidy and dry which contribute to a safe working environment. We have done our part by providing a safe physical environment and we expect our contractors to play their part through effective site safety management which emphasises ***supervision, precautionary measures and training***.

Safety Precaution and Supervision

Our contractors' involvement begins with the mandatory submission of a Safety Management System to ensure that there are adequate safety provisions. The contractors are also required to implement a host of site safety measures such as the use of metal scaffolding, safety (anti-fall) net, working platforms and overhead shelters and to issue suitable personal protective equipment to workers. Our contractors are also required to employ full time qualified site safety supervisors, whose duties include promoting safety conduct, inspecting and rectifying unsafe place of work and correcting unsafe practices.

Safety Training

Many of the workers at our worksites are foreigners who come from cultural backgrounds as diverse as the languages they speak. Most of them have differing perceptions and regard for safety. Furthermore, due to the high turnover of our foreign workers, many of them are relatively new and inexperienced and may not be aware of the hazards lurking at the worksites.

Bearing these factors in mind, we require our contractors to employ only workers who possess valid Safety Orientation Course Certificates and we insist on such workers attending a prescribed safety refresher course at appropriate intervals.

We also require our contractors to send employees who perform supervisory roles such as Safety Supervisors and Foremen and skilled workers such as crane operators to attend a wide variety of safety training courses conducted by the Ministry of Manpower and the Construction Industry Training Institute.

Through these comprehensive safety measures, the frequency of accidents which may lead to costly unproductive work stoppages at our worksites have been reduced tremendously. In 1998, the accident frequency rate at HDB worksites averaged 0.72 accidents per million man-hours worked, which is much lower than the national average of 2.7.

In recognition of our relentless pursuit of site safety excellence, we were conferred in 93 with the prestigious Royal Society for the Prevention of Accidents (RoSPA) International Sector Award. This year, we were once again recognised for our achievement in site safety excellence when we won the RoSPA Occupational Health and Safety Award (Merit).

We impart to our contractors and workers a greater awareness of effective safety practices. Such practices will hopefully permeate the industry through these contractors and workers as they also work on non-HDB sites. This vision is attainable because the safety management system implemented at our worksites can be easily adopted for use by the industry.

TOWARDS AN INTEGRATED CONSTRUCTION INDUSTRY

The construction industry is highly **fragmented** due to the **sequential** nature of the development process prevalent under the conventional design-bid-build system commonly practised in Singapore. The designers develop and complete the design independently without the input from the contractor and the various specialist subcontractors or suppliers who have the expertise to otherwise incorporate buildability into the design. Under this conventional method, there is lack of co-ordination and interaction amongst the various key players who are often placed in adversarial positions.

As construction projects become increasingly complex, the inadequacy of the conventional approach becomes more apparent, which often manifests in costly disruptions such as late design changes in layout configuration due to incompatibility between original plan and actual requirements of the specialist contractors (eg. M&E services, etc). As such, it is clear that the poor integration of roles amongst the various industry players is one major cause of low productivity.

We think that one of the first positive steps towards greater productivity in the industry is to integrate the roles played by the key players. This can be achieved through alternative procurement methods such as Design and Build (D&B) whereby the roles of various players are integrated up-front.

Design and Build

Conceptually, D&B may result in increased buildability and hence, higher productivity because right from the start, the designers and the construction experts (comprising main contractor and specialist contractors) work and communicate as a team and constantly evaluate alternatives to come up with a balanced and buildable design.

While D&B, as one of the procurement methods could help to forge integration amongst the players, its use in Singapore is still at the infancy stage as compared to other countries with highly productive construction industries such as Australia and Japan (see chart). Looking at the high percentages of D&B projects achieved by these countries, there is a clear scope for considerably wider use of D&B in Singapore.

However, there are some concerns associated with D&B which have to be addressed before D&B can gain wide acceptance in the industry. Most notably are the ***high tendering costs, lack of clear design brief and standard documentation*** **and the need for** ***a transparent procurement practice and evaluation criteria***.

HDB has substantial experience with D&B to address these concerns. We are the first public sector organisation in Singapore to venture into a D&B building programme when we awarded our first D&B contract worth $73 million in 1992. To date, the total value of D&B contracts awarded by HDB has exceeded $3.6 billion with 18,167 residential units completed. We believe that we are able to assist in promoting D&B by sharing with others in the industry our substantial experience in overcoming the concerns associated with D&B.

HDB Design & Build Scheme

We adopt a transparent **two-stage open tender** system to procure our D&B projects. In the first stage, we pre-qualify the contractors and consultants based on pre-qualification criteria which are clearly laid down in the tender documents. The pre-qualified contractors and consultants will then form their own D&B teams.

For each D&B project, we would only invite 5 to 6 pre-qualified D&B teams to participate in the second stage. This has the effect of reducing the wastage of resources and at the same time maintaining the competitiveness. In the second stage, these pre-qualified D&B teams will submit their firm design proposals and tender bids based on **clear design requirements and standards** stipulated in the tender documents.

The design proposals are then evaluated rigorously against a set of criteria covering site layout, block design, dwelling unit design, external and landscaping design, carpark design and maintenance consideration. For transparency, these criteria are also clearly stated in the tender documents.

The design proposals that satisfy the stated criteria will be shortlisted for financial evaluation and awarded design premiums corresponding to their level of compliance with the criteria. The financial evaluation takes into account the total sale proceeds of each shortlisted design proposal and his development cost to determine the most cost-effective tender.

The sale proceeds include the selling price of each dwelling unit type plus the design premium whilst the development cost includes the construction cost, the consultant's supervision fees, in-house professional fees, land cost and financing cost. The design proposal which gives the best financial return will be recommended for award of the contract. Our D&B scheme can serve as a platform for the industry to adapt and build on. We hope that through our D&B scheme which entails close partnership with the private sector, we can do our part in promoting the wider use of D&B in the industry.

CONCLUSIONS

The current state of the construction industry, with its very low levels of productivity and excessive reliance on unskilled foreign workers is unsustainable and incompatible with the future development of Singapore's economy. This state of affairs is caused by an array of deep-seated inter-related reasons which no single party can resolve on its own.

There is a pressing need for a fundamental review to re-invent the construction industry so as to remove inefficiencies at all levels and stages of the development process. Currently, this task is being undertaken by Construction 21committee, which is a Singapore Government effort to reform and prepare the construction industry for the challenges of the new millennium.

As a major client in the industry, we can play a role in helping to achieve the goals of Construction 21. Through our quality and productivity initiatives, we have demonstrated that we can contribute in the areas of ***productivity, safety and integration of the roles of key industry players***. We have consistently shown that high levels of productivity are attainable through the use of highly buildable designs which are integrated with industrialisation of construction systems. Our public housing designs have achieved the highest buildability scores due to our emphasis on standardisation and modular co-ordination as well as our innovation in and increasing use of prefabrication technology.

Through the high volume of prefabrication in public housing projects, we have helped to stimulate its demand and promote its acceptance. We have further facilitated the growth of the precast industry by setting aside sufficient land for precasters and related activities.

As the use of technology has begun to receive wider acceptance in the industry, new and wider applications of design, material and construction technology which suit local conditions must be found to satisfy the demand and sustain the enthusiasm. In this regard, we are steadfastly committed to R&D and other quality initiatives to develop innovative applications.

We have shown the industry that the construction worksite does not have to be dangerous. The first step towards achieving this is simplification of work processes and industrialisation of construction which remove hazards and keep the worksite clean, neat and efficient. We also ensure that our contractors take site safety seriously by requiring them to implement an effective safety management system which places emphasis on supervision, precautionary measures and training.

Last but not least, we take pride in contributing towards integrating the roles of key industry players by promoting the use of Design & Build. HDB has established that Design & Build is a viable alternative to the conventional procurement method which breeds divisiveness amongst the key industry players.

Sweeping changes are expected to be unleashed across the industry as the recommendations of Construction 21 are implemented in the near future. We are proud to have already surpassed some of the industry targets, such as those in the areas of buildability and safety, which have been recommended by Construction 21. We will be happy to share our experiences with the industry to meet whatever challenges the new millennium may have in store. We are confident that all key industry players will seize the opportunity and move in tandem with the changes to transform the Singapore construction industry from being Dirty, Dangerous and Demanding to ***Professional, Productive and Progressive***.

Cost Comparison of Materials Handling Systems for High-Rise Construction

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Abstract

Cost overruns in materials handling systems in high-rise construction sometimes due to the mindset of construction companies to use traditional materials handling systems and lack of construction planning are not uncommon in the construction industry. This paper describes various options for materials handling systems in high-rise buildings with a case study done on a twenty-storey retail cum residential project built in Sydney during 1997-98. The paper briefly describes the possible options for materials handling systems in their totality and looks at non-traditional cost saving combinations for these systems. An objective cost comparison of various options is also done to clearly illustrate the cost savings of upto 60% on costs of materials handling systems based on empirical results. Whereas the paper concludes that there is no generalisation possible, it emphasises the need and time for pre construction planning during which all possible cost-effective combinations of materials handling systems should be explored to ensure the optimum and most effective method possible for a specific project.

Keywords: *Material Handling Systems, Cranage, Case Study, Construction Management, Cost Comparison.*

INTRODUCTION

The selection of effective materials handling systems is the lifeline of any fast-track construction project. The larger and higher the project the importance of the material handling systems increases dramatically. The prompt movement of materials, labour and equipment across the construction site is essential to the success of a project and hence care must be taken in planning the combination, location and capacity of the various materials handling systems.

The various plant and equipment required on construction sites are classified into minor plant, major plant and specialised plant. A study of alternative types and use of plant should be carried out to obtain the most efficient and cost effective plant to be used. The main difficulty the estimators encounter is how long the plant will be required on the job. This is because they come across such variables as productivity of combination of plant and labour, site delays, strikes, plant breakdowns, size of gang, weather, site difficulties, idle time, and so on.

Although combination of the above variables makes estimation of these costs a challenge, it is imperative to be done by contractors meticulously to bid for projects. This paper critically analyses the approach taken on a case study project in Sydney.

DEVELOPMENT OF MATERIAL HANDLING SYSTEMS: GLOBAL PERSPECTIVE

Materials handling systems have evolved from the very basic to sophisticated equipment designs. At the very basic end human labour was, and is still used in certain parts of the world for virtually all the movement of materials on site. The natural progression is the movement away from high usage of human labour to mechanised materials handling systems. The movement away from labour intensive to mechanised systems is dependent on the cost of labour, training, productivity needs, construction materials used, construction techniques used and proportion of off site tasks used for construction projects (such as concrete and precasting).

The choice and use of various materials in the construction process are also dependent on specification, availability, suitability and construction processes prevalent in that country. The obvious solution should match all the above considerations. As the construction project participants are going global with the marketing of services and materials, there is a need for these companies to consider the use of local contractors due to the above reasons. There are some areas where uniformity of use of equipment around the world will make a lot of sense due to the health, safety and environmental concerns, but from an economic point of view this may not be feasible. Sophisticated materials handling systems are making inroads into developing countries due to the time and cost savings they can offer. The construction industry's approach to materials handling has proceeded in quantum leaps during the past decade (ABCH, 1997).

Equipment such as telescopic masts, fork lifts, and man and materials hoist, are now an everyday tool for the construction worker. These equipment on site are not considered luxuries, but an essential cost effective strategy in the construction industry although they could still be luxury in some developing countries. However, in most countries, it can be said that the construction industry's approach to materials handling has gone ahead in quantum leaps in relative terms during the past decade.

CASE STUDY PROJECT DESCRIPTION

Project Name: Empress Gardens
Project Address: 600 Railway Parade Hurstville NSW 2220 Australia

The drawings are attached in the appendix. They include the project site plan and elevation with marked up materials handling systems.

"Empress Gardens" is a 20-storeyed development located at Hurstville, a regional commercial and residential suburb south of Sydney, with streets on three sides of the site: Railway Parade (front), Woniora Road (side), and Empress Lane (rear). The site area is approximately 3270m².

The project comprises, besides others, 165 apartments and three levels of underground carpark (levels 1, 2 and 3) with a capacity to accommodate 314 cars. Level 4 houses the main reception lobby, heated swimming pool, spa, gymnasium, indoor golf practice area, sauna, 9 Shops and Woniora Gardens which is a public park built on a suspended slab. Levels 5 to 18 comprise units in two separate towers with each tower per floor on the typical floors having 2 three-bedroom units, 2 two-bedroom units and 2 one-bedroom units. Level 19 comprises the mechanical plant room. Part of the floor below level 1 comprises the underground water tank, fire pump room and cold-water pump room.

MATERIAL HANDLING REQUIREMENTS FOR CASE STUDY PROJECT

The material handling requirements for the project is discussed in this section with reference to the major trades and items to focus on the critical requirements. This section focuses on the requirements for cranage, loading platforms, rubbish removal and concrete pumping. The section also lists the requirements of the major trades and materials to be handled and placed on various floors of the project to give the readers an idea of the scale of materials handling requirements of this project.

Quantities of Materials Requiring Handling

The following were the approximate material handling requirements for some of the major trades in the project.

Formwork	30,100 m^2
Gyprock	13,700 m^2 (internal ceilings: balcony areas excluded)
Render	16,200 m^2 (for both towers)
	1,008 m^2 (for podium)
Brickwork/ Blockwork	21,400 m^2
Concrete supply and pump	9,300 m^3
Kitchens	165 no
Granite	967 m^2
Sprinkle and hydrant pipes	11,150 m
Carpet	10,220 m^2
Tiles	12,300 m^2
Paving	420 m^2
Electrical wiring	102,000 m
Glazed Balustrade handrails	1,925 m
Soil	610 m^3 (garden and planters)
	14,224 m^3 (excavated)
Roof area	950 m^2

Prime Cost Items:

Ovens, Cooktops, Dryers, and Wardrobes 165 off each
Shower screens, Vanities, Mirrors and WC and cisterns 280 off each
Bathtub 112 off
Kitchen sink, Laundry tubs 165 off each
Tapware 898 sets.

Materials Handling Strategies for Major Trades

Material handling strategies for all the major trades on the project are discussed in this section.

Formwork

The external profile of the building from Levels 5 to 18 was almost identical. The formwork system used was that of collapsible steel frames, timber beams and ply with preformed steel curved edged hobs for balconies. The lift shaft was formed using a jumpform system with a trailing platform made out of steel, aluminium and ply weighing 2 tonnes. Landing platforms being used to unload formwork from stripped floor and moved up three floors. All formwork was either on pallets or strapped prior to cranage to and from the site and within the site.

Plasterboard

The plasterboard sheets came to site in large pallets and unloaded in the basement using a forklift. The steel studs were delivered packed in bundles and the other suspension rods etc. came packed in cardboard boxes. From the basement to the required floors they were transported by hoist.

Brickwork

The bricks, cement and sand came to site on pallets and were unloaded in the basement using a forklift. From the basement to the required levels they were transported by hoist.

Concrete

Concrete batching was done in concrete plants away from the site and was transported to site on concrete trucks. Details of concrete pumping are mentioned separately in this paper.

Cement Rendering (Plastering)

The building was cement rendered internally and externally. The sand for the cement render came in 1 tonne pallet bags and the cement came in pallets. The sand, cement and mixer were transported to the required floors by the hoist. The cement render was mixed on the required floors.

MATERIAL HANDLING SYSTEMS: OPTIONS AVAILABLE AND USED ON CASE STUDY PROJECT

Based on the previous section, the options available for the case study project for the various tasks is discussed in this section. The integrated material-handling model used on the case study project is developed using these components.

Cranage

Tower Crane

A tower crane would be most commonly used in a project of this size and type, as the building was 20 storey high. However, due to cost saving possibility, an alternative that is a non-traditional option was considered and used on the project. The tower crane option was not used.

Mobile Crane

A combination of 25 tonne and 50 tonne mobile crane was used around the site and at the centre of the podium level (level 4) between the two towers. A newly introduced crane in Australia which was a track mounted 50 tonne mobile crane with retractable tracks, vertical mast reaching 40 metres high and jib with a reach of 28 metres was used for the towers. The crane was located between the towers at the podium level (level 4). Backpropping of the slab where the crane was located had to be done. The most critical load for the crane was the lift shaft formwork that weighed 2 tonnes and the topmost level were 44 metres high and 17 metres from the centre of the crane. This crane, although mobile, had to have its mast and jib assembled on site using two 25 tonne mobile cranes. For the formwork in the basements, a combination of truck with hiabs and mechanically operated pallet trolleys and in certain areas 25 tonne mobile crane was used. The crane was primarily used for movement of formwork on towers, reinforcement, post tensioning material and equipment, structural steel and timber for roof and roof sheeting. The use of this crane over the tower crane option resulted in a cost saving of approximately $89,000 as per details enclosed.

Cost Comparison of the Cranage

There were 2 options considered at the time of deciding cranage. Following is the summary of the comparison.

(a) Option 1- Tower Crane from basement to level 19

Basement	8 weeks duration on site
Towers	21 weeks duration on site (see appendix on material handling programme)

LOCATION	DESCRIPTION	FLOAT	HIRE	TOTAL
Basement + Towers	29 weeks on site	$50 000	$174 000	$224 000
				S224 000

Total cost of Option 1 comes to $224,000

(b) Option 2 – 25T and 50T Mobile crane from basement to level 4 and Chosen Crane from level 4 to level 19

<u>Mobile Crane</u> – combination of 25T and 50T

LOCATION	DESCRIPTION	FLOAT	HIRE	TOTAL
Basement	4 visits x 8 hours x 25 T	$780	$4 160	S4 940
	2 visits x 8 hours x 50 T	$465	S2 480	$2 945
	2 visits x 24 hours x 50 T	$465	$7 440	$7 905
				$15 790
Towers	0 visits (chosen crane used)			

<u>Chosen Crane</u>

LOCATION	DESCRIPTION	FLOAT	HIRE	TOTAL
Basement	0 visits (chosen crane used)			
Towers	21 weeks on site	$10 000	$109 200	$119 200
				$119 200

Total cost of Option 2 comes to $15,790 + $119,200 = $134,990

Comparing the 2 options, there was a cost saving of $89,010 or approximately 40% by using the mobile crane option as against the tower crane option in this case study. The other advantages were that the builders had the option of replacing the chosen crane if there was an industrial or other commercial problem.

Man and Materials hoist

A man and materials hoist is indispensable for a high rise building specially in Australia, because of the statutory government regulations for the movement of construction workers on a project like this. In this project, the hoist was used more than usually done in a project of this size. Besides construction workers, it was used to transport bricks, blocks, plasterboard, tiles, balustrades, sand for render in 1 tonne bags placed on pallets, PC items, sprinkler and plumbing pipes and other materials. However since only one hoist was used per tower, breakdown of the hoist would lead to delays as the running of the hoist was critical to the movement of men and materials. Prior to the stripping of the hoist, which happened prior to the internal render, tiling and plasterboard and the subsequent trades to the top two levels, the materials had to be pre-loaded on these two levels.

LOADING PLATFORMS

Loading Platform for Each Level Each Tower (retractable)

A retractable loading platform is the most commonly used option for a project of this size where there were 14 typical levels above the podium level in the towers. The advantage of using retractable loading platforms is that they can be stacked vertically above each other and do not have to be staggered in elevation (something that may not have been possible in this project without the use of a very large tower crane). If this type of loading platform were used, it would have been used for plasterboard, sand, cement, bricks, tiles, kitchens PC's etc.

Loading Platforms for 2 Towers (non-retractable)

A non-retractable loading platform was the system that was used on the site where each tower had a loading platform that was moved up with the building of the structure. The loading platform was only used on the level where the formwork was being stripped for moving to the higher level where the slab was being formed. The platform was used in conjunction with the crane for formwork movement. The loading platform was moved up one level at a time and was generally 3 levels below the level where slab was being formed.

Cost Comparison of Loading Platform Options

Unlike other projects of similar size, the combination of materials handling systems required the loading platform to be used only for the movement of formwork from the stripped floor to the upper floor. While considering loading platforms for material handling, and more particularly for the use of formwork, the options were either to go for a retractable system discussed earlier in the paper or to go for one loading platform per tower which would move up with the structure. The cost comparison table in the appendix shows the total costs involved. The option of using retractable loading platform would cost $75,260 over the duration of the project whereas the option of using one non-retractable loading platform per tower and moving up with the structure cost $10,660. There was a saving of 86% by using the non-retractable loading platform option.

The other significant cost that must be accounted for is that by using the retractable loading platform, the cranage time would have increased substantially and it would not have been possible to use the wheelie bin option for rubbish removal. This option cost $21,194. This still leaves a substantial saving overall.

Rubbish Removal

Rubbish removal is an important material handling activity with major implications for the creation of a safer work place for all trades, project costing and creating clean space for all the trades working along side to achieve the progress on the project. Design and implementation of rubbish removal strategy should encourage prudent waste management and speedy removal from the site. A few different methods were considered before deciding on the one best for the site in terms of the simplicity, flexibility and costs associated.

Chute

The rubbish chute is a vertical stack of chutes that are added as the levels of the building rise and the material is thrown into the chutes at each level. The lowest opening of the chute opens into a rubbish bin. The size of the chute (ie. the size of the hole) depends on the requirements and the height of the building and also on the type of material intended to be thrown down. The chute could be through the inside of the building through an opening or it could be fixed on the outside. This system had limitations in size in terms of what one can dispose down the chute (eg. large pieces of plasterboard cannot be disposed down the chute) so it is not a complete rubbish removal system in itself.

Loading Platform for Every Floor

The method of single retractable platforms discussed in the above section was discarded for cost and space restrictions with staggering of the platforms across the perimeter of the building not being a viable option. The one loading platform that was installed and moved on each tower was used for rubbish removal occasionally pertaining to the structural trades only.

Use Hoist with Wheelie Bins and 2 m^3 Bins

A system of hoist with wheelie bins was the one used in the case study because of its simplicity and cost effectiveness. The system was flexible with a mobile bin on each level. The wheelie bins were carted using the man and material hoist down to the ground level where it was emptied into 2 m3 bins and brought back to the level. The programming of this task was undertaken to avoid usage of the hoist during the peak times.

Cost Comparison of Rubbish Removal Options

There were 2 options that were considered. Following is the cost comparison of the options.

(a) Option 1

Consists of rubbish chute and a 2 m3 bin on each level. This option works in conjunction with retractable loading platforms per level per tower.

Hire rubbish chute (from appendix cost comparison spreadsheet)		$8,500
Hire of 2 m3 bins 28 levels x 8 weeks x $100/bin/week		$22,400
	Total cost	$30,900

(b) Option 2

Consists of wheelie bins and 4 x 2 m3 bins in the basement.

Purchase of Wheelie bins	28 no x $75/ each	$3,000
Purchase 2m3 bins in basement	4 no x $500	$2,000
	Total cost	$5,000

Note: In both the above options the labour costs and cranage or hoist time have been ignored, since they would be balanced out in both cases. Also, in both options, the overall quantum of rubbish removed from the site finally through 15 m3 bins treated in the streets remains the same.

Comparing the 2 options, there is a cost saving of $25,900 or 83.8% by using the wheelie bin option as against the rubbish chute option on this case study.

Concrete Pumping

On reinforced concrete buildings, concreting is the major construction activity on the site and movement of concrete is a major material-handling requirement. Depending on the site constraints, consideration was given to 3 methods. This task is normally the responsibility of the concreting sub-contractor on the project. On considering the costs alone the line pumping option proved to be the most cost-effective. However this option was not used due to the commercial realities of the construction industry. The sub-contractor is this instance owned the boom pump and hence used it on the project. The boom pump could reach only up to Level 12. For concreting beyond level 12 the boom pump was used upto Level 12, where the connection was made to a line pump that went through the slab right up to the top level. Location of the penetration for the line pipe had to be such that it was not located in a wet area of the building. In this instance, it was through a bedroom of a unit.

A combination of line and boom pumping was used on this project not purely due to cost considerations, but due to the ownership of the equipment by the subcontractor, hence subsidising the true cost on the project. In this instance subsidising was on the part of the sub-contractor.

CONCLUSION

The materials handling systems for a project should be understood as an integrated system comprising various issues or in other words to be compared in totality. This paper refers to five issues: cranage, loading platforms, rubbish removal, concrete pumping and hoist. Whereas this is by no means an exhaustive list pertaining to materials handling systems, it includes some of the most important issues deserving deliberation in a paper such as this. Empirical comparisons and results are demonstrated to arrive at logical conclusions for the cranage, loading platforms and rubbish removal only.

The man and materials hoist is common for both the options and hence it is not priced in the comparison. In option 2 it would be used more than in option 1 but would not make any difference to the cost which is time related and not use related. The concrete pumping options are mentioned for subjective comparison but not for monetary comparison due to reasons explained earlier. Table 1 shows the comparison between traditional and non-traditional options.

Table 1: Comparison between traditional and non-traditional materials-handling options

OPTIONS	1. CRANAGE	2. LOADING PLATFORM	3. RUBBISH REMOVAL	4. CONCRETE PUMPING	5. HOIST	TOTAL COST COMPARION OF CRANAGE, LOADING PLATFORM AND RUBBISH REMOVAL
1. Traditional integrated M.H. System used in project of this size and type	Tower crane $224,000	Retractable platform 1/tower/ level $75,260	Chute and 2m3 bins on each level $30,900	Line pump	Man and materials hoist	$330,160
2. Non-traditional and actually used integrated M.H. System with case study project	Mobile and Chosen crane $119,200	Non-retractable platform 1/tower $10,660	Wheelie bins with 2m3 bins in basement $5,000	Boom pump to level 12 and line pump above.	Man and materials hoist	$134,860

Option 1: Total cost of the traditional integrated M.H system for cranage, loading platform and rubbish removal is $330,160.

Option 2: Total cost of the non-traditional and actually used M.H system in case study project for cranage, loading platform and rubbish removal is $134,860.

Overall, by using option 2 which is a combination of non-traditional options for materials handling systems a saving of $195,300 or 60% of the materials handling costs over the traditional options was achieved.

Compared with the overall costs of the project which was approximately Australian $26 million, a saving of 0.75% over the total project cost was achieved by using the chosen materials handling systems. In an industry that is normally known for blowing out costs of preliminaries including costs of materials handling, this provides an incentive for efforts to be channelled in meticulously assessing materials handling systems and not discounting the possible advantage of using non-traditional options for materials handling. This is possible only if time and resources are made available for pre-construction planning which may result in substantial cost savings.

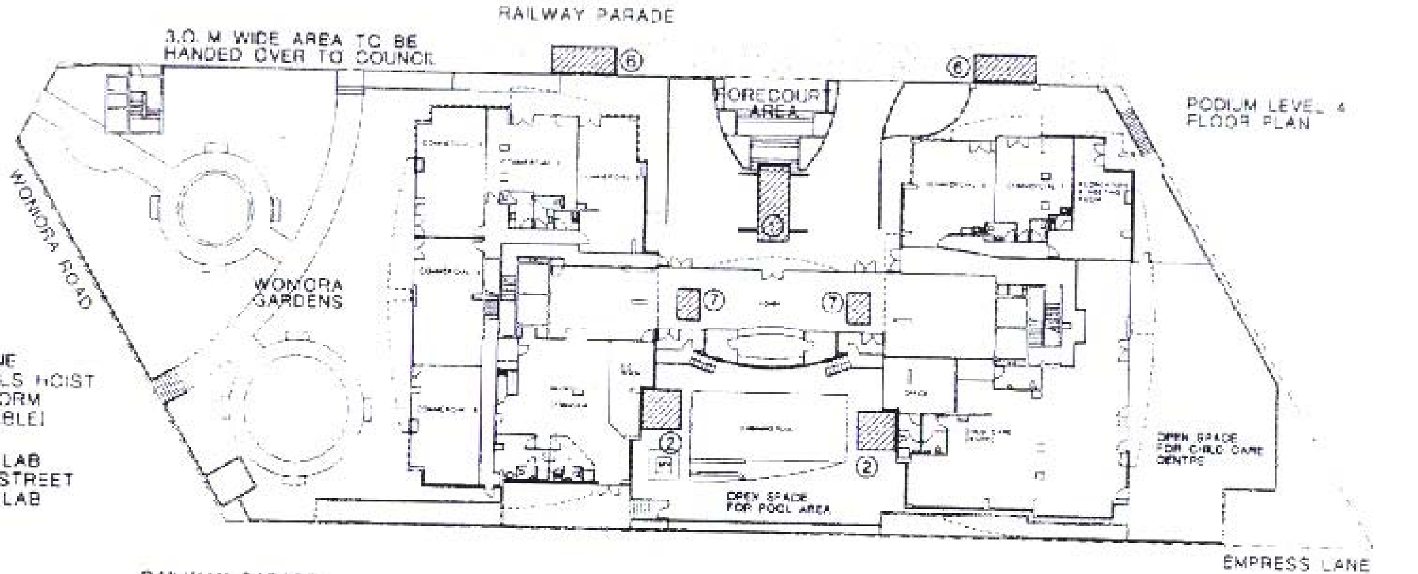
REFERENCES

1. Australian Building Construction and Housing (1997) Former luxuries now everyday tools. September, p. 31.

APPENDIX

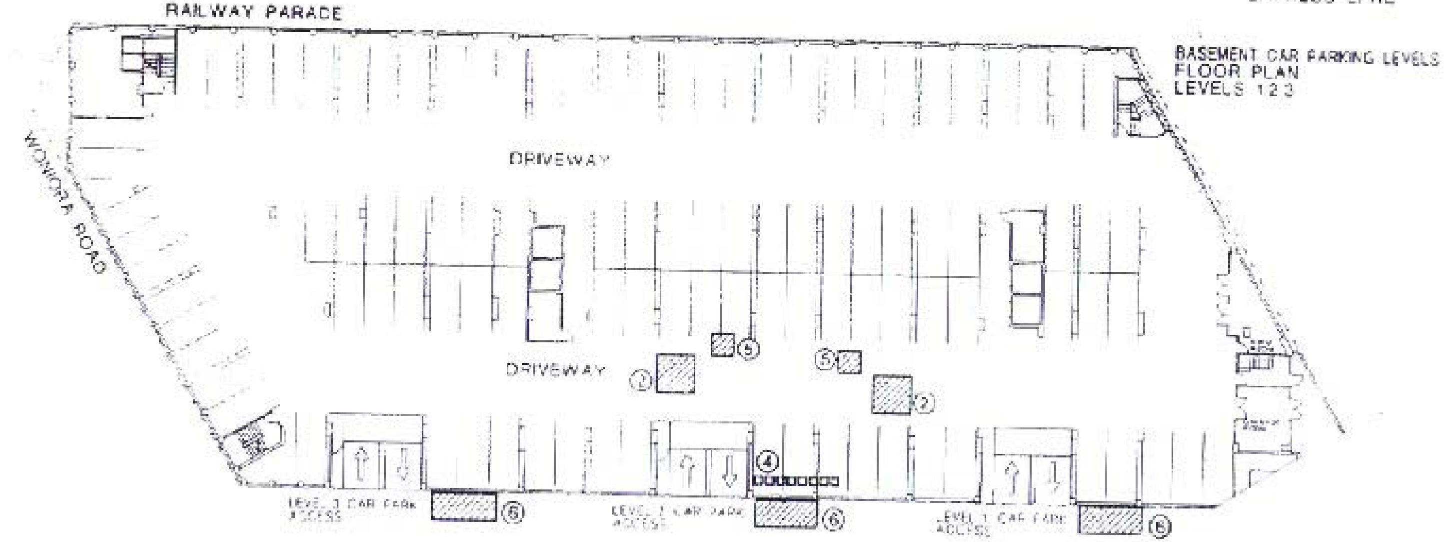
List of appendices

1. Project site plan with marked locations of material handling systems
2. Project site elevation with marked locations of material handling systems
3. Table of cost comparisons of materials handling systems
4. Table of construction program of major activities on the two towers



LEGEND

1 50 TONNE CRANE
2 MAN & MATERIALS HOIST
3 LOADING PLATFORM
(NON RETRACTABLE)
4 WHEELIE BINS
5 2 M³ BINS ON SLAB
6 15 M³ BINS ON STREET
7 6 M³ BINS ON SLAB



LEGEND

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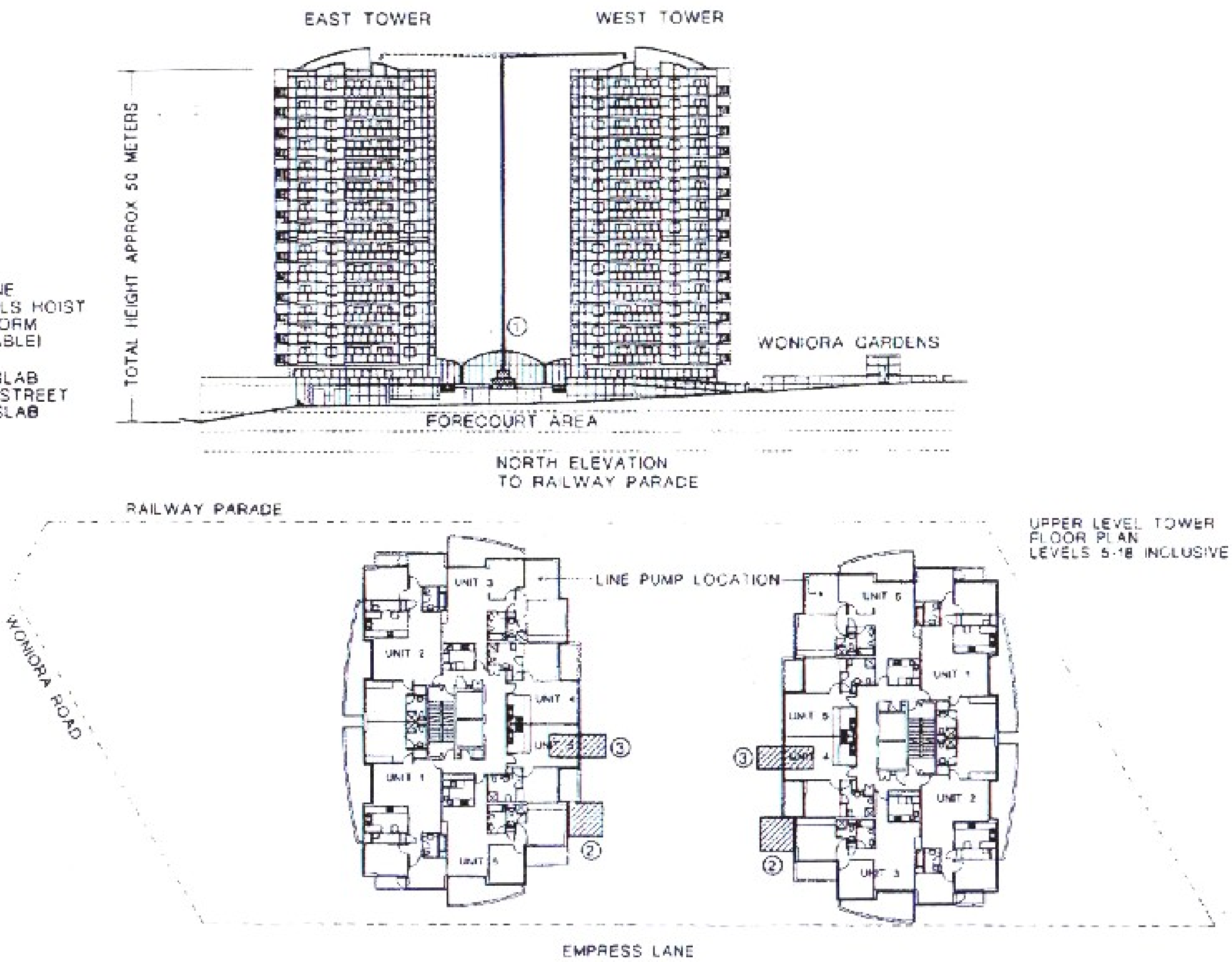

COST COMPARISONS OF MATERIALS HANDLING SYSTEMS

Schedule of Rates

NO	MATERIALS HANDLING SYSTEMS	OPTIONS		COST				
				UNIT	RATE	QUANTITY	AMOUNT	SUB-TOTAL
1	CRANAGE	1	TOWER CRANE					
		(a)	establishment, erection, dismantling & transport	LS	$50,000	1	$ 50,000	
		(b)	hire	weeks	$6,000	29	$ 174,000	$ 224,000
		2	MOBILE CRANE					
		(a)	float or transportation costs - 1.5 hours time each trip	no of			depends on size of crane	
		(b)	hire 25 T mobile	hours	$130		quantified in the main paper	
		(c)	hire 50 T mobile	hours	$195		as above	
		3	CRANE USED ON SITE					
		(a)	establishment, erection, dismantling & transport	LS	$10,000	1	$ 10,000	
		(b)	hire	weeks	$5,200	21	$ 109,200	
2	LOADING PLATFORM	1	1 LOADING PLATFORM PER TOWER (non-retractable)					
		(a)	transport	LS	nil	nil	nil	
		(b)	cranage (50T crane - 2 hours time)	per lift	$310	26	$ 8,060	
		(c)	hire	weeks	$100	25	$ 2,600	$ 10,660
		2	1 LOADING PLATFORM PER LEVEL PER TOWER (retractable)					
		(a)	transport	LS	nil	nil	nil	
		(b)	cranage (50T crane - 2 hours time) per loading platform	per lift	$310	26	$ 8,060	
		(c)	hire	weeks	$200	336	$ 67,200	$ 75,260
3	RUBBISH REMOVAL	1	RUBBISH CHUTE					
		(a)	establishment, erection, dismantling & transport	LS	$3,500	1	$ 3,500	
		(b)	hire of 2 chutes - 1 for each tower	weeks	$100	50	$ 5,000	
		(c)	2 m3 Bins - 1 per level	weeks	$100	224	$ 22,400	$ 30,900
		2	USE MAN & MATERIALS HOIST WITH WHEELIE BINS & 2M3 BINS					
		(a)	purchase of wheelie bins	no of	$75	40	$ 3,000	
		(c)	Purchase of 2 m3 Bin	no of	$500	4	$ 2,000	$ 5,000

CONSTRUCTION PROGRAM FOR TOWERS ONLY
- PODIUM LEVEL (LEVEL 4) TO ROOF LEVEL (LEVEL 19)

ID	TASK NAME	DURATION (working days)	DURATION (calendar weeks)	START	FINISH	PREDECESSOR
1	**WEST TOWER**	112 days		08-May-99	15-Sep-99	
2	Podium level L4 slab poured	1 day		08-May-99	08-May-99	
3	Form Reo Pour Level 5 West Tower	6 days		10-May-99	15-May-99	2
4	Form Reo Pour Level 6 West Tower	6 days		17-May-99	22-May-99	3
5	Form Reo Pour Level 7 West Tower	6 days		24-May-99	29-May-99	4
6	Form Reo Pour Level 8 West Tower	6 days		31-May-99	05-Jun-99	5
7	Form Reo Pour Level 9 West Tower	6 days		07-Jun-99	12-Jun-99	6
8	Form Reo Pour Level 10 West Tower	6 days		14-Jun-99	19-Jun-99	7
9	Form Reo Pour Level 11 West Tower	6 days		21-Jun-99	26-Jun-99	8
10	Form Reo Pour Level 12 West Tower	6 days		28-Jun-99	03-Jul-99	9
11	Form Reo Pour Level 13 West Tower	6 days		05-Jul-99	10-Jul-99	10
12	Form Reo Pour Level 14 West Tower	6 days		12-Jul-99	17-Jul-99	11
13	Form Reo Pour Level 15 West Tower	6 days		19-Jul-99	24-Jul-99	12
14	Form Reo Pour Level 16 West Tower	6 days		26-Jul-99	31-Jul-99	13
15	Form Reo Pour Level 17 West Tower	6 days		02-Aug-99	07-Aug-99	14
16	Form Reo Pour Level 18 West Tower	6 days		09-Aug-99	14-Aug-99	15
17	Form Reo Pour Columns & parapet to roof West Tower	18 days		16-Aug-99	04-Sep-99	16
18	Strip formwork to parapet West Roof	2 days		06-Sep-99	07-Sep-99	17
19	Structural Steel to Roof West Tower	2 days		08-Sep-99	09-Sep-99	18
20	Timber to roof West Tower	4 days		10-Sep-99	14-Sep-99	19
21	Metalroof material to roof West Tower	1 day		15-Sep-99	15-Sep-99	20
22	**EAST TOWER**	112 days		28-May-99	06-Oct-99	
23	Podium level L4 slab poured	1 day		29-May-99	29-May-99	2SS+18 days
24	Form Reo Pour Level 5 East Tower	6 days		31-May-99	05-Jun-99	23
25	Form Reo Pour Level 6 East Tower	6 days		07-Jun-99	12-Jun-99	24
26	Form Reo Pour Level 7 East Tower	6 days		14-Jun-99	19-Jun-99	25
27	Form Reo Pour Level 8 East Tower	6 days		21-Jun-99	26-Jun-99	26
28	Form Reo Pour Level 9 East Tower	6 days		28-Jun-99	03-Jul-99	27
29	Form Reo Pour Level 10 East Tower	6 days		05-Jul-99	10-Jul-99	28
30	Form Reo Pour Level 11 East Tower	6 days		12-Jul-99	17-Jul-99	29
31	Form Reo Pour Level 12 East Tower	6 days		19-Jul-99	24-Jul-99	30
32	Form Reo Pour Level 13 East Tower	6 days		26-Jul-99	31-Jul-99	31
33	Form Reo Pour Level 14 East Tower	6 days		02-Aug-99	07-Aug-99	32
34	Form Reo Pour Level 15 East Tower	6 days		09-Aug-99	14-Aug-99	33
35	Form Reo Pour Level 16 East Tower	6 days		16-Aug-99	21-Aug-99	34
36	Form Reo Pour Level 17 East Tower	6 days		23-Aug-99	28-Aug-99	35
37	Form Reo Pour Level 18 East Tower	6 days		30-Aug-99	04-Sep-99	36
38	Form Reo Pour Columns & parapet to roof East Tower	18 days		06-Sep-99	25-Sep-99	37
39	Strip formwork to parapet East Roof	2 days		27-Sep-99	28-Sep-99	38
40	Structural Steel to Roof East Tower	2 days		29-Sep-99	30-Sep-99	39
41	Timber to roof East Tower	5 days		01-Oct-99	05-Oct-99	40
42	Metalroof material to roof East Tower	1 day		06-Oct-99	06-Oct-99	41
43	**CRANE HIRE ENTIRE PROJECT**	120 days	21 weeks	17-May-99	06-Oct-99	
44	Start Crane Hire	0 days		17-May-99	17-May-99	43SS
45	Finish Crane Hire	0 days		06-Oct-99	06-Oct-99	42
46	**LOADING PLATFORM HIRE WEST TOWER**	74 days	13 weeks	04-Jun-99	28-Aug-99	
47	Start Loading Platform Hire West Tower	0 days		04-Jun-99	04-Jun-99	7SS-2 days
48	Finish Loading Platform Hire West Tower	0 days		28-Aug-99	28-Aug-99	16FS+12 days
49	**HOIST HIRE WEST TOWER**	80 days	14 weeks	12-Jun-99	14-Sep-99	
50	Start Hoist Hire West tower	0 days		12-Jun-99	12-Jun-99	7
51	Finish Hoist Hire West Tower	0 days		14-Sep-99	14-Sep-99	18FS+6 days
52	**LOADING PLATFORM HIRE EAST TOWER**	74 days	13 weeks	25-Jun-99	16-Sep-99	
53	Start Loading Platform Hire East Tower	0 days		25-Jun-99	25-Jun-99	28SS-2 days
54	Finish Loading Platform Hire East Tower	0 days		16-Sep-99	16-Sep-99	37FS+12 days
55	**HOIST HIRE EAST TOWER**	80 days	14 weeks	03-Jul-99	05-Oct-99	
56	Start Hoist Hire East tower	0 days		03-Jul-99	03-Jul-99	28
57	Finish Hoist Hire East Tower	0 days		05-Oct-99	05-Oct-99	39FS+6 days

Uncommon Sense and Artificial Intelligence for Re-Engineering Procurement Systems

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Abstract

Common sense and occasional innovations have hitherto failed to fuel more than incremental improvements in construction procurement systems. Even the bolder initiatives have not yet unleashed promised productivity gains which have been allegedly restrained by adversarial and otherwise inappropriate procurement systems. Both (a) the present proliferation of procurement options; and (b) the scattered body of experiential knowledge about their applications - appear to need more structured consolidation in ‘knowledge-bases’, also so that they may be efficiently harnessed through an ‘expert system’ front-end. A recent pilot study project in Hong Kong led to the development of such a knowledge-based model of a proposed decision support system for improved procurement choices. This paper summarises relevant results and related observations from this study, that confirm the usefulness of such structured ‘knowledge-based’ advice for the upstream re-engineering of construction processes and relationships, through ‘smarter’ procurement and synergistic management.

Keywords: *Decision support, expert system, integrated management, neural network, procurement options.*

FROM EVOLUTION TO REVOLUTION?

Many structures were procured under what may be termed ‘single-point’ procurement systems using ‘master-builders’ in previous centuries. The present century, while having seen division of labour and specialisation in many industries, sometimes led to an unhealthy fragmentation of the construction industry. While the need for independent professional designs and oversight were valid at that time, the polarisation of production from design has been questioned from as far back as the 1960’s, for example in the Emerson and Banwell Reports on the UK construction industry. The fact that the Latham and Egan Reports of the 1990’s appear to draw on similar perceptions of inappropriate procurement systems suggests that we may still be trapped within an outdated paradigm.

Meaningful industry development into the next millennium may require a larger leap than the hitherto incremental steps on different aspects (sub-systems) of procurement, such as work packaging, contract types and participant (e.g. contractor) selection. Project-specific procurement options will of course need to be linked to appropriate operational systems. Murray and Langford (1998) observed: (a) ‘significant changes in the way in which the construction industry operates’; and (b) that growing client power and economic pressure as well as enablers such as ‘partnering’, concurrent engineering and information technology, could be fuelling these changes. Tucker and Ambrose (1998) similarly noted that ‘in recent decades the industry has developed a range of procurement strategies to overcome the perceived inefficiencies of the traditional process’ - for example in management contracting, design and construct and partnering. However, they also observed that ‘each of the strategies tackles at least one of the inefficiencies in the procurement process, but none takes an holistic approach, with the result that the overall effectiveness of each is not assessed’.

The approach to improved procurement presented in this paper (in contrast to the above observation) is based on a holistic conceptualisation (Kumaraswamy and Dissanayaka, 1998). This recognises the various procurement options within each procurement sub-system (such as ‘contract type’ or ‘payment modality’), the many operational imperatives (such as for quality or safety), and the growing but scattered pockets of specialist knowledge/experience in their use. The proliferation of options (such as in different types of Design-Construct or BOT) and the complex interactions of the many project variables suggest a need to reach beyond ‘common sense’ choices of apparently appropriate systems. Even a structured decision-making process may not achieve the dramatic productivity gains that are now demanded from the industry (Kumaraswamy, 1998). This paper proposes a decision support system for assembling appropriate procurement and operational frameworks for a given project scenario, incorporating an expert system front-end and modules that use Artificial Neural Networks as well as statistical tools that are designed to mobilise the scattered ‘knowledge’ about the various available options.

BACKGROUND STUDIES

A Slow learning Industry?

Lessons learnt in the last few decades should be consolidated in order to launch the proposed integrated ‘construction performance enhancement’ system in the new millennium. Some lessons have been learnt by individuals (experts and ordinary practitioners) and a few construction organisations. However, many lessons that should have been learnt (from both project successes and failures) have been lost to the industry; because of the rarity of structured post-project evaluations and/or the documentation of such findings. Recent efforts by researchers and industry related bodies have sought to rectify this lack of learning that doomed us (a) to repeat mistakes (both of ourselves and of others); and (b) to remain reluctantly shackled to the so-called tried (but not necessarily trusted) systems of procurement and/or operation.

Thus many researchers have analysed and compared the various emerging procurement options such as in the many variations of Design-Construct, BOT, contract conditions, payment modalities and general risk allocation. Meanwhile, industry-related bodies have been set up in many countries to address specific industry development issues such as productivity, quality, partnering, constructability, contractor selection and IT aids. Kumaraswamy, (1998) scanned the usefulness of some of these bodies, such as: (a) the Construction Industry Institutes of USA and of Australia and the European Construction Institute that brought industry and academia together in such ventures; (b) the Construction Industry Development Boards of Singapore, Malaysia and South Africa that also benefited from governmental sponsorship; and (c) the old CIB (which was then translated as International Council for Building Research Studies and Documentation) that spans many countries in bringing together researchers and disseminating information.

However, gaps persist in the ‘conventional wisdom’ and the industry appears to be still in search of significant solutions. For example: (a) Kumaraswamy and Dissanayaka (1998) compared a cross-section of disparate findings by previous researchers on the impact of different procurement systems on project performance (where the relative importance of procurement choices/variables was debated in comparison with non-procurement-related variables); and (b) ad hoc attempts to ‘bolt on’ quality systems, safety systems or dispute reduction systems at different times have often led to mere ‘lip-service’ mismatches and lowered productivity. The latter could have been avoided had integrated solutions been formulated at the outset.

A Comparison of Procurement and Non-Procurement related factors

The first of the foregoing gaps was investigated in a specific study that compared the relative influences of various 'procurement choices/variables' and 'non-procurement variables' on "project performance" (Dissanayaka, 1998). However, only two easily quantifiable aspects of project performance were considered in this study: 'time' and 'cost' performance. The 'procurement' choices/variables were in fact the various options within each of the five postulated procurement sub-systems as described by Kumaraswamy and Dissanayaka (1998). This comprehensive conceptualisation of procurement systems incorporated the five sub-systems of (1) Work Packaging; (2) Functional Grouping; (such as whether 'Separated' or 'Integrated' Design and Build functions, or 'Construction Management/Management Contracting' type groupings); (3) Payment Modalities (such as lump sum or remeasurement); (4) Conditions of Contract; and (5) Selection Methodologies.

Detailed data from thirty building projects in Hong Kong was used to develop 'time performance' and 'cost performance' models. Multiple linear regression was used for model development in the first instance. Significant independent variables in the 'time over-run' models were found to include: 'level of design complexity', 'client type', 'construction complexity due to sub-contracting' and 'project team motivation and goal orientation'. Significant variables in the cost over-run models were found to be 'risk retained by client for quantity variations', 'construction complexity related to new technology' and 'payment modality' (such as whether 'lump sum fixed price' or 'remeasure').

These significant variables were next fed as inputs into an Artificial Neural Network model. The resulting '2nd generation' time and cost performance models were found to be more reliable in predicting time and cost performance. This was concluded after testing a sample of six projects (Dissanayaka, 1998). Both the Mean Average Percentage Error and the Root Mean Square Error between such predictions and achieved values were considerably reduced when using the Artificial Neural Network models.

It was thus confirmed by the above study: that both procurement choices and non-procurement variables contributed to time and cost performance; that the identification of significant variables could be approached via statistical analysis (eg: multiple regression); and that refined performance models could be derived using 'AI aids' such as Artificial Neural Networks.

MAIN FEATURES OF THE NEW STUDY

Research Study Formulation

Observations from a further literature review, preliminary interviews of practitioners and the findings of the above study (Dissanayaka and Kumaraswamy, 1999) prompted a proposal for a knowledge-based decision support system to generate improved ('intelligent') procurement choices, while taking into consideration the allowances needed for the significant non-procurement variables in each project scenario. The 'Expert System' components were considered necessary to model project scenarios to assemble and make intelligent use of the interacting knowledge bases. A basic model of such a client advisory system for optimising procurement choices had already been conceptualised by Kumaraswamy and Dissanayaka (1997). The new investigation was formulated as a pilot study to develop this model and test its feasibility.

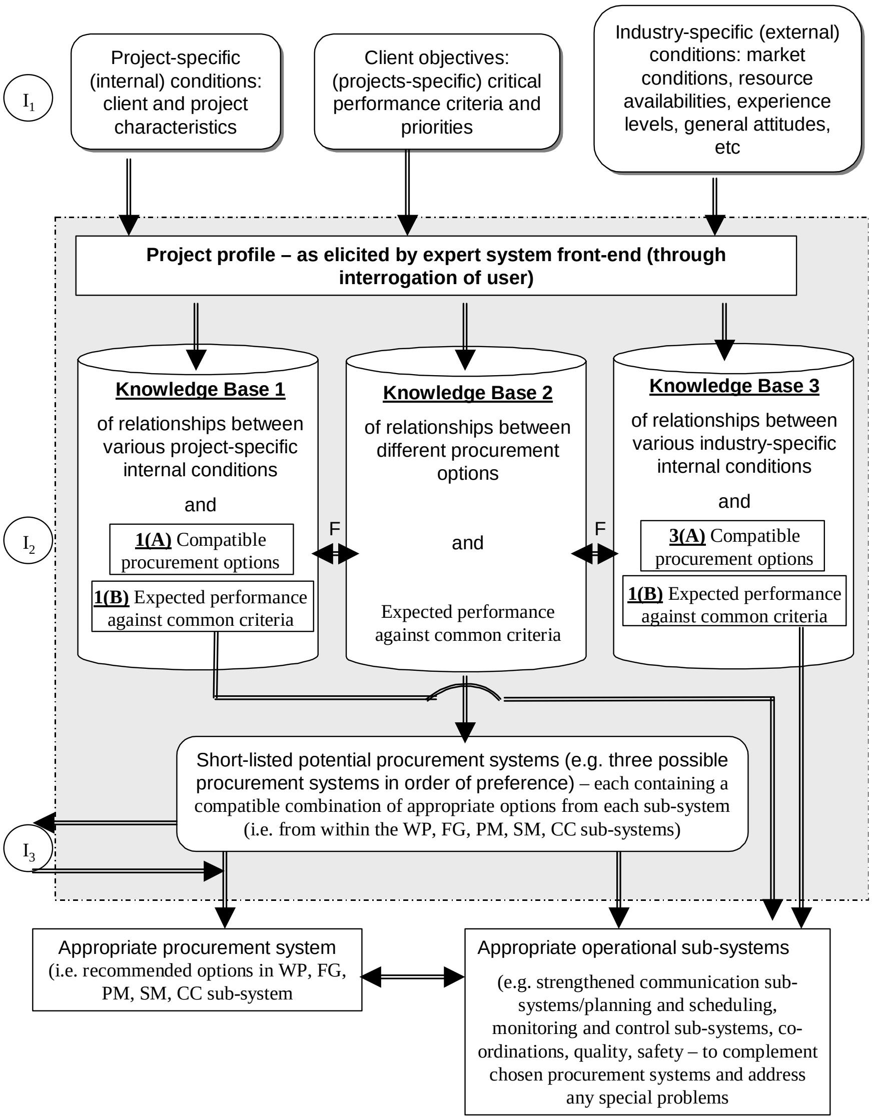
Eleven performance criteria were initially chosen - from the 38 potential criteria/priorities listed by Kumaraswamy and Dissanayaka (1998) - as being more likely to be of importance to clients of building projects in Hong Kong, based on interviews and general findings in the previous study:

(1) Lower capital cost
(2) Lower life cycle costs
(3) Cost certainty
(4) Shorter pre-construction duration
(5) Time certainty
(6) Shorter construction duration
(7) Effective and efficient communication
(8) Higher quality
(9) Effective and efficient decision making
(10) Dispute Minimisation
(11) Overall client satisfaction (also including other aspects)

Fig 1 illustrates the structure of the proposed decision support model. The three knowledge-bases at the core are designed to capture and incorporate any causal relationships linking project performance levels (as measured against the above criteria) against each of the following three sets of independent variables: (1) project-specific internal conditions (such as client characteristics); (2) procurement options (for example, a ‘fixed price lump sum’ payment valuation method); and (3) external conditions (including ‘resource availabilities’, such as the availability of relevant specialist contractors, or ‘market conditions’ relating to the principal materials needed for the project).

Another set of relationships (that could both constrain and guide the selection process) is incorporated in the proposed model. These arise from the need to choose ‘compatible procurement options’ (i.e., to exclude those options incompatible with the prevalent internal or external condition, based on past experience or ‘knowledge’). This provision enables appropriately integrated processing of the three knowledge-bases.

The proposed ‘Expert System’ front-end will request user inputs to model the project profile (at ‘I_1’), for comparisons against the assembled knowledge-bases. User inputs at the final selection stage (at ‘I_3’) would remobilise ‘human intelligence’ to re-check compatibilities, special conditions and any unforeseen (by the knowledge-bases) possible side effects of about three shortlisted procurement systems. The decision support system will later be developed to suggest appropriate parallel management sub-systems (such as for scheduling, monitoring, co-ordination, information flows, quality and safety) that would be compatible if not synergistic with the recommended procurement system. These would also help to address any significant non-procurement variables (such as external conditions) that may affect performance, despite appropriate procurement decisions.



Abbreviations

CC – Contract conditions
PM -- Payment modalities
WP – Work packaging
FG – Functional grouping
SM – selection methodologies

Fig. 1: Proposed model of decision support system for optimising procurement protocols and complementary operational sub-systems

Key:

I USER INPUTS

I_1 MODELLING PRESENT PROJECT PARAMETERS

I_2 CHECKING WHETHER ANY PROJECT PARAMETERS (INTERNAL OR EXTERNAL CONDITIONS) COULD CRITICALLY AFFECT THE EFFECTIVENESS OF CERTAIN PROCUREMENT OPTIONS (This are temporary input requirements at the 'F' interfaces, which will be later replaced by additional knowledge base modules)

I_3 RE - CHECKING THE COMPATIBILITIES AND ANY POSSIBLE SIDE-EFFECTS OF THE SHORTLISTED PROCUREMENT OPTIONS

EXPERT SYSTEM BOUNDARIES

F FOR FUTURE KNOWLEDGE BASE DEVELOPMENT

Fig 2 provides a schematic representation of the principal interactions. The main variable sets are taken as **I**nternal conditions (I), **E**xternal conditions (E), Procurement **O**ptions (O), and **P**erformance criteria (P). Databases are needed for each of the foregoing four variable sets. On the other hand, knowledge-bases (incorporating experience-based relationships/rules, rather than mere data) are necessary to model the relationships between them, such as at the interfaces IO, IP, EO, EP and OP. These relationships are modelled in the knowledge-base modules 1(A), 1(B), 3(A) and 3(B) and the knowledge-base 2 respectively, in Figure 1. The three-way relationships in IOP are modelled in knowledge-base 1 that integrates modules 1(A) and 1(B). Similarly, the three-way relationships in EOP are correspondingly modelled in knowledge-base 3. IEPO on the other hand, represents the fully integrated interface which would lead to recommended options (O_r) for a specific project based on the prevalent project-specific internal conditions (I_S), external conditions (E_S) and targeted performance profile (P_S) that must be 'fed into' the system as inputs.

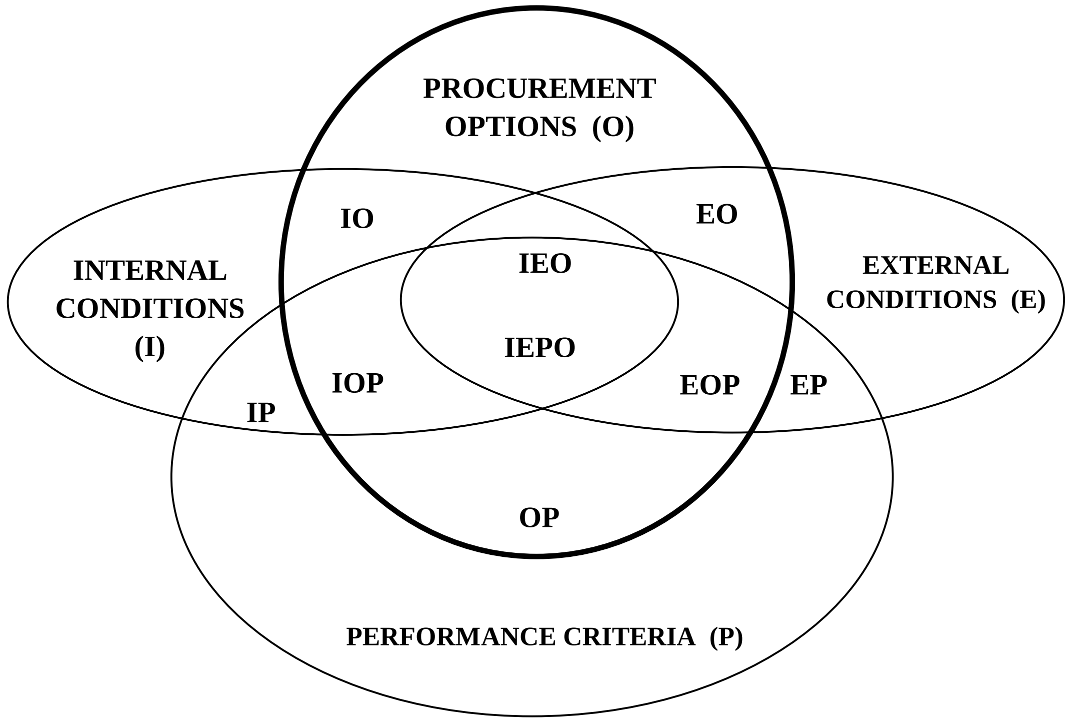


Fig. 2: Schematic representation of interacting sets of variables and the envisaged databases and knowledge-bases

Note: I, O, E, P represent data-bases, while IP, IOP, IEPO etc. represent the knowledge-bases that are needed to capture the relationships at these interfaces

Pilot Survey

The eleven performance criteria (as listed above) were incorporated into each of two 13-page comprehensive questionnaire/data sheets. The first questionnaire seeks out experience based perceptions of the more experienced/expert practitioners on the effects or impacts of each of the clearly listed procurement-related and non-procurement-related variables on each of the above criteria in turn. The second questionnaire was aimed at collecting information from specific projects on the effects of the same procurement and non-procurement-related variables on the performance levels attained against the same set of eleven criteria. Additional questions were designed to extract the project profile in terms of client priorities and basic project parameters.

50 experienced practitioners in Hong Kong were targeted for either one or both of these data-sheet type questionnaires, depending on their specific experience and availability. 22 'experience-based' and 18 'project-specific' data-sheets were obtained after follow-up and clarifications by two experienced Research Assistants. These clarifications were necessitated by the length and complexity of the questionnaires. The information from the data-sheet questionnaires was next structured in sets of inter-linked spreadsheet formats.

Initial Analysis and some Interim Observations

While it is not possible to describe the full methodology nor the detailed analyses and results in this paper, it is hoped that the details would be published elsewhere (Kumaraswamy, under review).

In summary, a structured set of exercises was designed for initial statistical analysis of the data and knowledge-bases. For example, the first exercise was developed to assess OP relationships (as in Figure 1); and to construct knowledge base 2 (as in Figure 2). The results from this statistically constructed relationships module (Kumaraswamy, under review) confirmed that attempts to optimise OP relationships by themselves are not useful. Instead IEOP relationships should also be explored simultaneously via the parallel inputs of internal and external variables that influence performance levels. For example, although an apparently 'optimal' 'Design-Build' Functional Grouping appeared to be the best choice (following an integrated assessment against the 11 criteria) for many projects, it ('Design-Build') was rarely chosen because of dominant factors such as market constraints and/or client preferences or unfamiliarity.

Modelling IEO-P Relationships

Success with Artificial Neural Networks (ANNs) in the previous study encouraged attempts to model the complex IEP-O patterns using the 18 project-specific data sets collected in this new study. The first ANN model was formulated to use only 11 inputs, viz. the specific project priority ratings against the eleven chosen performance criteria. Four 4 outputs were chosen to represent: (1) Functional Grouping (FG) with 3 possible outcomes (corresponding to 3 possible options, such as 'Design and Build'); (2) Payment Modality-Valuation Method (PMV), where these could have 3 possible outcomes (such as Fixed Price Lump Sum); (3) Payment Modality-Timing (PMT), where these could have 2 possible options (i.e., 'Milestone' or 'Monthly); and (4) Contract Conditions (CC), where there were 5 possible outcomes (such as the Hong Kong Institute of Architects Conditions of Contract). The foregoing target outcomes were selected according to those commonly chosen in the 18 project-specific data sets obtained from the Hong Kong-based building project sample.

14 project-specific data sets were used to train the ANN, and the remaining 4 to test it. It was found that the ANN 'outputs' obtained for the 4 test projects diverged substantially from the chosen procurement option in this first trial. This divergence could again be explained as another unsuccessful attempt to relate procurement options to expected performance levels by themselves (i.e., to rely on OP relationships alone); as also seen in the previous sub-section. This re-confirmed the need to simultaneously consider the non-procurement (I {internal} and E {external}) factors as well.

Another ANN model was therefore formulated in a second trial – to add 15 of the more 'important' non-procurement-related factors as 'inputs'. These 15 factors were chosen on the basis of their importance, as determined by the factors having the 15 highest overall average impact values as assessed in the preceding statistical analysis (Kumaraswamy and Dissanayaka, under review) by averaging the combination of specific perceptions in each project, as regards the impacts of all non-procurement-related factors initially considered). These additional 'important' variables were eventually found (after the above rigorous selection process) to comprise: 5 project characteristics (such as 'ease of site access'); 5 client characteristics (for example, 'client experience'); and 5 external condition variables (such as 'availability of manpower'). The input value for each of these 15 (non-procurement) variables was assigned as 'high', 'average' or 'low' according to the responses received from that particular project, i.e., from each of the project-specific data sets.

Specific results from the ANNs are tabulated elsewhere (Kumaraswamy and Dissanayaka, under review). A much lower level of divergence (if not direct correspondence) between the chosen options and the ANN outputs was clearly evident in the results derived from this second ANN model. It is envisaged that the incorporation of more data-sets from a further study should further enhance the predictive capacities of this

ANN model, given that only 14 project data sets were used for training, compared to the relatively high number of input (26) and output (4) variables. This expanded (second) ANN framework thus appears suitable for utilisation to model the IEPO knowledge-base envisaged in Figure 2. It also draws simultaneously on the IP, EP and OP project relationships, for example, in selecting the significant input variables for the ANN.

Conclusions of the Pilot Study

The interim observations from the new study (some of which are summarised in the paper) substantiated the buildability, viability and usefulness of a knowledge-based procurement decision support system as in Figure 1. It must be acknowledged that many modules, including data bases and knowledge-bases need to be developed in an expanded study that has already been proposed. A re-engineering of procurement systems is envisaged through such comprehensive approaches. It is also evident that the various procurement sub-systems must be 'synergised' with project-specific internal and external factors, as well as an explicit targeted performance profile (priorities of different performance criteria). Furthermore, intelligent up-front procurement decisions should be sustained and supported by appropriate downstream management of the processes. Complementary operational /managerial sub-systems thus need to be simultaneously selected or designed in order to achieve the desired synergies with 'smarter' procurement.

CONCLUDING OBSERVATIONS

Synergising Operational Sub-Systems

The construction industry has often reacted to sudden public or client outcries for greater quality, safety or dispute reduction, for example, with somewhat hastily contrived safety, quality or 'partnering' programmes. Such ad hoc and independent strategies have failed to generate the required commitment to make them self sustaining. Duplicated and/or conflicting procedures from such independent sub-systems have reduced productivity. IT tools may be harnessed in integrating the desired operational sub-systems, such as quality and safety, with others such as planning and control, communications, environmental management, claims management and dispute reduction. A step in this direction was demonstrated by Ng (1999) in structuring an integrated management system incorporating quality, environmental and safety elements. For example, even within the realm of quality and environmental management alone, ISO 9000 and ISO 14000 have merely provided basic guidelines for general process frameworks. Akao (1999) urged the formulation of broader systems that were also capable of assuring final product quality, as well as environmental quality using what he termed as 'Quality Function Development'. In another example, Zineldin (1999) proposed the integration of TQM (Total Quality Management) with TRM (Total Relationship Management) in order to achieve better quality relationships and product or service in addition to process improvements.

Back to the Bottom Line

The proposed paradigm shift should be based on the bottom line, albeit with a wider and longer-term perspective. Walker (1999) drew attention to the 'triple bottom line' which balances 'company profitability' with 'delivering value to society' and 'improving the ecological environment'. Such a conscious outreach beyond project performance, to organisational development, societal benefits and indeed industry development led to the development of the model proposed in Fig 3 of this paper. This illustrates the necessary integration of re-engineered procurement and operational sub-systems, together with over-hauled education and training and technology development sub-systems that must be synergised to launch a proactive and sustainable industry development initiative at the onset of the third millennium.

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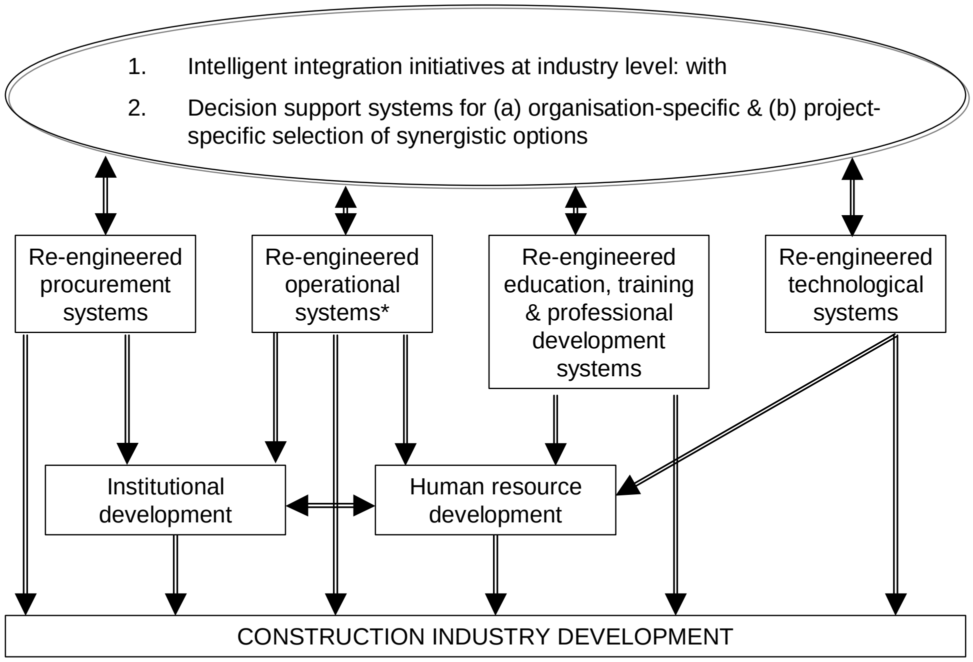

Fig. 3: A basic model of the necessary integration for institutional and industry development

* Operational Systems such as: Planning and Control, Information management, Quality management, Safety management, Environmental management, Dispute reduction

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Rapporteur’s Report for Papers in Theme C- Development of Teams and Procedures

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Abstract

Theme C deals with ‘development of teams and procedures’. It contains ten papers, and the common thread is the issue of improving performance, such as higher productivity and quality, and lower costs. Bertelsen and Nielsen (1999) provided a broad sweep of how productivity may be improved by proposing seven methods. Performance can be improved through various means, such as (a) implementing quality assurance systems (Jefferies et al., 1999; Love et al., 1999), (b) procurement system, such as management contracting (Shor et al., 1999), partnering (Bhattarai, 1999), co-contracting (Edum-Fotwe et al., 1999), (c) selection of designers with the right ‘hard’ skills (Ling et al., 1999a), (d) adopting best practices (Proverbs and Corbett, 1999), and (e) emplacement of an integrated management system, such as a decision support system for optimising procurement protocols (Kumaraswamy, 1999) and integrating Just-In- Time principles with ISO 9000 quality management system (Low, 1999).

INTRODUCTION

Theme C of the 2nd International Conference on Construction Industry Development, and 1st Conference of CIB TG29 on Construction in Developing Countries deals with ‘Development of Teams and Procedures’. The issues covered, as defined by the Conference organisers, comprise the following:

> Procurement approaches; contractual relationships; strategic alliances among practitioners and entities within the industry; cultural, legislative and institutional facilitators and constraints on the performance of construction enterprises and national industries; re-engineering the construction process and industry; benchmarking best practices.

Altogether, 10 papers were published under this theme. The authors were from some eight countries, consisting of Australia, Denmark, Hong Kong SAR, Malaysia, Nepal, Singapore, South Africa and United Kingdom.

SUB-CATEGORIES

While the main theme is ‘Development of Themes and Procedures’, the major issue threading through the 10 papers is performance improvement. This can be performance with respect to time, cost, quality, safety, and the environment. Further, it is possible to classify the papers into sub-categories. These are suggested below.

(a) Quality assurance (Jefferies et al., 1999; Love et al., 1999), and its link to Just-in-Time concepts (Low, 1999).
(b) Procurement- selection of an ‘ideal’ procurement method using artificial intelligence (Kumaraswamy, 1999), selection of designers with the right ‘hard’ skills (Ling et al., 1999a), improving performance

through various procurement methods such as management contracting (Shor et al., 1999), partnering (Bhattarai, 1999), and co-contracting (Edum-Fotwe et al., 1999).

(c) Best practice (Proverbs and Corbett, 1999; Bertelsen and Nielsen, 1999).

The papers under the sub-categories are now discussed.

QUALITY ASSURANCE

Quality assurance is defined as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality (Low, 1999). Many studies have shown that construction firms that have adopted quality assurance perform better. However, in some developing countries that urgently need the constructed facility at the lowest cost, quality may no be one of the main considerations in these construction industries as yet.

Jefferies et al.'s (1999) paper "Introducing quality assurance in the Seychelles construction industry" therefore investigated whether contractors in Seychelles are ready to embrace quality assurance. The authors collected data via structured questionnaire. The top management of seven construction firms, which have more than 100 staff were interviewed. They concluded that quality assurance may be implemented successfully in the Seychelles' construction industry, although several constrains may be faced. These problems include poor communication, inconsistent technology, lack of commitment and cultural resistance. Their studies also showed that government related companies are more ready to embrace ISO 9000 quality management system, compared to the private sector. In addition, bigger firms are more ready than smaller firms. It is concluded that for Seychelles to implement quality assurance successfully, it has to be a top down approach, starting with government related firms.

In many developed countries, it is common for contractors to adopt quality assurance programmes. However, Oakland and Aldridge (1996) found that design firms are more reluctant to do so. Love et al.'s (1999) paper "Managing service quality and value in the construction supply chain" investigated how ISO 9000 quality management system, if implemented by architectural and engineering firms, could improved service quality and value in the construction supply chain. They used a case study approach to illustrate their point about the need for quality system. The case in point was for the construction of a residential apartment block, procured using a traditional lump sum contract, with the client engaging a project manager. The structural steel design and supply chain was chosen for analysis because it exhibited several problems. Data were collected through non-structured one-to-one interviews with the client's project manager, architect, structural engineer, structural steel subcontractor and draftsman. It was found that the lack of a quality assurance programme led to the following problems:

- poor responsiveness to customer needs;
- poor coordination of information;
- poor understanding of customers requirements;
- lack of pro-active decision-making;
- poor quality contract documentation;
- poor understanding of customer requirements;
- unsatisfactory communication;
- professional incompetence; and
- higher cost of doing business.

Love et al. (1999) concluded that design firms need to start satisfying customers by implementing quality assurance systems. After that, the next step is to aim for total quality management (TQM). This is because ISO 9000 provides the guidelines for service quality, while TQM provides the environment for continuous improvement.

Love et al. (1999) demonstrated through the case study that service standards can be affected if firms do not implement quality assurance systems. They further proposed a model for the service quality loop interface between firms in the supply chain.

Both Jefferies et al. (1999) and Love et al. (1999) highlighted some problems that firms face with ISO 9000 certification. These include:

- high costs associated with achieving and maintaining a certification program (Gnome, 1995a), which include registration fees, auditing fees and consultancy fees (Kennedy, 1995);
- ISO 9000 requirements being too sophisticated, and do not value-add to small and medium sized businesses (Gnome, 1995b);
- increase amount of paperwork ; and
- indirect costs incurred.

While quality assurance is important, ISO 9000 quality management system should not be implemented in isolation. Low (1999), in "Linking JIT productivity with ISO 9000 quality for construction industry development: lessons for developing countries" pointed out that it is possible to integrate different management systems to achieve synergy. He argued that the manufacturing concept of Just-in-Time (JIT) can also be successfully integrated with ISO 9000 quality management system, to achieve higher productivity in the construction industry. His paper showed how the seven concepts of JIT, viz. elimination of waste, Kanban or pull system, uninterrupted workflow, total quality control, employee involvement, supplier relations, and continuous improvement, could be incorporated into the existing ISO 9000 quality management system, to achieve productivity in the construction industry. The model proposed by Low (1999) could be used by companies which already have ISO 9000 quality management system in place to adopt JIT. Low (1999) also proposed that other systems be integrated to obtain a truly integrated management system. He suggested integrating ISO 9000 with JIT principles, ISO 14000 Standards for environmental management and safety management system.

One of the benefits of having a construction industry that is not fully developed or matured is that it can learn from others, without re-inventing the wheel, or making the mistakes that were made in the past. It is also easier to improve on existing methods, instead of designing new ones. The lessons to be learnt include aiming for total quality management, instead of just quality assurance (Dotchin and Oakland, 1993; Oakland and Sohal, 1996), and to integrate the various management systems instead of implementing each one in isolation (Low, 1999)

PROCUREMENT

Pre-contract issues are said to be important, as they are 'upstream' activities, which will affect the success of the project at the 'downstream'. An important pre-contract issue is the choice of procurement system. Various models are available to facilitate the decision on the choice of procurement system (Nahapiet and Nahapiet, 1985; Skitmore and Marsden, 1988; Mohsini, 1993; Love and Skitmore, 1996; Newcombe, 1996). Skitmore and Marsden's (1988) model requires project owners to evaluate their projects on seven factors, comprising importance of speedy completion, certainty of price, flexibility in making alterations to the design, quality level of the project, complexity of the project, degree of risk avoidance, and price competition.

Kumaraswamy (1999), in "Uncommon sense and artificial intelligence for re-engineering procurement systems", argued that improvements in construction procurement systems are slow, mainly due to two reasons; present proliferation of procurements options, and the scattered body of experiential knowledge about their applications. He reasoned that there is a need for a more structured consolidation in 'knowledge bases', so that they may be efficiently harnessed through an expert system. He presented a pilot study of a knowledge-based model of a proposed decision support system for improved procurement choices. The decision support system could be used for assembling appropriate procurement and operational frameworks for a given project scenario. It incorporated an expert system front-end and modules that use artificial neural networks and statistical tools that mobilise the 'scattered' knowledge about the various available options. The proposed decision support model would be useful for selecting the optimum procurement system, so that the important upstream decision is made right, and thus, ensure that the downstream activities would be more successful.

As mentioned earlier, there are many procurement options available. In this conference, three options were presented; partnering, co-contracting and management contracting. These are now discussed.

Partnering

Bhattarai's (1999) paper "Partnering- an experience of Nepal Engineering College" discussed how the partnering concept was used in the construction of the US$0.8 million Nepal Engineering College in Bhaktapur, Nepal. He discussed partnering from the client's point of view, as he is also the principal of the private college. The project was successful, in the sense that it was completed early, below budget, with minimal variations, and no disputes between the client and the contractor. Bhattarai (1999) identified eight factors that contributed to the success of the project. These are listed below.

- Close tender or selective tender, in lieu of open tenders.
- Selection criteria was not based on price alone, but contractor's past performance and financial capacity.
- Client's team leader was an inexperienced person, but given all the necessary authority.
- Client's project manager was an experienced person, with high moral and ethical values.
- Contractor had extensive construction experience.
- Clear objectives for the project, and clear guidelines on how problems were to be addressed, were set.
- Project team members, including the contractor, attended a one-day seminar on partnering.

In this project, while partnering appeared to be the main driving force to ensure project success, it would be interesting to see if partnering could still be effective if the projects are of larger values, more complex and involve more actors. Furthermore, the suitability of partnering for public sector clients should also be investigated.

Co-contracting

Edum-Fotwe et al's (1999) paper "Subcontracting or co-contracting: construction procurement in perspective" pointed out that the construction industry has a high level of subcontracting. In order to achieve higher productivity, the relationships between companies that form the supply chain of the construction process need to be managed. They proposed that while clients and contractors can have partnering, at the supply chain, contractors and subcontractors can have co-contracting amongst themselves. Co-contracting agenda exists when there is close association between major construction companies and smaller companies. There should be effective alignment of management systems, operational processes, and information systems such that boundaries between different firms at various stages of the supply chain becomes blurred without reaching the point of actual merger. Co-contracting between two firms engenders an atmosphere of equal partners in which each partner's interests are taken care of.

This finding is consistent with the concepts of 'non-equity alliance' (Gulati, 1995) and 'quasifirm' (Eccles, 1981). Future research into the relationships between contractors and subcontractors should attempt to amalgamate the scattered body of knowledge in co-contracting, non-equity alliances and quasifirms, with Granovetter's (1985) Network Theory of Embeddedness.

Management Contracting

Management contracting is defined as a procurement system whereby the contractor is engaged as a professional agent of the client and retained on a fee basis. The role of management contractor at the design and planning stages is to provide clients and designers with information regarding cost, buildability, productivity, programmes, schedules, market conditions, and labour and material availability (McKinney, 1983).

Shor et al's (1999) paper "Management contracting in South Africa" investigated whether the South African construction industry is progressing towards management contracting. They conducted their investigation by looking at the extent of subcontracting in South Africa. They used structured interviews and questionnaires to collect data for their study. They found that, compared to six years ago, construction firms are:

- subcontracting more of their works;
- engaging less direct employees; and
- involved more in the management of contracts, rather than actual construction.

The authors then concluded that the South African construction industry is moving in the direction of management contracting.

From the definition of management contracting given above, it appears that a contractor only becomes a management contractor when he or she is engaged by the client to work with the design team. Therefore, it does not follow that when contractors subcontract more of their works, the construction industry is necessarily moving towards management contracting. One example is the Singapore construction industry, in which subcontracting various parts of the construction work is done extensively, but the number of management contracts are few and far between.

Selection of Designers

One of the upstream activities that may affect the quality of downstream activities is the quality of designers who are engaged for a project. In Ling et al.'s (1999a) paper "Hard skills: relevance to architects and engineers, with particular reference to design-build projects", they argued that it is important to select consultants with the right attributes. They proposed two major sets of attributes; hard skills and soft skills. Soft skills were discussed in Ling et al. (1999b). The scope of their present study was therefore confined to hard skills. Based on literature review, they uncovered 13 different hard skills, classified under four main categories; general mental ability, job knowledge, task proficiency, and job experience (Schmidt et al., 1986). They surveyed 55 consultant architects and engineers, and found that the three most important skills are:

- consultant has good problem solving ability and project approach;
- consultant has good knowledge of economical design; and
- consultant has good knowledge of buildable design.

They concluded that these three attributes are consistent with the need for consultants to satisfy the three main project objectives of time, cost and quality.

BEST PRACTICE

Construction industries in many countries are not performing well. This made it important to commission major studies to investigate how it could be improved. Recent studies in the UK include Latham (1994) and Egan (1998), while in Singapore, the Construction 21 Report (1999) was launched on 21 October 1999.

Proverbs and Corbett (1999) mounted a study "A cost minimisation model of contractor performance based on European best practice" to identify possible construction practices in Europe that could lead to lower construction costs. The most important practice that lead to the highest cost savings in Europe is 'labour utilisation'. Working schedules exceeding five working days per week were found to be counter productive. In addition, they found that choosing the appropriate formwork method also gave considerable cost savings.

Bertelsen and Nielsen's (1999) paper "The Danish experience from 10 years of productivity development" drew upon Denmark's productivity development programmes within the last 15 years to highlight several issues that need to be considered to develop the construction industry. These are listed below.

- Building construction process should be industralised, and make use of lean construction principles and prefabricated components.
- Programme administrators must be firm in keeping to the objectives of improving productivity, but flexible in their programme administration.
- The owners of the productivity improvement results (companies, clients, authorities, or institutes) must be involved from the beginning.
- Productivity results must be measured, so that the problems can be properly understood.
- The number of competitive suppliers should be reorganised, to allow organisational learning. The authors proposed a limited number of consortia to compete for projects over a five-year period.
- The construction industry should provide business frameworks that stimulate changed behaviour. Bertelsen and Nielsen (1999) argued that tough price competition is difficult to increase productivity.
- The construction industry should develop a new culture, with a new mindset, such as moving away from tough price competition to long term co-operation.

CONCLUSION

Several papers in this theme advanced knowledge in the construction industry domain. Kumaraswamy's (1999) model to help decision makers choose the appropriate procurement system using artificial neural networks is a notable example. Low's (1999) matrix which amalgamates JIT principles into existing ISO 9000 quality management system is helpful to contractors who appreciate the importance of an integrated management system. Ling et al. (1999a) identified the types of hard skills that employers should look for when they engage design consultants.

Proverbs and Corbett's (1999) model which identified measures to reduce costs advanced the knowledge of best practice in cost optimisation. The construction community should also take heed of the lessons documented, and advice offered by Bertelsen and Nielsen (1999) on how construction industry's productivity could be improved. One of the suggestions by Bertelsen and Nielsen (1999) is consistent with Edum-Fotwe et al.'s (1999) proposal on co-contracting.

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Managing Service Quality and Value in the Construction Supply Chain

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Abstract

Architectural and engineering firms concerned with design have eschewed implementing quality assurance (QA) systems and other subsequent aspects of quality such as continuous improvement. Their reluctance to embrace QA has been found to be a factor that contributes to poor quality contract documentation being produced. Missing, conflicting, erroneous information within contract documentation, are major sources of rework and customer dissatisfaction in construction projects. This paper suggests that if design firms are to significantly improve the quality of service they provide, they should implement ISO 9000 quality management and assurance standards. A case study is used to identify the factors that inhibited 'value creation' and poor service quality provided by design firms involved in a structural steel supply chain. The need for design firms to implement ISO-9000 quality management and assurance standards so as to improve their service quality is discussed based on the case study findings.

Keywords: Service quality; design firms; value; information; rework; ISO-9000 standards.

INTRODUCTION

Many organizations have found that quality programmes can generate significant costs without observable gains (Powell, 1995). Architectural and engineering firms in particular have eschewed implementing QA systems and other subsequent aspects of quality such as continuous improvement (Bhuta, and Karkhanis, 1995; Oakland, and Aldridge, 1996). The reluctance of design firms to embrace QA has been found to be a factor that contributes to poor quality contract documentation being produced (Love et al., 1999). Missing, conflicting and/or erroneous information within contract documentation are major sources of rework and customer dissatisfaction on construction projects (Love et al., 1999). Rework can have an adverse effect on a firm's morale, profit, and productivity. It can also indirectly affect, in both monetary and non-monetary terms, other participants who rely on the firm's information to proceed with their work. If design firms are to significantly improve the quality of service they provide, they should implement ISO 9000 quality management and assurance standards (Oakland, and Aldridge, 1996). By implementing such standards it is envisaged that design firms will be able to contribute more effectively to the value-adding process in the construction supply chain. Essentially, the service offered by design firms should be viewed as a key component of value that drives its success and that of projects.

Design firms have had to become leaner in order to adapt to today's increasingly volatile and competitive environment (Richardson, 1996). Anecdotal evidence in Australia suggests that the quality of the contract documentation produced is a major concern to those who rely on the information contained within these documents to conduct their business effectively (Syam, 1995). According to DeFraites (1989), the overall level of professional services provided is a major determinant of overall project quality. DeFraites also states that the process by which services are selected and fees negotiated may also determine the extent and quality of the service provided. Abolnour (1994) found a relationship between the actual fee charged and documentation quality. That is, project costs tend to increase when design fees are reduced. Nelson and Nelson (1995) however, acknowledge the importance of fees, but do not consider them to be a significant factor that influences service quality. Mohapatra et al. (1998) suggest that design firms have become reactive to the increased demands of clients by advocating that fees are too low, thus affecting the quality of service they provide.

All firms involved in the procurement of construction, especially those providing professional services, need to recognize that in order to improve their service quality they must establish a quality culture (Love et al., 1999). However, the absence of a quality focus in design firms has meant that the concept of service quality has not been given the recognition it deserves. Consequently, contractors and subcontractors, who are indeed customers in the supply chain, invariably act as 'quality buffers'. In essence, they are left to identify and evaluate quality deviations in contract documentation. Mohapatra et al. (1999) suggest that when a firm submits a low design fee for a project, it may 'time box' tasks. That is, a fixed period of time may be allocated to complete each task, irrespective of whether the documentation or each individual task is complete or not. Such practices may contribute to customer dissatisfaction and cause errors to be made by other parties who rely on the designers' information.

A case study is used to identify 'hygiene factors' (see definition under Defining Service Quality) that inhibited value creation and poor service quality provided by design firms involved in a structural steel supply chain. From the case study findings the need for design firms to implement ISO-9000 quality management and assurance standards so as to improve their service quality is discussed.

DEFINING SERVICE QUALITY

Janson (1989) suggests that a service is 'useful labor that does not produce a tangible commodity' or a 'facility supplying some public demand' or 'one providing maintenance or repair'. These definitions suggest that services are characterized by the fact that they are intangible, cannot be stored and indeed the participation of the customer is required in the production process. These characteristics do not apply to all services, as there are some aspects of construction that are very tangible.

The most popular definition of quality relates to fulfilling or exceeding expectations. However, there is neither an accepted nor best definition of quality for every situation. Excellence, conformance to standards or specifications, and fitness for purpose have all been criticized as definitions of quality (Dotchin and Oakland, 1993). Expectations are not necessarily consistent or predictable. They are subject to many influences including management communication or advertising. There has been some debate about the empirical versus diagnostic value of incorporating expectations in any measurement of quality. Value seems more stable as a definition but this does not mean that its attributes are not subject to different rank ordering due to the human bias of placing those factors which are less attended to a higher importance level (Dotchin and Oakland, 1993). Like the concept of quality, service quality also has several different definitions. Previous research has demonstrated that there are between seventeen and ninety-nine activities that constitute service activities (Donaldson, 1988). Knowing how different aspects of services might affect customers would also be useful. Lewis (1995) categorized service quality into the following three dimensions:

- hygiene factors – those things expected by the customer and will cause dissatisfaction when not delivered;
- enhancing factors – those things which may lead to customer satisfaction but, when not delivered, do not necessarily cause dissatisfaction; and
- dual threshold factors – those things which when delivered above a certain level of adequacy lead to satisfaction but when delivered at a performance level perceived to be below that threshold cause dissatisfaction.

Design firms need to be customer focused in all their activities, as they are in a pivotal role where they can add value to other businesses involved in the construction supply chain. It is through adding-value that design service's ultimate success will be measured and evaluated. Value can be described as the benefits received for the burdens endured – such as price, an inconvenient location, unfriendly employees, or an unattractive service facility. On the other hand, service quality is a key component of value that helps an organization to “maximize benefits and minimize non-price burdens for customers” (Berry et al., 1994: p.32). The challenge for design firms is not only to be a provider of a service, but also to understand what creates value in their customers’ existing and changing needs as well as those of project team members.

CASE STUDY

The case study project had a contract value of $10.96 million and a contract period of 43 weeks. The project consisted of two 6-storey residential apartment blocks, containing 43 units. Underground parking, a landscaped podium, and swimming pool are facilities incorporated in this development. The project was procured using a traditional lump sum contract, with the client employing a project manager to act as their development representative. The role of the client’s project manager was to administer, integrate and co-ordinate the consultants and contractor. The contracting organization was the primary focus of the research as they were typically at the interface between the design service and construction production process. For a description of the research methodology refer to Love *et al*. (1999).

The project described in this paper had some good and bad features. For the purpose of this paper the authors concentrate on one poorly performing subcontract trade package. The structural steel design service and supply chain has been chosen for analysis because it exhibited several interesting and identifiable service deliver problems. Each participant involved in the structural steel supply chain was interviewed (Figure 1) which shows ***the various participants involved in this supply chain. Representatives from each group were interviewed and were conducted on a one-to-one basis so as to stimulate conversation and breakdown any barriers that may have existed between the interviewer and interviewee (Creswell, 1991). The interviewees were allowed to talk freely without interruption or intervention, so as to acquire a clear picture about their perspectives about the causes of rework.

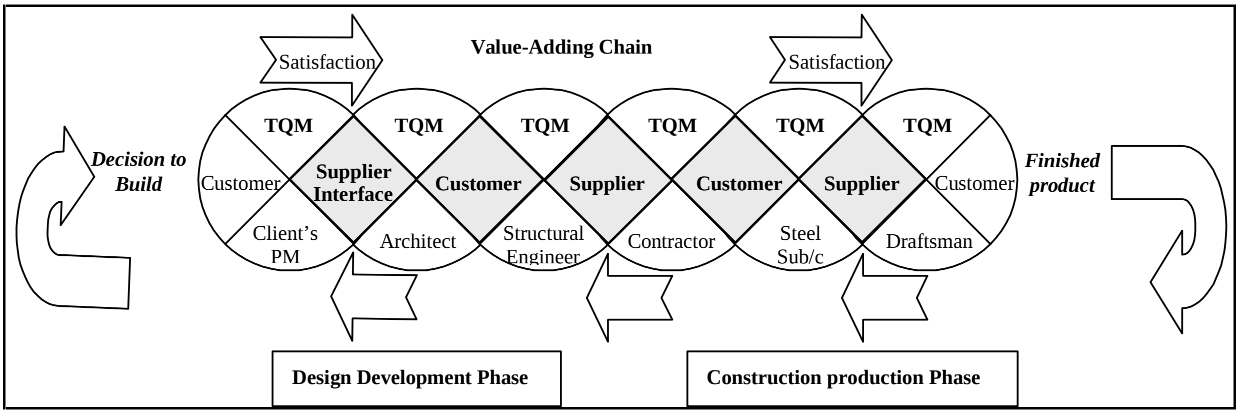
Findings

The absence of a quality focus throughout the supply chain contributed to significant amounts of rework being experienced. Interviews were conducted with the client’s project manager, architect, structural engineer, structural steel subcontractor and draftsman and an analysis of responses revealed that a number of factors could be considered as inhibiting ‘value creation’ and contributing to rework. These can be summarised as:

- poor responsiveness to customer needs;
- poor coordination of information;
- poor understanding of customers requirements;
- lack of pro-active decision-making;
- poor quality contract documentation;
- poor understanding of customer requirements;
- unsatisfactory communication;
- professional incompetence; and
- cost of doing business.

Each firm is a critical link in the supply chain and therefore must have a customer-supplier focus, which is implicit in TQM. However, it was found that there was a general absence of such a focus at each organisational interface. External quality failures (for example, rework) which originated due to design errors and omissions emerged downstream during construction. For instance, in the selected structural steel supply chain it was found that the cost of rework for the structural steel subcontract package was considerably higher in relation to other subcontracts. The original contract value of the structural steel subcontract package was $90 408, and the amount of rework experienced was found to be $32 308, which is an additional 35% to the contract. This subcontract package was a major factor that contributed customer dissatisfaction throughout the supply chain.

Figure 1: Service quality in a construction supply chain



Poor responsiveness to information needs

The contractor invited three subcontractors to tender for the structural steel contract. Each subcontractor identified fundamental errors in the tender documentation and immediately brought them to the attention of the contractor. Thus, the contractor had to send requests for information (RFI) directly to the client's project manager/representative, who then distributed the RFIs to the architect and engineer. The contractor stipulated that the information was urgently needed because the lead-in time to procure and manufacture the steel was critical. The required information arrived three weeks late because the architect needed additional time to complete and answer all the queries identified. Moreover, the nominated person responsible for documenting and coordinating the project had taken a vacation. There were no staff who had been involved in documenting the project in the office who could answer the RFIs that were raised almost a week previously. In order to expedite the process, the contractor asked the subcontractors to estimate and make an allowance in their tenders for erroneous and missing information supplied in the tender documents.

Poor co-ordination of information

The client's project manager had limited experience in the construction industry and did not understand the complex nature of the procurement process inasmuch as the project manager failed to acknowledge that when a task is process dependent, effective coordination of information flow between sub-units becomes critical. This lack of coordination during the design process, meant that the architect and engineer lost sight of their respective roles and pursued their own special objectives, at the expense of customers downstream. In essence, both the architect and engineer were reluctant to coordinate their work as they considered this to be the responsibility of the project manager. Such abrogation of responsibility acted as a barrier to forming good working relationships and hindered the decision-making process. In fact, it is suggested that the insularity of the firms in pursuing their own objectives is a major factor that inhibited dialogue and information flow between participants.

Lack of pro-active decision making

The project manager was responsible for the organization and management of the project team. The project manager informed the architect that they had to comply with the structural engineer's recommendations and amend the design of the roof in accordance with the building regulations and local authority requirements. The steel could not be ordered until certain critical dimensions had been resolved. Meetings were held with the project team to discuss the issues raised by the contractor. The contractor emphasized that a decision pertaining to the dimensions of the roof was urgently required, as delay was becoming inevitable. The contractor informed the project team that tenders had been received for the supply and installation of the structural steel, despite being hampered by missing information. The design team members did not want the contractor to let the subcontract package until the fundamental design issues were resolved, irrespective of the consequences, which they deemed to be short term. The dilemma was that if more time were spent on the problem at hand it would lead to fewer problems being incurred later in the project. However, at this late stage of the project, more time was not available.

Poor quality contract documentation

The architect and engineer implied that they had a lack of skilled resources available to resolve the RFIs raised. They blamed low design fees for any errors made in the documentation. They stressed that the scheduled program and lack of resources prohibited them from producing fully documented working drawings. Accordingly, deficiencies in the design arose on-site.

Poor understanding of customer requirements

The architect and engineer misinterpreted the project brief and simply did not understand the requirements of the client, contractor and subcontractors. Essentially, they under-estimated the time and effort needed to complete their respective tasks, which adversely affected their profit. The design service may also have been subject to 'time boxing' but the authors have no admission of this from the architect or engineer. Thus, less time may have been spent on preparing documentation in order to maximise profit, which resulted in rework. Moreover, conflict brought about by inadequate feedback and interaction along the supply chain significantly contributed to further rework.

Unsatisfactory communication

The design team had not worked with the contractor before and, although the contractor was recommended for appointment, there was a great deal of tension between the parties and a reluctance to work together. The lack of attention to quality by the designers inhibited the development of teamwork and joint problem solving throughout the supply chain. Because of the delays that were experienced due to missing information, the contractor advised their steelwork subcontractor to order the steel in spite of not receiving the necessary information. The revised drawings were issued to the subcontractor three weeks after the date initially required. The steel subcontractor used a draftsman to produce the roof's *shop drawings*. The dimensions contained within the revised drawings were also erroneous, as they had been not coordinated. The design team had not learned from their previous mistakes. The obvious lack of a quality focus meant they did not value their direct and indirect customers. The subcontracted draftsman generated additional RFIs. These were distributed to the steel subcontractor who then distributed them to the contractor etc.- a time consuming process. The longer it took to resolve the RFIs, the greater was the risk that the project would run over time and budget.

Professional incompetence

To save time the formal communication process was sacrificed for a more flexible and informal process of information transfer whereby RFIs raised by the subcontracted draftsman went directly to the architect and engineer. The creation of an informal work orientated communication framework allowed the formal task hierarchy to be bypassed, and thus increased the effectiveness of inter-organisational communication. This enabled shop drawings to be completed and submitted for approval in a more efficient form. The contractors waited over three weeks for the architect and structural engineers to approve the 'shop drawings'. Naturally, this delay had a negative impact on the contractor's program and required certain elements of the projects to be re-scheduled. Both the architect and engineer had overlooked the building regulations and eschewed coordinating their changes. Such professional incompetence was the root cause of rework experienced in this subcontractor package. To compound the problem the architect decided to change the pitch without informing the engineer. As a result, another major re-design was required. In total the draftsman raised over 90 RFIs relating to the revised geometry of the roof.

Cost of doing business

The additional time spent correcting mistakes was costly to the steelwork-drafting firm. The draftsman's staff had to work overtime and additional resources had to be employed. The draftsman estimated the administration cost to generate each RFI was $90 and took approximately one hour to prepare. The total estimated cost of correcting the shop drawings was $16 000. This loss of income included the indirect costs of two contracts worth $3000 and $5000. Similarly, both the architect and engineer estimated the additional cost of re-designing and the making appropriate changes to their drawings for the structural steel roof to be $14 000 and $10 000 respectively, which was considered to be approximately 25% of their fee. Noteworthy, these additional costs could not be claimed from the client.

The structural steel roof was erected three weeks late. The contractor took a risk by ordering the steel before the shop drawings were complete. If the steel had not been ordered when it was by the contractor the project could have been delayed by over nine weeks. Minor incidents pertaining to sections of steel having to be shortened on-site were experienced, but did not have an adverse affect on the project. As a result of the avoidable difficulties experienced with the roof, the contractor had to adopt an alternative construction methodology to deliver the building, which in this case proved to be successful. While the roof was delayed, the whole project finished ahead of schedule, but a cost overrun was experienced. As mentioned above, in the case of the structural steel package an additional 35% increase was experienced. Besides the additional cost, the client also experienced a great deal of stress, as there was always the possibility that the project would not finish on time and that they would incur additional interest charges on borrowed capital.

DISCUSSION

From the description given above it can be clearly seen that both the architect and engineer were primarily responsible for initiating the rework experienced in the structural supply chain. Although only one case study has been presented, it is suggested from the authors' experience that the *hygiene* factors identified herein are prevalent in the construction supply chain. Latham (1994) and Egan (1998), like their predecessors Simon (1944) and Banwell (1964), have also identified these problems, albeit in different forms. Sadly, it would appear that nothing has changed in over fifty years. Furthermore, it is suggested from the authors' experience that nothing will change until firms involved in the procurement process of construction recognize that they are all related in a supply and quality chain.

With the impact of changing procurement patterns, privatization, the use of information technology, and role redefinition with multi-disciplinary teams, architects and engineers are forced to be specialist service providers on the supply side of the industry. Thus, design professionals need to become more commercially orientated if they are to survive in the long-term and contribute to improving the construction industry's performance. Bearing in mind the case study findings, the authors suggest that design firms need to not only produce quality work but also quality service. It is possible for a client to be satisfied with the technical and design input of a particular practice but dissatisfied with the level of service.

A simple lack of recognition of the needs of the client and project team members contributed to the project's cost overrun. It is suggested that if the architectural and engineering professions are to survive in the long-term they must begin to address quality at both the organizational level and customer-supplier interface (Figure 1). It is further suggested that low design fees are used as an excuse for poor service, and it is therefore urgent that both the architectural and engineering profession embrace TQM in a proactive and integrated manner.

Total quality management provides the overall concept that fosters continuous improvement in an organization (Oakland and Sohal, 1996). The TQM philosophy stresses a systematic, integrated, consistent, organization-wide perspective involving all employees. It focuses primarily on total satisfaction for both internal and external customers, within a management environment that seeks continuous improvement of all systems and processes. The basic philosophy of TQM is applicable to any organization, regardless of the type of industry. The path to TQM implementation is sequential in nature and begins with QA (Love *et al*., 1998).

In essence, QA is simply an overall system of monitoring activities and a mechanism that aims to prevent quality deviations and to give early warning of poor quality being produced so it can be rectified. If a design firm is to implement an ISO 9000 standard, it must recognize why such a standard should be used. According to Love and Li (1999), many firms in the Australian construction industry have taken this certification route for the wrong reasons. That is, because they see that "everybody else is doing it" or because "it is supposed to improve performance". Whereas research undertaken by Buta and Karkhanis (1996) suggests that quality certification was sought to reduce the incidence and cost of rework and to improve marketing. There are a number of reasons as to why design firms should implement ISO 9000 quality systems as identified below:

- to achieve total quality;
- to satisfy a specific requirement from one or more customers;
- because of increasing competitive pressures;
- because of the regulatory environment; and
- due to internal and external benefits.

Rothery (1993) considers ISO-9000 to be a tool that can be used as an effective control mechanism, which seeks to reduce waste (e.g., rework) and labor inefficiencies in a process to ensure quality in the delivery of contract documentation. According to Street and Fernie (1993) the justification for a firm to become certified to ISO 9000 is normally based on the premise that it will acquire benefits such as:

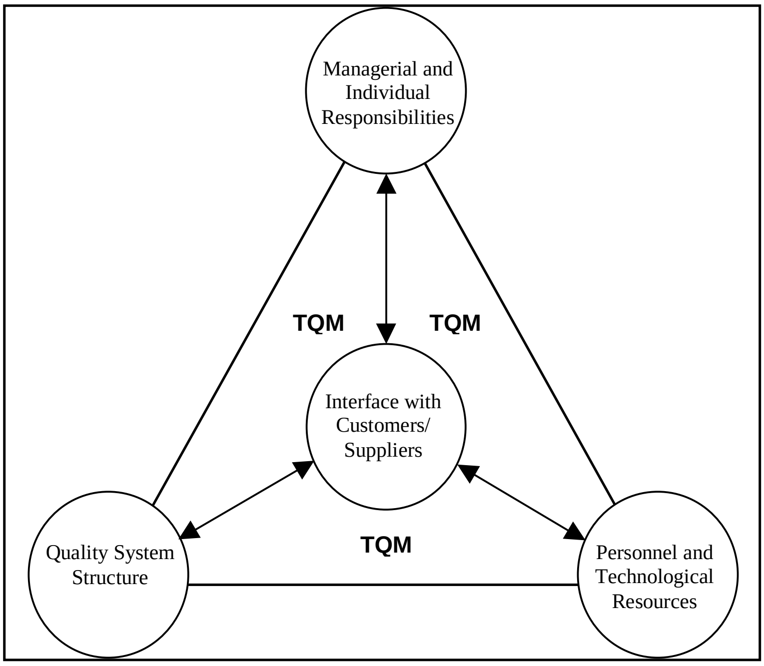
- improved performance;
- increased customer satisfaction;
- better customer and staff morale; and
- opportunity to use it as a first-class marketing tool.

While there are benefits to be gained from implementing QA, it must be acknowledged that many small and medium sized organizations have voiced their concerns over the difficulty and cost of introducing an ISO quality system (Buta and Karkhanis, 1996). Gnome (1995a) contends that the ISO-9000 series is inappropriate to small and medium organisations as the high costs associated with achieving and maintaining a certification program could significantly damage their business. In fact, Gnome (1995b) goes as far as to state that ISO 9000 requirements are far too sophisticated and do not add-value to small and medium-sized businesses. The direct costs of obtaining and maintaining ISO certification include registration fees, auditing fees and the optional consultant fees (Kennedy, 1995). Another barrier to certification that is often experienced is an increase in paperwork and associated indirect costs. Thus, organizations often do not see the advantages of improved productivity and reduced rework (Sanders, 1994). Ho (1995), however, points out that if an organization can gain a comprehensive understanding of the flexibility of the ISO 9000 standards then it can implement an effective system with minimal paperwork.

Service quality in architectural and engineering firms

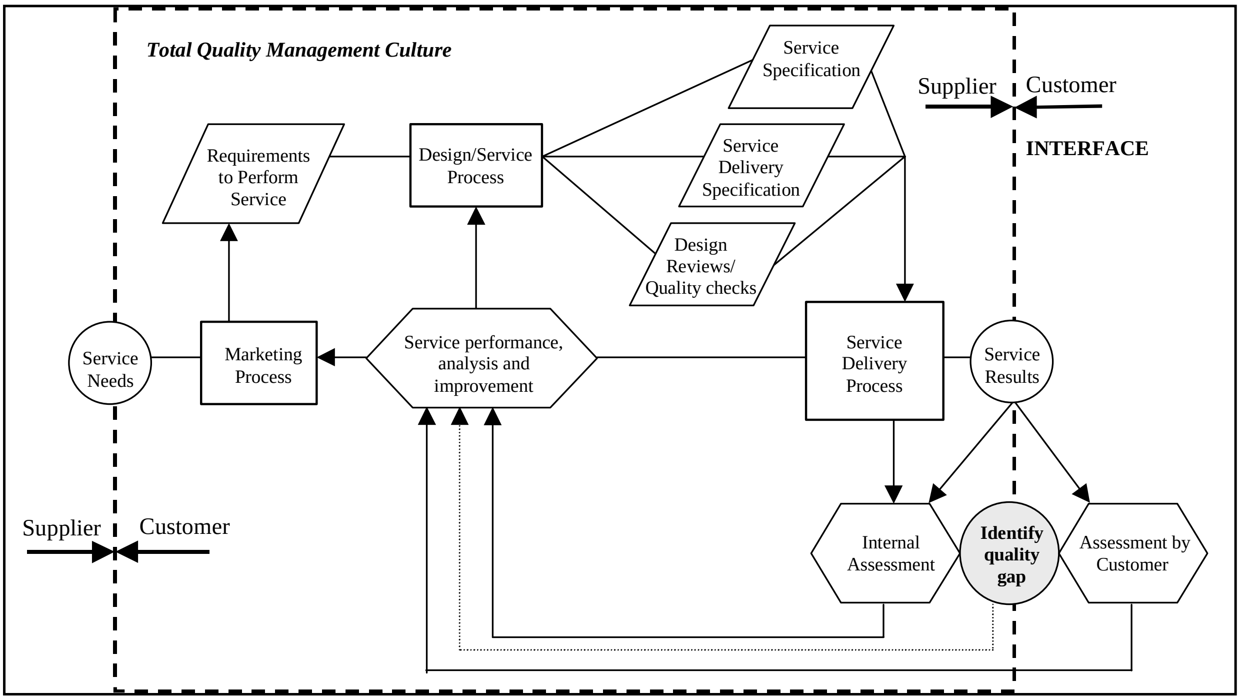
Recognizing the importance of quality in services, the International Organization for Standardization issued, as part of the ISO 9000 series of standards, a standard set of guidelines for the elements of a quality system for firms providing professional services such as those provided by architectural and engineering firms. This standard encompasses everything in a quality system from the first steps identifying customer's needs to the delivery of the service to the customer and subsequent analysis of its quality. It applies to main services as well as ancillary services that accompany either a main service or tangible product. Thus, it covers a number of situations, ranging from one in which a service accompanies a transaction involving a tangible product to one in which the tangible product involved bears less importance in the transaction, to one which no tangible product is involved. The needs of both the internal and external users of services are also addressed by ISO 9004-2. This standard also states that the requirements of the service to be provided by design firms must be clearly defined in terms of observable characteristics that can be assessed by their direct client. It also states that the process used to provide the service should be defined in terms of its characteristics that directly affect the execution of the service, even if they may not be observable by the client. Although clients do not directly use the services provided by design firms and so on, other project team members who are contracted to the client do use their services, albeit indirectly. It is implied that the information provided is timely and of a good quality. Figure 2 identifies the main elements of a quality system for services as presented by the standard. At the center of the system is the customer/supplier interface.

Figure 2: Key aspects of a quality system



While the standard provides the guidelines for service quality, TQM provides the environment for continuous improvement. Each of the three factors identified in Figure 2 is interdependent. Senior management within design firms are responsible for establishing the quality policy and objectives. In addition, they must clearly assign the responsibility for quality to all individuals that directly affect the quality of the service provided to customers. The established quality system must be audited and continuously analyzed, as indicated in Figure 3. Results of the audit and the service they provide must be evaluated.

Figure 3: The service quality loop interface between firms in the supply chain



The standard requires design firms to adequately motivate, train, and evaluate their staff. As most design firms are small-medium sized in nature, all designers at some point may be in direct contact with their clients and other project team members. Thus, it is important that they have the training and the necessary skills to communicate effectively. In addition, an appropriate information system is essential for good communications and for the production of the service required. The service quality loop in Figure 3 is another component of ISO-9004-2 and comprises of the following main processes:

- *The marketing process*: This process identifies clients and their needs through market research, examining what the competition has to offer clients and consulting with all staff within the firm to confirm their commitment and their capacity to meet the clients requirements. As there is currently an increasing shift toward the use of novation and design and construct procurement systems, design firms are now finding that contractors are more often than not their immediate clients. According to Oakland and Sohal (1996) marketing establishes the requirements for the service. These must be communicated throughout the firm in the form of specifications. Marketing is therefore seen as the process through which requirements are defined and communicated throughout all levels of the firm. Marketing is at the heart of TQM and the customer-supplier interface.
- *The design process*: The design process ensures that the service being offered is designed to suit the needs identified through the marketing process. The service, the process required to produce it, and the process required to control its quality are specified. Every design firm should attempt to exceed the expectations of its client (and indirect customers) in order to acquire repeat business.
- *The service delivery process*: The service delivery process includes the following steps – providing information regarding the service offered; responding and processing client requests, RFIs etc; and invoicing and collecting payment. The design firm should assess its service results. Their client and project team members should also

evaluate them. This assessment is the most important. The service delivery process is analyzed, and based on this analysis and on the assessment of the supplier and the customer, the process may be modified to improve the service.

The quality of service provided by design firms can be assessed using a number of techniques. Project team members should also evaluate the quality of service and the added value the design firms have provided to their service and *vice versa*. This approach could act as a mechanism for effectively promoting and sustaining continuous improvement in an environment were strategic partnering/alliances are operating. However, further work is required in order to establish the criteria to be used.

CONCLUSION

Each activity undertaken in a construction supply chain should add value to the final product. Starting with the identification of client needs, the service provided by design firms should add value to every link along the supply chain. This process culminates when clients and project team members are presented with a valuable service that is able to satisfy their needs so that the project can be constructed within predefined objectives. Design firms have a significant role to play in adding value to the final product. It is suggested that improvements in their overall service quality can significantly improve the overall performance of the construction supply chain, as it during the design process that the greatest savings in time and cost can be made in a project. A case study was used to identify *hygiene factors* that inhibited value creation and which led to customer dissatisfaction. To overcome these consequences, it was suggested that design firms adopt a TQM philosophy so as to improve their overall service quality. Before TQM can be adopted design firms should first adopt the ISO 9000 standards in order to lay the foundations for a quality culture. By implementing such standards the quality of contract documentation produced might be improved, which in turn may reduce the direct and indirect costs of rework experienced in projects. If the service quality of professional firms, particularly design firms, is to be improved on behalf of their clients it is essential that they measure and evaluate the value they provide to each other's business together with the final product itself.

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Development of Construction Technology for Application in Space: Challenges in the Millennium

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INTRODUCTION

Shimizu Corporation was founded in 1804. In the 195 years of its existence, it has grown into a leading Japanese construction company. In the changing world environment, the company intends to make the best use of its accumulated experience to undertake construction in space. It therefore established the Space Project Office, now known as the Space Systems Division, in 1987.

This division has been undertaking research and development (R&D) activities in the following areas:

1. Improvement of space structures using terrestrial construction technologies.
2. Application of space technologies to construction engineering and design on the earth.
3. Support for manned space activities.
4. Contribution to social benefits through space R&D.

In this paper several activities in this division are highlighted.

SPACE STRUCTURES

Last year the construction of the International Space Station started and will be completed in 2004. The size of this structure is 110m×75m, and its weight is 415t. In case of these large structures, *construction* is a very important activity, different from constructing conventional small space structures like artificial satellites.

The idea of Solar Power Satellite (SPS) was proposed in the USA more than 30 years ago. Recently, several countries re-examined this system to tap power from space. This system needs much larger space structures, for example several km, to receive solar power, convert it to electric power, and transmit this power to the earth. In order to realize SPS, the technology of space construction would be getting much more important in the 21st Century.

Generally speaking, space structures should be designed very light, because space transportation cost is very expensive. For the construction of large space structures using those light parts, there are 3 kinds of construction systems as follows:

1. Erectable: transport small parts from the earth and connect them in space.
2. Extendable: transport folded structure from the earth and extend it in space.
3. Inflatable: transport flexible bag from the earth and inflate it by gas in space.

TRUSS ASSEMBLY EXPERIMENT BY ROBOT

Space robot is very important for space construction, because the construction environment in space is very dangerous for human beings. Commonly used space robots are space manipulators, which are used on the USA space shuttles and international space stations.

In Japan the Space Robotic Experiment on the Engineering Test Satellite-7 (ETS-7) has been carried out since last year and completed recently. The objective of this experiment is to undertake space construction technologies using space robot. This experiment includes construction and deconstruction of erectable and extendable truss systems. Shimizu Corporation has been in charge of this experiment, which was successfully completed.

LUNAR OXYGEN PRODUCTION

Oxygen is one of the most important materials for various activities on the moon, because this element is indispensable for life support and for space transportation systems. Consequently, it will be the first material to be produced on the moon. If lunar oxygen production is realized, our space activities will be greatly expanded.

Shimizu Corporation has been conducting research on lunar oxygen production since 1991. There are some proposals for the oxygen production system using lunar materials. Shimizu has been focusing on hydrogen reduction of ilmenite as one of the most realistic processes.

Ilmenite sand is heated in a three-stage fluidized bed reactor, so that reduction occurs at a reaction temperature of about 1000 ^{0}C. In this reaction, water vapor can be produced. The water is decomposed continuously to oxygen and hydrogen which is recycled.

CONSTRUCTION ON THE MOON

Lunar base development consists of preliminary unmanned research and preparation missions, and manned missions for the full-fledged exploration and resource exploitation. The manned exploration stage includes construction of habitat and laboratory modules, with large electric power supply and communication facilities.

The prime candidate of lunar-based construction system is a modular assembly system using several modular units like the International Space Station. As the larger the structure, the greater the transportation cost, so further study has been conducted into deployable and inflatable structures.

Shimizu Corporation and McDonnell Douglas (now, Boeing) have carried out several joint studies on lunar base construction, and proposed several construction systems on the moon. These proposals include modular systems and inflatable systems.

One of unique ideas is a construction system using concrete on the moon. Use of concrete has two principal advantages; its material properties and inexpensive production cost. The former has proved effective in constructing primary structures and shielding radiation. The latter is possible as there would be some degrees of in-situ creation.

SPACE TOURISM

Astronauts' anecdotes and documentary films provide us opportunities to become familiar with space. Several surveys conducted in Japan clearly showed that the idea of space tourism is becoming increasingly popular. If low-cost fully reusable space vehicle is successfully developed, space tourism will be a viable market.

Shimizu Corporation proposes the Space Hotel to support the development of this promising business opportunity. This hotel is a large-scale space structure consisting of a 240m long elevator shaft and four functional element; energy supply, platform, public area, and guest room.

Tour participants will spend a pleasant time in the space hotel, viewing at the ‘transparent blue’ Earth, thin veil atmosphere, beautiful floating clouds and the dawn of the Earth.

SIGNIFICANCE OF R&D FOR SPACE IN A CONSTRUCTION COMPANY

Many kinds of advanced technologies in aerospace and construction can be transferred to each other through space related R&D in a construction company. And new business opportunity can be generated through these activities.

For young engineers, space related R&D is very much attractive, and they can reap many technical fruits. Thus, these activities can be one of the effective in-house education systems for creative engineers.

For the top management, they can have a global view through these activities. They can watch their future business.

Of course, these activities are very effective for public relations. Many newspapers, magazines, and television stations report on our activities, so that the level of technology in Shimizu Corporation is very much appreciated.

Measuring European Construction Output: Problems and possible solutions

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Abstract

Construction industries are often characterised as large or small by reference to the proportion which gross construction output represents of the national economy. While this may be adequate in developed western economies, it is not so helpful in developing economies, or economies in transition, where data on both construction output and the national economy are particularly uncertain. This paper presents available data, discusses evidence of inaccuracy and examines a number of methods for improving the quality and reliability of that data. The paper concludes that this is an important topic and that there are methods of addressing it, including establishing internationally agreed definitions for comparable international values, specifically for construction.

Keywords: Construction, output, measurement, undercounting, international.

INTRODUCTION

Construction output is difficult to quantify with any accuracy. This is partly because of difficulties in definition: what should be included, what should be excluded? But it is also because it is intrinsically difficult to measure. Construction output in this paper refers to gross output: the total value of all inputs to construction work and the value added by the construction industry itself. In simple terms this is the price paid for construction work by the industry's ultimate customers. Typically, in national accounts, construction output is net output, the value added by the construction industry. Inputs - mainly building products and materials - will generally appear as outputs from manufacturing industry or mining. Gross output is usually measured; value-added is always an estimate. If construction is measured gross, in most countries it would be the single most important economic sector.

The usual bases of measurement for gross construction output include surveys of contractors, estimates of work approved or completed, and financial returns by major clients of the industry. All of these, however, have their shortcomings. Construction work is geographically dispersed and takes time to complete; much of it is small scale and undertaken by small firms or individual tradesmen (who may be missed by surveys); and, when it is large scale, much of the work is often subcontracted (and then there is danger of double counting). Often physical measures – such as m² built area – are adjusted to value measures using dubious conversion factors. In addition, in many countries a significant proportion of construction work is informal, if not illegal, and, more often than not, is unrecorded or under-recorded. It can also be difficult to estimate the importance of "do-it-yourself" (DIY) and self-build activity.

The usual units of measurement are, of course, national financial units. This is because these are the only common units we have to add together houses, roads, dams, schools, *et cetera*. But construction value is not necessarily a good indicator of construction volume particularly for international comparisons. For example, different (space and quality) standards and different conditions prevail in different countries and price levels in some countries can be significantly higher or lower than those in others. Moreover, methods of measuring construction output are different across countries and no standard international procedures have been agreed (Eurostat, 1995 and United Nations, 1997). Even when physical measures of output (*e.g.*, cement) are used, the differences in the use of the item measured are only partially related to the actual volume of construction. Construction output is quite heterogeneous in nature and country-specific construction processes can be important in relating resource inputs to construction output.

The purpose of this paper is to review the problems in obtaining data reflecting real national construction output in selected countries and which is comparable between countries. The paper is in six parts including this introduction. Part 2 reviews published data on construction output for selected countries in Western and Eastern Europe. Part 3 discusses the evidence for inaccuracy. Part 4 looks at volume data as an indicator of construction output. Part 5 attempts to reconcile different data sets and Part 6 presents some conclusions and recommendations.

CONSTRUCTION OUTPUT AND ITS SIGNIFICANCE

Table 1 summarises key data for eighteen countries in Western and Eastern Europe. The first three data columns provide contextual information on the relative sizes of the countries' population, economy and construction industry. The last two columns provide normalised comparable data. Output *per capita* is relatively high in Switzerland and Germany and relatively low in Spain and the UK in Western Europe, while it is relatively high in Slovenia and relatively low in Romania in Eastern Europe. The last column indicates the importance of gross construction output in the economy.

Table 1: Indicators of construction output in selected countries, 1997

Country	*Population (millions)*	*GDP ($US bn)*	*Gross construction output ($US bn)*	*Gross construction output per capita ($US)*	*Gross construction output as a proportion of GDP (%)*
Finland	5.1	120.0	12.6	2,443.3	10.5
France	58.6	1,395.6	109.7	1,872.1	7.9
Germany	82.1	2,099.4	222.4	2,709.4	10.6
Italy	57.5	1,146.3	111.8	1,943.3	9.8
Netherlands	15.6	360.8	39.1	2,507.3	10.8
Spain	39.3	532.7	61.0	1,551.7	11.5
Sweden	8.9	227.9	22.6	2,546.3	9.9
Switzerland	7.1	255.5	25.5	3,593.8	10.0
UK	58.5	1,288.5	95.7	1,626.4	7.4
Weighted average	-	-	-	2,111.9	9.4
Czech Republic	10.3	51.9	6.8	658.0	13.1
Estonia	1.5	4.5	1.0	692.7	22.4
Hungary	10.1	45.8	2.9	289.8	6.4
Latvia	2.5	5.4	0.7	276.0	12.4
Poland	38.6	135.9	13.8	358.3	10.2
Romania	22.6	35.0	4.6	205.0	13.2
Russia	147.3	447.6	53.7	364.7	12.0
Slovak Republic	5.4	19.5	2.2	408.0	11.2
Slovenia	2.0	18.2	2.4	1,189.2	13.0
Weighted average	-	-	-	368.5	11.5

Sources: based on IMF International Financial Statistics and Euroconstruct conference paper, Berlin, December 1998.

Table 1 indicates wide variations even in the last two columns. Relative to the Eastern European group of countries, the Western European countries tend to have high construction output *per capita* but low construction output as a proportion of GDP. In general terms the more mature economies have relatively high output *per capita*, in line with relatively high GDP *per capita*, but relatively low output as a proportion of GDP, largely because they are well provided with built infrastructure. Italy has close to archetypal Western European output characteristics; the Slovak Republic is a close to archetypal Eastern European economy. Slovenia is the Eastern European country most similar to the Western European ones.

It is important to note, however, that the data in Table 1 are not necessary very reliable. The next three sections of this paper address and comment on this issue.

EVIDENCE OF UNDERCOUNTING

Construction output data are not consistent in content. There is no generally accepted standard international definition and what is included and excluded varies from country to country. The Statistical Office of the European Communities (Eurostat) has, however, suggested such a definition (Eurostat, 1995). According to Eurostat, construction is defined as an industry, not as an activity including households. It follows, therefore, that it is not possible or desirable to attempt to measure the construction activity of households. Another Eurostat conclusion is that industry output should be measured through sample surveys of construction firms including small firms and self-employed tradesmen.

The authors have reviewed construction output data for two of the countries included in table 1 – Finland and the UK. These two countries were selected because the relevant information was available. Table 1 indicates that Finland's construction output *per capita* and its construction output as a proportion of GDP are 50% and 42% respectively higher than UK's. Finland's figures are higher than the Western European average; UK's are significantly lower. There is evidence, however, that Finnish output tends to be overstated and UK output understated. Table 2 summarises what is known to be included and excluded in the two countries' official construction output figures.

Table 2: Construction output in Finland and UK

Components of output	*Finland*	*UK*
Contractors output (including sub and		
specialist contractors)	included	included
Direct works organisations output *	included	included
Unrecorded output	not known	not known
Construction services	included	excluded
Black economy in construction	included	largely excluded
DIY materials	included	excluded
DIY labour	included	excluded
Taxes (including VAT)	probably excluded	VAT excluded

** UK output explicitly includes public direct works output and explicitly excludes private direct works output. Finland includes public output; it is not clear about private output.*
Source: Euroconstruct, 1997.

It is commonly agreed that construction services (design, management and other consultancy work) should be included in construction output. There is rather less agreement about the DIY sector: probably DIY labour should be excluded but possibly DIY material should be included. Similarly, treatment of the black economy varies from country to country. Generally, taxation should be included if it is paid by the industry's customers.

A recent report for the EU (Deloitte and Touche, 1997) suggests that the informal economy accounts for 12% of GDP in the UK. The percentage is considered to be around 35% in Greece, 25% in Spain and Italy and around 13% in France and German. The percentage of informal output in the construction sector is likely to be greater than that in the economy generally. Research from the University of Michigan Business School (1997) estimates the contribution of the illegal economy to GDP in Eastern Europe from 1989 to 1995. A comparison of their estimation for 1995 with Euroconstruct estimates of illegal work in construction in 1996 gave the following results: in the Czech Republic it was estimated to be around 11% in the total economy against 13% in construction; the figures for Hungary were 29% and 28%; the figures for Poland were 13% and 20%; and the figures for the Slovak Republic were 6% and 9%. In the former Soviet Union states the share of the black economy in GDP is reckoned to be even higher, on average 40% of GDP in 1995, from a low of 11% in Estonia to a high of 63% in Georgia.

Recent work in the UK (Davis Langdon Consultancy, Construction Forecasting and Research, 1997) suggests that construction services, DIY work and the black economy in the construction industry account for 21% of total output. Hence the share is equivalent to more than 1.5% of GDP (21% of 7.4%) or around US$20 billion.

Allowing for construction services and the black economy, but ignoring DIY activity, UK construction output might be as much as, say, 8.9% of GDP or US$1,966 *per capita*. Reducing Finnish construction output by, say, 2% to allow for DIY materials and labour would make it 8.5% or US$1,984 *per capita*. Hence, both output *per* capita and output as a proportion of GDP in Finland become lower than the UK. This example is illustrative only but it serves to support the argument that official output data even when it is considered reliable, may not be comparable.

A review of definitions of construction output in European countries (Euroconstruct, 1997) suggests that new construction work by contractors is relatively well recorded but that data on work to existing buildings are rather less reliable. Construction services, DIY activity and the black economy may be included to at least some extent but are often based on estimates, rather than formal measurement; VAT is normally excluded.

National construction output data are known to have been revised due to undercounting. In the UK, for example, there have been at least two occasions when output data were revised – upwards - to take account of activity by firms missed by surveys (Hillebrandt, 1984). And in Egypt in the early 1980's the authors know that national construction output data were adjusted to take account of unrecorded activity (World Bank, 1981).

As suggested above, the purchasing power of different currencies can vary. Purchasing power parity is an alternative approach to the determination of exchange rates. The underlying economic concept is the "law of one price", which says that a good should have only one price in a competitive environment. Purchasing power parities generalise the law of one price to the general price level of a country. According to this, the exchange rate between, say, British pounds and US dollars should equate the general British price level with the general US level. Table 3 lists GDP *per capita* in nominal exchange rate terms and in PPP (Purchasing Power Parity) terms for the same countries as Table 1 as calculated by the World Bank.

Table 3: GDP in nominal and PPP terms for selected countries, 1997

Country	*Per capita nominal GDP ($US th)*	*Per capita GDP (PPP) ($US th)*	*Ratio nominal to PPP*	*Gross construction output per capita in PPP terms ($US)*
Finland	23.3	19.9	117.5	2,078.6
France	23.8	22.5	105.7	1,770.7
Germany	25.6	21.2	120.7	2,245.6
Italy	19.9	21.6	92.4	2,102.1
Netherlands	23.1	22.0	104.9	2,389.6
Spain	13.6	16.3	82.9	1,871.2
Sweden	25.7	19.9	129.3	1,968.9
Switzerland	36.0	24.3	148.2	2,424.5
UK	21.9	21.1	103.7	1,567.7
Weighted average	22.4	20.9	106.9	1,973.9
Czech Republic	5.0	10.9	46.4	1,418.2
Estonia	3.1	6.4	48.6	1,425.0
Hungary	4.5	7.2	62.5	463.4
Latvia	2.2	4.2	51.8	532.8
Poland	3.5	7.3	48.4	740.1
Romania	1.6	5.1	30.7	668.2
Russia	3.0	4.7	64.7	563.7
Slovak Republic	3.6	8.6	42.2	966.1
Slovenia	9.1	9.8	93.4	1,273.9
Weighted average	3.2	5.6	56.5	654.2

Sources: based on IMF International Financial Statistics, CIA World Factbook 1997 and Euroconstruct conference paper, Berlin, December 1998.

GDP *per capita* in nominal exchange rates and in PPP terms tend to be similar in developed countries - they are identical in USA, because it is the base country. They diverge significantly in less developed and transition economies: the Czech Republic, Estonia and Poland have purchasing powers for their national currency more than double that obtained by using commercial exchange rates. The estimation of PPPs for the construction industry is difficult because output can be very different in content across countries. Variations in design, materials and standards can make comparisons problematic. Moreover, on average, construction generally relies on national resources and is non-traded.

Vermande and van Mulligen (1999) show that the PPP methodology (applied by OECD/Eurostat) for the construction sector is not foolproof. If standard, identical buildings are compared there is a loss of representivity. On the other hand, if functionally similar buildings are used, the gain in representivity is offset by more heterogeneity and comparability will suffer. In this paper we approximate PPPs in construction with PPPs in the general economy. The implication is that the same amount of US$ buys about three times as much construction in Poland as it does in Switzerland. The evidence is that this is probably true for small-scale domestic construction but rather less true for major sophisticated foreign investment projects (where much of the material and some labour are likely to be imported).

This section demonstrates that not only can definitions of construction output distort international comparisons but so also can international exchange rates. Table 3 suggests that general price levels in Finland are some 13% higher than those in the UK, hence the relative difference between construction volume in the UK and Finland should be adjusted again.

CEMENT CONSUMPTION AND DWELLING COMPLETIONS AS INDICATORS OF OUTPUT

Other research (Meikle and Hillebrandt, 1988) suggests that some construction resources can be used as indicators of construction output. Cement is an example. It is usually manufactured in large-scale plants and reasonably reliable production data are maintained. Data are usually also available on exports and imports and, since cement does not have an extended shelf life, annual consumption figures can be calculated with reasonable confidence. Table 4 is compiled from data obtained from the international trade association. It presents data for fourteen countries. Excluding the highest and lowest figures in each group (Spain and Sweden for Western Europe and Hungary and Estonia for Eastern Europe), the range of national figures for cement consumption *per capita* is relatively narrow. It is narrowed even further when PPP's are used.

Table 4: Cement consumption data for selected countries, 1997

Country	*Cement consumption (000 tonnes)*	*Cement consumption per capita (kg)*	*Cement consumption per 000$ construction output (kg)*	*Cement consumption per 000 $ construction output in PPP terms (kg)*
Finland	1,332	259.1	106.1	124.7
France	18,729	319.6	170.7	180.5
Germany	34,258	417.3	154.0	185.8
Italy	33,768	587.1	302.1	279.3
Netherlands	5,444	349.0	139.2	146.0
Spain	26,794	681.4	439.2	364.2
Sweden	1,315	148.4	58.3	75.4
Switzerland	3,663	516.6	143.8	213.1
UK	12,765	217.0	133.4	138.4
Czech Republic	4,182	406.0	617.1	286.3
Estonia	201	136.7	197.4	96.0
Hungary	2,982	293.8	1,013.7	634.0
Poland	12,473	322.7	900.8	436.1
Slovak Republic	1,686	313.4	768.1	324.4

Sources: based on IMF International Financial Statistics, CIA World Factbook 1997 and DLC estimates based on Cembureau, Brussels.

Cement consumption per unit of construction output in Eastern and Central Europe was formerly probably at least double that in Western Europe. This was because of the highly concrete-intensive technology used, for example, for high-rise multi-storey flats and factory buildings. It may also have been due to the low price put on construction output which would make cement, expressed in real terms, high in relation to undervalued output. The countries which have high apparent consumption of cement are often those where the GDP in PPP terms is higher than the money GDP and those with low consumption of cement are those where GDP in PPP terms is lower than the money GDP. Since the collapse of the command economy in Eastern and Central Europe, less cement-intensive methods of construction are being used so that some of the differences in apparent cement intensity may disappear in the future.

Cement may be a useful indicator of the real volume of construction output. Table 4, for example, tends to support the earlier conclusions that, despite the official data, construction output in the UK may be higher, rather than lower, than construction output in Finland. The shortcomings, however, of cement as an indicator of construction volume include taking account of the types of technologies used: some countries use or used highly cement intensive construction technologies (World Bank, 1992). There can also be problems with data: while production figures are usually reliable, figures for exports and imports are often less so. Cement data can, therefore, be a useful guide but cannot be a substitute for direct measures of construction output.

Data on housing completions give some indication of one – albeit a significant – sector of construction output. However, they cannot be considered as a reliable indicator of the total amount of construction work. In the past the proportion of housing in total work was fairly stable in Eastern and Central Europe; now, however, disruption in the economies means that such relationships are much less reliable.

Table 5 presents data on dwelling completions for thirteen countries. The data in the second column confirm that, generally, the construction industry builds more dwellings *per capita* in Western Europe. In the Western European countries only Sweden and, to a certain extent, the UK show low output. Conversely, the data in the third column, and to a lower extent in the fourth column, show a different picture. When normalised by output, housing completions are relatively higher in Eastern countries than Western countries.

Table 5: Dwelling completions data for selected countries, 1997

Country	*Dwelling completions (000's)*	*Dwelling completions per 000 population*	*Dwelling completions per m $ housing output*	*Dwelling completions per m $ housing output in PPP terms*
Finland	58	7.2	10.7	12.6
France+	272	4.6	11.7	12.5
Germany	501	6.1	6.4	7.8
Italy	226.3	3.9	10.9	10.1
Netherlands	92.3	5.9	9.8	10.4
Spain	272.0	6.9	13.8	11.5
Sweden	13.0	1.5	10.9	14.2
Switzerland	34.2	4.8	4.4	6.5
UK	178.2	3.0	13.8	14.3
Czech Republic	15.9	1.5	21.2	9.9
Hungary	28.1	2.8	36.6	23.0
Poland	73.7	1.9	49.2	23.9
Slovak Republic	7.2	1.3	26.9	11.4

Sources: DLC estimates based on Euroconstruct conference paper, Berlin, December 1998.
+ starts

Generally, in housing statistics, a building is classified as residential when more than half its gross floor area is used for dwelling purposes. It is unclear whether this distinction for number of dwellings also applies to value of output. Some countries collect data on number of dwellings only in these residential buildings and there may or may not be a substantial number of dwellings in other buildings. There are also problems the other way round. It is common in some countries for commercial and professional offices to be located in primarily residential buildings so that the statistics of non-residential building may not reflect, and therefore understate, the actual new occupation of office space.

Labour is an indicator which, in theory, should provide a reasonable estimate of construction output. Unfortunately, labour figures are often not reliable and can distort both inter-industry and international comparisons. One problem is the extensive use of part-time and self-employed workers. But the main problem is that a substantial number of construction workers undertake work on a piece-work basis and, therefore, their employment is not recorded. Brick consumption (or production) is another possible indicator. Again, substantial differences in building technology across countries – and the ability to stockpile bricks indefinitely – reduce the reliability of this indicator.

The next section brings together and compares some of the different approaches to assessment of construction output.

RECONCILING ESTIMATES OF CONSTRUCTION OUTPUT AND OTHER INDICATORS

This paper reviewed definitions of construction output and the differences these can make to the available data; it has also discussed how purchasing power parities can help to adjust nominal exchange rates value measures of output to a more comparable basis; and it has considered how physical resource units such as cement consumption can help to indicate output. Table 6 presents output data in nominal and PPP terms and cement consumption and dwelling data for fifteen countries. All output are expressed in terms of indices with the All Europe Average being equivalent to 100.

Table 6: Comparisons of measures of construction output

Country	*Gross construction output per capita in nominal terms index**	*Gross construction output per capita in PPP terms index**	*Cement consumption per capita index**	*Dwelling completions per capita index**
Finland	177.7	146.3	72.7	129.2
France	136.1	124.6	89.6	114.2
Germany	197.0	158.0	117.0	150.1
Italy	141.3	147.9	164.6	96.8
Netherlands	182.3	168.2	97.9	145.6
Spain	112.8	131.7	191.1	170.2
Sweden	185.1	138.6	41.6	36.1
Switzerland	261.3	170.6	144.9	118.7
UK	118.3	110.3	60.9	74.5
Average	168.0	144.0	116.2	117.6
Czech Republic	47.8	99.8	113.9	38.0
Estonia	50.4	100.7	38.3	NA
Hungary	21.1	32.6	82.4	68.1
Latvia	20.1	37.7	NA	NA
Poland	26.0	52.1	90.5	46.9
Romania	14.9	47.0	NA	NA
Russia	26.5	39.7	67.1	79.1
Slovak Republic	29.7	68.0	87.9	32.8
Slovenia	86.1	89.7	NA	NA
Average	35.8	63.0	91.5	69.0
Average - All Europe	100.0	100.0	100.0	100.0

Index based on each column's average value for all countries listed
NA = not available

All of the data in Table 6 are presented in *per capita* terms but the output columns take no account of differences in definition. It is interesting to see that some columns indicate that some countries are very similar while other columns show very different figures. For example, Germany and Switzerland score high on every single indicator whereas Finland and Estonia score low only on cement consumption but this may well be due to the particular construction techniques adopted in those countries. Gross construction output *per capita* in nominal terms is generally higher in Western Europe and always lower in Eastern Europe than the other measures. Generally, the physical measures (cement and dwellings) are as good if not better indicators of output *per capita* in PPP terms than output *per capita* in nominal terms. The table does not prove that cement or dwelling completions are consistently reliable indicators but suggests they may be used along with other measures. Presentation of the data in this way raises more questions than it answers.

CONCLUSIONS AND RECOMMENDATIONS

In order to demonstrate clearly the relative importance of construction output within and between countries it is essential that a standard international definition is established. This should be in current financial terms in national currency and should probably include:

- all construction work undertaken by contractors, tradesmen or direct works organisations at the value charged to the customer including tax, if appropriate.
- all technical professional services related to construction work (whether or not the work is undertaken) at the value charged to the customer including tax, if appropriate. This will include design and other technical services and project management services but will generally exclude financial and legal services unless directly associated with the construction work.

Professional services should be included because increasingly the boundaries between work done by contracting and consulting companies are becoming blurred. In package deal and design and build contracts, for example, design and management charges are usually part of the total contract value and hence total construction output.

Care should be taken to allow for all work whether formal or informal. If, however, construction output is not included in recorded economic activity so that both construction and total national output are underrecorded, then this should be taken into account when assessing the contribution construction makes to the economy. It is likely that there is rather more informal activity in construction than there is informal activity in the economy generally. A recent proposal from the European Commission suggested that lowering value added tax (VAT) on construction could help to increase revenue. It could also, incidentally, by reducing the volume of informal construction, improve construction statistics. Improved data on construction output could influence allocations of funding within the European Union and between the Union and other countries.

Recognising that value measures of construction output are not necessarily good indicators of construction volume, more work needs to be done on international construction comparisons. PPPs need to be developed specifically for construction work. Initial work on construction cost comparison methodologies in European countries has been undertaken (Eurostat 1995; United Nations, 1997); this will need to be extended to less developed and transition economies.

Having established that construction output is generally undercounted, does it matter? The authors of this paper believe that it does. It matters because it understates and, by implication, underepresents the significance of construction in national economies and in the world economy. It also matters because it distorts comparisons among countries. But, perhaps most of all, it matters because what is undercounted tends to be under-valued in national policies.

The authors would welcome comments on the issues raised in this paper.

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The Financing of Public Infrastructure Investment in South Africa

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Abstract

This paper is based on recent work by the author reviewing infrastructure investment for the South African government. It includes the following:

1. a historical review of infrastructure investment with a particular emphasis on different sectors and types of assets;
2. a brief review of the post-1994 infrastructure trends in relationship to changing government policy priorities;
3. particular public-sector constraints to the financing of infrastructure directly through the fiscus;
4. the effects on construction industry development arising from these fiscal constraints; and
5. the infrastructure investment environment in the future.

The basic conceptual framework for this analysis derives both from the economic theories of investment cycles and theories of infrastructure investment. Whilst recognising the fiscal limitations of the current Government policy, this paper offers a relatively positive prognosis of the potential for future investment in infrastructure.

Keywords: *Infrastructure delivery, business cycles, fiscal constraints, backlogs.*

INTRODUCTION

The investment in infrastructure has always been an integral part of the South African development strategy, but in the late 1980s, when expenditure on the war in defense of Apartheid redirected resources into the security apparatus, infrastructure spending faltered. However, the post-1994 government reasserted the need to invest in infrastructure, albeit mainly to redress past inequalities in service provision and re-orient the economy towards regional and international trade.

Since the publication of the Growth, Employment and Redistribution (GEAR) policy, the new government's fiscal strategy has been made clear. Key elements of this strategy lie in reducing the budget deficit in order to reduce fiscal pressures on the capital markets and to reduce debt servicing costs, which remains the largest line item on the budget (GEAR 1996, Budget Review 1998).

The fiscal conservatism of this strategy is however, meant to be balanced by an expansion in private-sector industrial investment that will generate the revenues and employment to pay for increased service delivery. Fundamental to promoting sustained economic growth and job creation, is the intention to accelerate infrastructure development. The Department of Finance have described their intentions regarding infrastructure investment in the following terms:

….. [one of the objectives of GEAR is] an expansionary public infrastructure investment programme to provide for more adequate and efficient economic infrastructure services in support of industrial and regional development and to address major backlogs in the provision of municipal and rural services (GEAR 1996: 4).

…. investment in infrastructure builds economic capacity and enhances competitiveness, while contributing to the quality of life of poor people. Energy, transport, communications and social infrastructure bring significant benefits to women and children, particularly (Budget Review 1998: 1.5).

The Department of Finance's infrastructure investment strategy therefore relies quite strongly on the public corporations, largely financed through private-sector equity or loans, to contribute to infrastructure investment, especially in transport and telecommunications provision. They have however noted that, in order to address infrastructure backlogs, and

…. recognising the limited capacity of the fiscus, Government is committed to the application of public-private sector partnerships based on cost-recovery pricing where this can practically and fairly be effected (GEAR 1996: 16).

It can therefore be expected that public-private partnerships and other alternative forms of service delivery will be used to address the mounting backlogs brought about by Apartheid and a lack of rehabilitation and maintenance.

A historical review of infrastructure investment

Historical evidence for the period 1960-1998 indicates that gross domestic fixed investment (GDFI) peaked in 1981 (R70 billion in 1990 prices) declined 35% until 1994 (R46 billion). In the past four years it grew 45% by the end of last year (R67 billion). The graph below shows that private-sector investment has been significantly greater than public-sector investment and that public authorities were the second most significant investors until the 1980s when public corporations began investing an increasing proportion of the public-sector share (see Graph 1, below).

Between 1960 and 1993, the proportion of investment coming from the public-sector (public authorities and corporations) ranged between 30% (1993) and 52% (1979). Interestingly, given the stated policy objectives of the new government, the public-sector infrastructure share has declined to between 25% and 27% from 1994 to 1997, only increasing again to 33% in 1998 (SARB 1994: B 53-57, 1999: S115). Although the level of public investment increased marginally during these years, it was the surge in private-sector investment which boosted overall GDFI expenditure. As noted below, part of the shift from public to private investment is due to explicit government policy to shift infrastructure spending, but the growing predominance of private-sector investment predated this policy shift.

Fig. 1 also shows that for the first fifteen years under review, public corporations contributed significantly less that public authorities to GDFI, but by the late 1970s these contributions had almost equalised. Although the public corporations contribution to GDFI increased from 7% to about 20% by the 1980s, public authorities' contribution declined from 37% to 23% over the same period, which has meant that the total contribution of the public sector had declined relative to that of the private sector.

If public-sector infrastructure spending is examined in more detail, we find that construction works made up the vast bulk of the investment of both public authorities and public corporations. In the case of public authorities, these construction works would largely comprise the roads, water and sanitation reticulation that are required for the development of communities. They would also include the national highway system and bulk water and sanitation infrastructure (dams, treatment plants). It is worth noting that the peak investment was in the early 1970s, and that such infrastructure investment has been declining ever since. However, the election of the new government in 1994 has turned the trend, and the past three years has indicated an increase in such infrastructure.

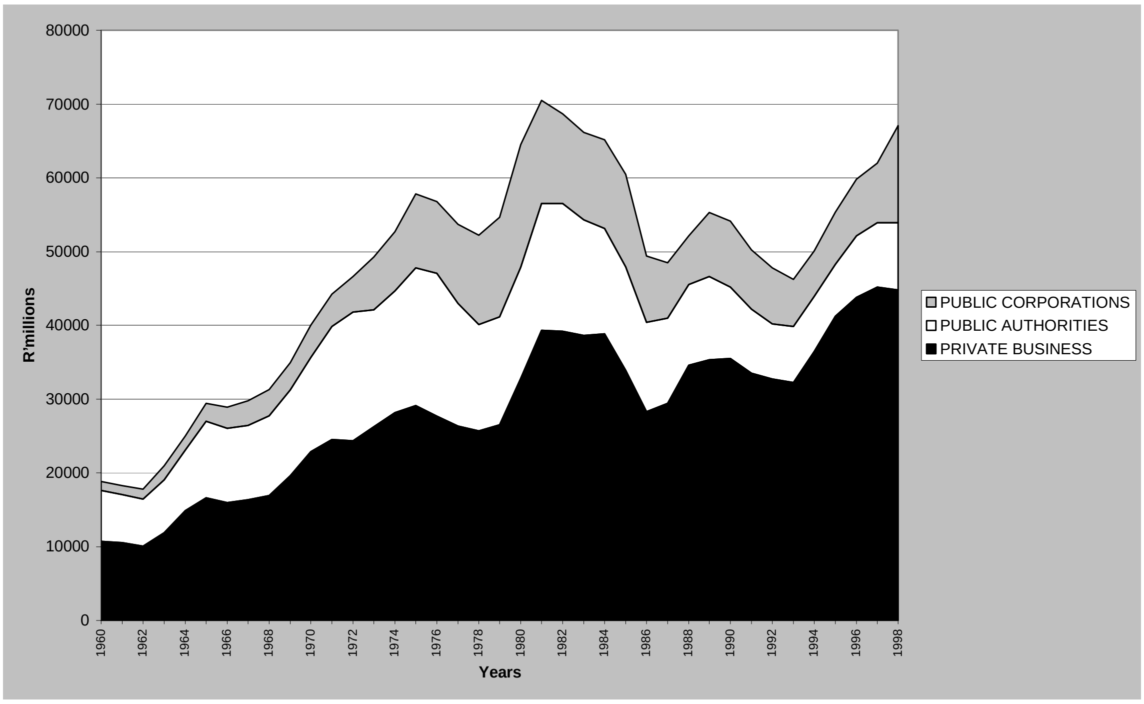

Fig. 1: Gross Domestic Fixed Investment (1990 prices) between 1960 and 1998 for Private Sector, Public Authorities and Public Corporations
(SARB 1994: B 53-57, 1999: S119).

In the case of public corporations, two large peaks in construction works represent a huge investment in power stations in the 1970s and the Petrol-from-Gas project in the late 1980s. It is worth noting that non-residential buildings (office accommodation, hospitals, schools and security facilities) peaked between the 1970s and 1980s, representing a shift to private accommodation in the 1990s. These trends also indicate that public-sector investment in housing has always been relatively smaller than other investment and has declined to virtual insignificance in the last couple of years.

To conclude this section on investment trends, Fig. 2 shows that public-sector economic infrastructure investment (defined as 'roads, bridges, dams, electricity and water supply') has consistently dominated social infrastructure spending (defined as 'schools, hospitals, etc. and administrative services').

The data indicates that the proportion of public-sector investment in economic infrastructure to total GDFI declined from an average of 28-36% of total GDFI in the 1960-1980s to 19% in 1995 before rising again to 29% of total GDFI in 1998. In the 1990s as private-sector fixed investment increased relative to that of the public-sector, economic infrastructure averaged around 20% of total GDFI although it has showed an increase in real terms since the new government was installed.

Public-sector social infrastructure investment has varied between 4% and 6% of total GDFI from the 1960s to the 1990s. Since 1994, despite political objectives aiming at an increase in social infrastructure spending, there has been a decrease relative to total GDFI (2.7% in 1994, 2.1% in 1995, 1.9% in 1996, 2.0% in 1997 and 1.9% in 1998) as a result of the increase in private-sector investment and in economic infrastructure although the latter category has not grown as quickly as the private sector.

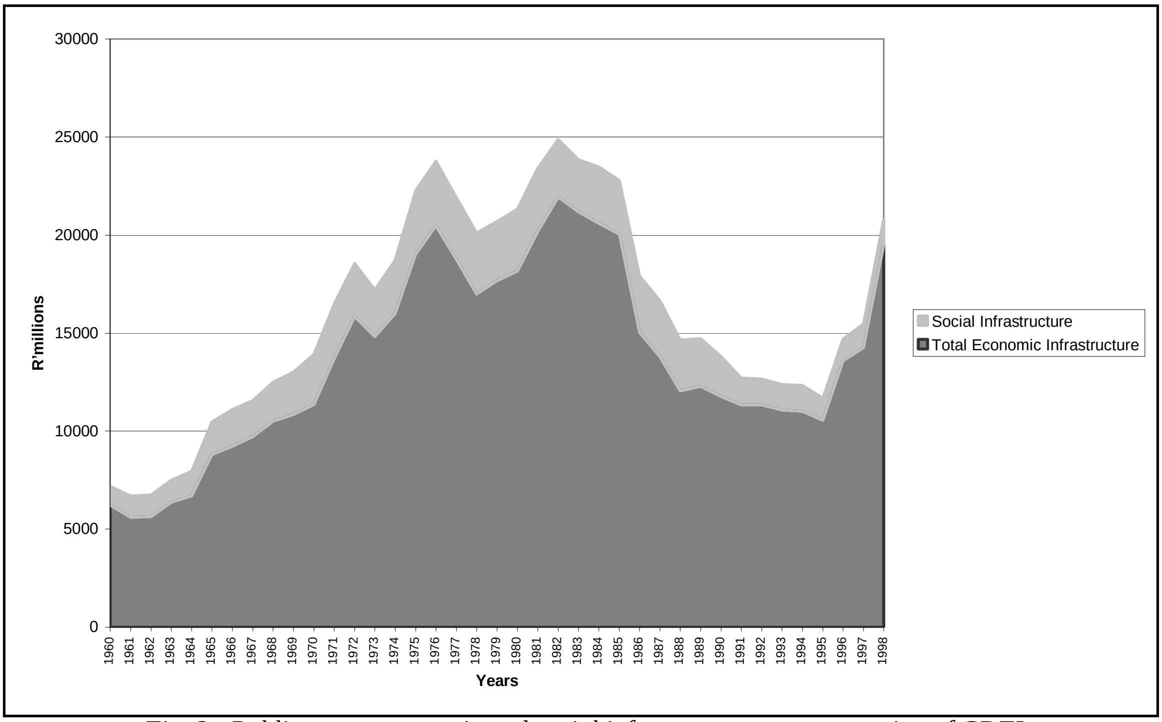

Fig. 2: Public sector economic and social infrastructure as a proportion of GDFI (SARB 1994: B 53-57, 1999: S115).

Discussions with those who compile the National Accounts made clear that the decline in social infrastructure investment is partially due to the fact that public-sector housing funded through subsidies has been classified as private-sector investment since 1990. This accounts for between R1-2 billion in 1990 prices and would therefore marginally change the shape of Fig. 2. However, the overall point remains that social infrastructure spending has not increased significantly with the new government.

An economic explanation of the trends

These trends have been analysed in other research on the South African construction industry. Langehoven (1993b) has sought to explain the decline of construction in the later 1980s and early 1990s, but in particular, the dramatic decline of civil engineering, in comparison to trends occurring elsewhere. He argued that the construction trend can be linked to a series of long-term cycles, the most significant of which is the 'Kuznets' and 'Kondratieff' cycles which relate to construction investment. The different duration of the cycles can therefore be related to the relative durability of different construction goods (Van Duijn, 1983, Langenhoven, 1993b: 12). Langenhoven (1993b) argued that construction could have been expected to decline in the 1980s as "a result of over expansion in various types of highly durable capital goods in the past" (p. 12).

Langenhoven suggested that the "accelerator-multiplier" effect associated with the fixed investment cycle is largely responsible for the volatility and perhaps the decline in the investment in construction, since many construction goods are supplied in large-scale entities rather than in many smaller units (Van Duijn, 1983). For instance, it may be uneconomic to supply many small power stations, so investment in power stations is likely to occur at infrequent intervals when capacity is expanded in large quantums. That new power station will then result in an over-supply of power, and hence remain a dampener on further fixed investments in power stations until economic growth has again expanded beyond the limits of the existing investment (Langenhoven, 1994: 3-4).

If these explanations are correct, then it is unlikely that future public spending on infrastructure will smooth the construction cycle, particularly for the civil sector whose products are generally of a larger scale than for building. Instead, the greater the scale of provision (as in the 1970s) and/or the greater the quantum (such as the recent Lesotho Highlands Water Project, and the large-scale steel and aluminium processing projects), the longer it will take for construction demand to recover. On the other hand, since much post-1994 spending is in the provision of construction goods on a smaller scale (township service reticulation rather than bulk treatment plants), this may imply a steadier demand in the near future.

Similar trends have been observed in the building sector. Snyman (1989a) shows that since 1946, the country has experienced a real growth rate in Gross Domestic Product (GDP) of between 4% and 5% per annum (constant 1980 prices). This trend faltered in the late 1970s, with a growth rate of only 0.3% in 1977, and in the mid 1980s, with the first absolute economic decline in the post-war period (Snyman 1989a: 13-14). There was a corresponding, although more exaggerated, trend with the investment in building. While the long-term investment in building has exhibited a growth rate of 4% per annum, the building industry has experienced absolute decline much more frequently, and with much greater variations than the trend for GDP. Total investment in buildings experienced an absolute decline in the periods 1950-1, 1955-6, 1959-62, 1968, 1971, 1978-9, 1982, 1985-1988 (Snyman, 1989a: 14).

The periods of absolute decline in private investment in buildings are cyclical and seem to exceed and last longer than those for the public sector. Snyman (1991b: 9-10) suggests that these variations can in part be attributed to a medium term "Kuznets Cycle". Snyman and Kilian found that there had been two Kuznets cycles in the private sector of the building industry. The first lasted from 1946 to 1962, while the second is evident from 1963 to 1978/9. A third upswing of the cycle was interrupted by the government "Austerity Package" of 1984, the effects of the 1985 Rubicon speech, and the high interest rates of the late 1980s.

Unlike the trends for private investment, public investment in buildings does not conform to the Kuznets cycle. Public residential investment experienced a sharp rise in the 1960s and 1970s and then declined dramatically in the early 1980s as a result of the change in government housing policy. Likewise, public non-residential investment rose rapidly through to the mid-1970s, and has declined considerably since then, although there was a modest revival in the mid-1980s and late 1980s (ibid.: 11-12). Kilian has shown that in the post-1946 period until the early 1970s, government investment on buildings has tended to counter-act and thus balance out the peaks and troughs of private investment. Since then, government investment has tended to move in parallel with the private sector with the result that the subsequent peaks and troughs of the building cycle have been further accentuated (Kilian 1980: 11).

If the South African construction cycles can be explained by 'Kuznets' and 'Kondratieff' cycles, we would expect these to be reflected in current government priorities. The 'Kuznets' cycle which was interrupted in the 1980s should have seen social infrastructure spending increased to re-address the demographic inequalities brought about by Apartheid policies. Interestingly, although this was part of the original Reconstruction and Development Programme (RDP), we have seen above that social infrastructure spending has not increased significantly. Similarly, if the 'Kondratieff' cycle is reflected in government priorities, we would not necessarily expect significant spending on economic infrastructure whilst existing capacity is not fully utilised. What we have seen however, is that a significant amount of new economic infrastructure has been commissioned, but insufficient attention is being paid to the rehabilitation and maintenance of existing infrastructure stock (see below).

Current budget backlogs in service delivery, maintenance and rehabilitation

The 1998/99 budget indicated that there will be virtually no growth in infrastructure investment financed by the fiscus itself and that capital expenditure financed directly by the budget will only increase approximately R2 billion (in current terms) by the end of the three-year budget period. A large contribution to capital expenditure will, however, come from the parastatals who will ensure that the public-sector contribution will increase to about 7% of GDFI, or R56 billion, by 2000/01 (Budget Review 1999).

Evidence from the 1999 Budget Review process also confirmed that social infrastructure continues to lag behind economic infrastructure investment in the same proportion that were described in the historical section above. This indicates that there has been little re-prioritisation towards social infrastructure investment since 1994. This trend was exacerbated by the 1998/99 budget which saw a significant cut in most of the budgets of the departments serving the household sectors (mainly social infrastructure) as budget rollovers were eliminated.

This lack of investment in infrastructure should be evaluated against estimated backlogs and the failure of the current Government to rehabilitate and/or maintain existing assets. The National Infrastructure Investment Framework estimated an infrastructure backlog of between R171 and R232 billion depending on economic growth and the rate at which these backlogs would be addressed (NIIF 1996: 18-82). On the basis of information supplied by a number of departments for the Budget Review process, the author also attempted to assess the extent of backlogs and potential costs (new construction, rehabilitation and maintenance, except where noted) to the fiscus as summarised in Table 1.

Table 1: Extent of backlogs and potential costs

	Total backlog and estimated years of spending required (amount and number of years supplied by the relevant departments)	***Annual cost not currently covered by the fiscus***
Public Buildings (only rehabilitation and maintenance)	R8.8 billion over five years	R1.5 billion
Health	R13 billion over ten years	R1.3 billion (ave.) R2.4 (max)
Education	R14-20 billion over nine years	R1.6 billion
Municipal and Rural Infrastructure (water and sanitation)	R45-77 billion over five years	R10 billion
Roads	R38 billion over ten years	R5.1 billion*
Total	**R 119-157 billion**	**R19.5 billion per annum**

* Excluding requirements of toll-roads which would not be funded through the fiscus.

To understand the fiscal implications of this under-investment, it is worth noting that historical evidence and research conducted by the author and others in the Provinces (where the bulk of infrastructure spending takes place), confirmed that capital expenditure has traditionally been crowded out by the pressures of current expenditure. In South Africa, as elsewhere, capital budgets are only allocated once personnel and statutory obligations have already been provided for. This has meant that infrastructure delivery targets have been sacrificed or delayed in an attempt to keep public spending within sustainable fiscal limits. Initial research suggests that about 60% of the capital budgets in the Provinces are being spent because of the crowding out by current expenditure.

It is can be concluded, on the basis of the above evidence, that not only are the current fiscal allocations insufficient to meet projected service delivery targets, but that unless an alternative source of funding is found, the public sector faces a serious risk of losing a significant proportion of existing assets. Some anecdotal evidence suggests that in the case of the education and health sectors, up to a third of the current asset stock could “fall off the map” if rehabilitation and maintenance is not undertaken urgently.

The effects on construction industry development

The trends described above have given rise to a situation where construction firms in South Africa have adopted more flexible production strategies (see Merrifield, 1994, 1999). These strategies, characterised by the shift towards sub-contracting, disrupted existing training processes and undermined the skills basis of the industry, which, over time, contributed to the long-term undermining of industry capacity and performance. Demand volatility also affected Small Medium and Micro Enterprise (SMME) development because emerging firms are not able to experience a continuity of work that would have enabled them to gain experience and grow.

Since fluctuations in demand have led to inefficiency and escalating costs, it has been argued that the government should attempt to schedule public-sector spending in a manner that it will counteract the shifts in private investments in order to reduce the amplitude of the construction cycle (DPW, 1997, 1999). This indeed has been one of the primary areas where the Government's Green and White Papers on construction industry development have received almost unequivocal support (Merrifield, 1997). However, such interventions have been viewed with more skepticism by orthodox economic thinkers as well as been seen as being fiscally infeasible.

Constraints to addressing the construction cycle

There are a number of reservations about using fiscal resources to address the volatility of the construction cycle.

Firstly, there has been rather mixed success internationally with government attempts to control demand. From a macro-economic perspective, there are questions whether such demand management is not counter-productive, since people learn to anticipate government actions and react in a manner which ultimate negates their effects. This led many governments internationally to reduce their reliance on fiscal measures and favour monetary control as their main lever of financial management (Lucas 1977, 1981).

A second argument against counter-cyclical public-sector spending arises not from the anticipated effects, but rather from the political and institutional difficulties of commissioning construction work when it is needed. It is argued that construction work has long lead times which often mean that projects commissioned to smooth out a cyclical downturn in private-sector spending are likely to come on stream during the next upturn, thereby exacerbating the cycle. The problem of scheduling is further complicated by the reluctance of political leaders to relinquish their prerogative to influence public investment. The combination of political influence and long lead-times means that public-sector fixed investment is characterised by a stop-go frequency which amplifies the cycle rather than smoothing it (Van Duijn 1983, Calitz 1996).

Thirdly, the overall decline in public-sector contributions to GDFI (see above) has meant that the state's ability to affect the business cycle has decreased. This decline in public-sector fixed investment can be seen in light of Government policy over the past fifteen years. As a result of considerable large-scale infrastructural investment in the 1960s and 1970s, the decline in infrastructural investment since the early 1980s was not generally considered a problem for those involved in National Planning since they believed (and some still believe) that the country was reasonably well provided for at an aggregate level. It has been argued that South Africa has until recently been comparable to similar developing economies in the provision of economic and social infrastructure (Budget Review, 1999). The problem has always been in its distribution.

The question remains whether amongst its many priorities, the South African government will address these questions of declining demand and increasingly volatility. While many key decision-makers are aware of the supply-side consequences for the construction industry of insufficient and uneven demand, they generally do not rate these problems as highly as other priorities such as fiscal discipline, the need to create jobs and address problems related to the Apartheid legacy (high unemployment, inadequate access to basic services, extreme income inequality and resulting crime). Moreover, although they also recognise that the construction sector contributes to addressing these problems (particularly unemployment and service delivery), it has been evident to the author that the industry is unlikely to receive any special attention.

CONCLUSION: INFRASTRUCTURE INVESTMENT IN THE FUTURE

Starting with a long-term perspective of infrastructure investment in South Africa, we have seen that the public sector, but in particular, public authorities, have reduced their investment in infrastructure significantly if measured against the other sectors. We also learnt that investment in social infrastructure has fallen significantly in the 1990s despite government objectives to re-prioritise the budget to address basic needs. Economic infrastructure has not declined as significantly, although an increasing proportion of all infrastructure is provided by the private sector.

The discussion of historical trends also examined the causes of the construction investment cycle and it was argued that it would be possible, if difficult, to moderate the cycle, if that were to become a political priority. One area where further public debate is required is in using public-private partnerships and alternative service delivery mechanisms to address the ever-increasing infrastructure backlogs. It is the contention of this paper, that without these alternative financing and delivery mechanisms, given the budgetary and capacity constraints of Government, its objectives of increasing infrastructure delivery and the knock on effect for construction industry development is unlikely to be realised.

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Implications of the Corporatisation of the Public Works Department, Singapore and Challenges for Singapore Construction Consultancy Organisations in the New Millennium

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Abstract

The paper touches on the corporatisation of the Public Works Department (PWD) in Singapore. It attempts to assess the implications of the formation of the PWD Corporation Pte Ltd on the development of Singapore's construction industry. It elaborates on the corporation's plans for the future and how it hopes to achieve these. The paper then touches on the challenges for construction consultancy organisations in Singapore in the new millennium. The paper concludes that the aim of the Construction 21 Committee is achievable and should be the aim of those involved in the construction industry.

INTRODUCTION

1April 99 is an important milestone for all of us in the Public Works Department. On that day, the consultancy arm and the estate management arms of the PWD were corporatised to form the PWD Corporation Pte Ltd (PWDC) with 2 subsidiaries, the PWD Consultants Pte Ltd and the PWD EMS Pte Ltd. The Building Control Division of the PWD and the Construction Industry Development Board merged to form the new statutory board, the Building & Construction Authority (BCA).

The corporatisation of the PWD is one of a series of corporatisation of government departments and the divestment of investment by the government of Singapore. The aim of the corporatisation of the PWD is to enable the department to deliver its services more efficiently and effectively so that they can be more responsive to the needs of its customers and be better prepared for the changing trends towards greater competition. The move is also in line with the government's aim of encouraging Singaporean firms to go regional and to build up an external wing to our economy.

IMPACT OF THE CORPORATISATION OF THE PWD ON STAKEHOLDERS

The impact of the corporatisation of the PWD can be examined from the perspective of the various stakeholders. In the past, the PWD's role is more than an architectural, engineering, cost and contract consultants to the government. We were the engineering authority in setting norms and standards. We represent the government in managing and in disbursing development fund for contracts administered by us.

With the corporatisation, government ministries and departments are required to handle their own finance. They would have to sign the contracts themselves, raise works orders and make progress payments. 2 forums were organised by the Ministry of Finance and the PWD Corporation to inform officers from user ministries on the new procurement procedures.

To many of us, the staff of the PWD, the transformation of PWD on 1 April 1999 is a very significant event in our lives. It marks the beginning of a new phase in our careers. The change from a government department to a private company is a very great step for many of us. We are glad to note that there are a sufficient number of us, including quite a number of the senior staff, who had decided to take the plunge. These people are already committed to changes in mindsets and in their operation. They also have decided that a positive attitude towards the change is the only alternative. They readily adopt the motto of "New Mindset, New Era" in facing the challenge.

Customer service and bottom line suddenly take on new meanings to all of us. It is a very daunting change. It is scary at times and can be very challenging.

Since not all staff joined the new company, additional new staff was recruited. The addition of new staff from the private sector provide insights and useful experience from the private sector. It also poses a challenge to management on how to ensure that the group work as a big corporate family in spirit and in operations.

Systems such as HR, Finance and Project Administration have to be put in place quickly. Some IT modules are still being developed to-date. On the whole, all staff has taken the change very positively. Many who have taken the plunge have already decided to gallantly take the challenge with a positive mindset.

Now that nearly 7 months have passed, I am glad to say that we have taken the change successfully. There were a few teething problems here and there. But on the whole, the change has been well managed. Personally, I would summarise the change as "Hectic but interesting and challenging". I believe many of my colleagues share my sentiments.

The new challenge also brought with it new business areas and business in the region. I believe many of us have taken on new duties and responsibilities very well and are well motivated to do their best. We are looking forward to our new vision and mission to be a leader in the region in the development and management of building and infrastructure facilities.

PWDC'S PLANS FOR THE FUTURE

We have a challenging task ahead of us to establish PWD Corp as a successful leading corporation, and a respected name in the infrastructure and building industry. The corporation must strive in more ways than one. We must also strive to make PWD Corp an innovative leader in infrastructure works and an employer of choice. As a corporation, we must be willing to accelerate learning, adopt new ideas and make changes for a better future.

Emphasising service excellence, we will re-organise to form more customer-oriented business units to provide better services and quicker response to our customers. We will strengthen our already strong IT division so that our competitive edge will continue to be maintained.

The values which we apply to our daily activities will be the driving force behind PWD Corp. Service excellence, drive and diligence, a caring culture and a strong learning spirit – these make up our corporate values and form the foundation of our organisation. They are the reinforcing threads of our corporation's fabric that will support and bind us as a dynamic team.

As a knowledge and human resource-based organisation, we must nurture every employee and allow every one to perform to his or her fullest potential. This means continuous training and re-training – every one should be prepared for that. All of us must have a strong sense of ownership of and belonging to the corporation.

As part of the action plan of the PWDC, it will develop new capabilities by forming strategic alliance and partnerships with specially selected firms. This will enlarge our resource base by networking into our partners' resources which synergies with our own, enabling us to expand our local client base. We will strengthen the marketing and business development divisions.

For overseas markets, our strategic focus is to enter into the international market for design consultancy, project management and possibly some infrastructure investment projects. We will boost our International Business Development Division to intensify our overseas marketing effort and vigorously sell our core business and services. We intend to establish new overseas network by setting up an office in China to facilitate potential future projects in China, as well as by working with international financial agencies to explore funded infrastructure projects.

IMPLICATIONS OF THE CORPORATISATION OF THE PWD ON THE CONSTRUCTION INDUSTRY IN SINGAPORE

One of the common feedback from the private sector on the development of public sector projects in Singapore is that many of the projects are in the hands of public agencies. As a result, private sector professionals lack the track records for them to venture overseas. The corporatisation of the PWD is a response in the right direction to this feedback.

An obvious impact of the corporatisation of the PWD is the relinquishing of monopoly of government projects, which will be tendered out to all players in the field after the 5 years moratorium given to the PWD Corp.

The corporatisation of the PWD also means that a big player with the track records is now in the market. This player may therefore have to play the leader's role in shaping the industry.

The downside would be the additional competition in the domestic market. A corporatised PWD with its track record of specialised infrastructural work could compete for overseas jobs. Some one said that the best thing that could come out of PWD's corporatisation is if the private sector can team up with it in joint ventures and compete for specialised jobs overseas and here.

Speaking on behalf of the PWD Corporation, while we have our own vision and mission, we are open to suggestion and are prepared to work with everyone to assert a positive impact on the industry. We hope to set the pace for the development of the industry.

CHALLENGES FOR CONSTRUCTION ORGANISATIONS IN SINGAPORE IN THE NEXT MILLENNIUM

The construction industry is a complex and fragmented industry. Many studies have been carried out on the industry in Singapore as well as in countries with similar practice. This section is written with the benefit of the reports listed in the reference section of the paper:

The construction industry is a labour intensive industry. Singaporeans have over the years shunned the industry as a potential career. One reason being the perception of construction work as dirty, dangerous and demanding. Construction productivity has declined by more than 15% between 1995 and 1998. The Construction 21 Committee sees the need to evolve the construction industry that has a place in the knowledge-based economy of the 21^{st} century. We need to enhance the professionalism of the industry players and inculcate partnership amongst the players in the industry. To do so, the public, private and people sectors will have to work together in a new spirit of co-operation. Such an extensive collaboration will enable the sharing of new ideas and technology amongst all and develop the capabilities for our builders and consultants. The superior capabilities will enable us to compete internationally. The creative capabilities of our consultants and builders will be integrated across the construction value chain to encompass design-construction-maintenance. The resulting synergy will enable the industry to constantly achieve high buildability and yet remain cost effective.

The construction industry is a very fragmented industry. Key players in the industry are professionals of their own right, regulated by different professional bodies. The development of their skills and actions taken in upgrading are more often than not confined within their own fields. Take IT for example, the architects and engineers developed their own systems very much in isolation and communication across professions is difficult. Difficulty for the integration of the whole development process is an important obstacle to the upgrading of the industry.

Consultants in the construction are service providers. They are not the ones who make the final decision on the projects. They have little bargaining power in the construction value chain. As long as the consultants stay within the confines of their profession, they would find it difficult to exert much influence on the value chain. To overcome this obstacle, consulting organisations would have to move up and down the value chain in order to assert influence on the whole chain.

Since the entry barrier for the consultancy industry is small, many small players are able to set up shops to market their services. This resulted in more than 95% of consulting firms which are small, many with less than a few employees. Small firms come with it a host of problems, such as lack of resources for major projects, lack of capital for upgrading, lack of network and critical mass for overseas ventures.

To be competitive, consultants need to continuously improve their operation and to innovate. They need to upgrade and be up-to-date with the latest IT systems in order for them to be competitive, especially with leading players in the world. Smaller firms without capital would find it difficult to compete. Smaller firms also find it difficult to provide the necessary training and re-training to keep abreast with the latest development in the industry.

In addition, the high manpower cost in Singapore is a great obstacle for us to be competitive with other players in the region. Other forms of innovative service integration utilising cost efficient manpower for successful accomplishment of development projects would have to be seriously looked into. Other players from bigger countries also have the advantage of the ability to specialise in certain niche markets since the opportunities for specialisation in a small country like Singapore is minimal. Strategic alliances with key players for mutual benefits is an alternative. We also need to continuously look for areas to value add in the whole value chain as business opportunities.

On the other hand, we have our Singapore brand name. We are well known for our strong integrity, efficiency and quick response to changes. In my view, it is up to us to capitalise on our strengths and to overcome our weaknesses.

The PWD Corporation is committed to the following drivers for change for the industry:

1. Committed leadership: the present leadership in the PWDC believes in and is totally committed to driving forward an agenda for improvement and communicating the required cultural and operational changes throughout the whole organisation.
2. PWDC is also committed to being customer-focused. We believe that customer drives everything.
3. PWDC being a multi-discipline organisation is better able to provide integration in the value chain of development products. At the moment, we lack the development and investment arm as well as the contracting arm in the value chain. It is to our interest to address seriously the missing links for us to be more effective in the integration process.
4. We are also committed to people development. Training and re-training is emphasised. The emphasis on training is to ensure effective training and application of new skills. The company is prepared to allocate a substantial amount of fund for training.

5. Service quality is one of our corporate values. For a former government department, this is a major mindset change. The change will take time and will be difficult. Top management is committed to the change and it is some thing that is being monitored closely at the highest levels.
6. The changes in the PWDC would address some of the pitfalls highlighted by the various studies on the construction industry. I believe we are on the right track and we have the confidence that it will work.

The C21 Committee hopes that one day the competencies and capabilities of our work force in the construction industry would be a force to be reckon with in the region and that we will have competitive products and designs to be shared with other countries. Our industry will not only establish itself within Singapore but also in the cities of other countries, and in that process, play an important role in laying the foundation for world-class cities.

The PWD Corp hopes to be a key player in the initiatives proposed by the C21 Committee. We are positive about our challenge and hope to work with others in Singapore in this exciting venture.

CONCLUSION

We in the PWD Corp are very positive about our corporatisation. We are hopeful that we will be able to take on the challenge to upgrade the industry in Singapore. Our vision is to be a leader in the region in the development and management of infrastructure and building facilities. As highlighted in the Construction 21 committee report, to bring the construction industry to a higher level, we need the concerted effort of the public and private sector. The PWD Corporation is a private company wholly owned by Temasek Holdings Pte Ltd, the government owned company. We can provide the connection between the public and the private sectors. We hope we will be the catalysts to bring about upgrading of the industry to a higher plain in the region. It is up to us in the construction industry to help ourselves.

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What Determines the Competence of a Construction Firm?

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Abstract

The environment in which a construction firm is fostered plays a crucial role in its ability to build up competencies. To a large extent, the construction industry depends on other industries, institutions and an array of specialized infrastructure for development of technologies, management systems and financial capabilities. If within this environment these industries and institutions are well developed and have reputable competencies, the development of the construction firm will benefit from them in one way or another.

This paper reports on a study that investigated the interconnection between ten large construction firms based in Gaborone, Botswana with suppliers of materials and construction plant, research and training institutions, and financial institutions. It was found that, while the construction firms endeavor to establish close ties with material suppliers, financial institutions and government bodies that are directly involved in construction, they hardly support or endeavor to establish ties with research and training institutions and other bodies that are not directly involved in construction activities. Based on this observation, the paper argues that the interconnection between industries and institutions that are based in the same environment has a synergic effect whether they are involved in directly related activities or not.

The paper concludes by emphasizing that efforts to develop the construction industry should not be directed only towards the activities that are directly related to the industry. Efforts that raise the productivity and competence of all institutions and industries in the same environment should be pursued.

Keywords: *Development of construction industry, material suppliers, interconnection between industries, financial institutions, research and training institutions.*

INTRODUCTION

When a top construction industry executive in Botswana was asked “What is the effect of the reduction of research funds at the University of Botswana on the industry?” he responded “none whatsoever”.

Linkages among the various sectors of the Botswana economy, as in many developing countries constitute an important area which, is sometimes neglected and often not well understood. Consequently, the importance of close and strong links among the various sectors of the construction industry to the competitiveness of the construction companies does not get the attention it deserves.

The global ease of transportation and communication has led many firms to move their operations to locations with low input costs, such as low wages, low utility costs and tax concessions. Recent studies (Porter, 1985, 1990) have shown that low inputs by themselves do not constitute competitive advantage. Locations with such inputs often lack efficient infrastructure, sophisticated suppliers and other important factors that can more than offset any savings from lower input cost. Porter (1990) has shown that when there is an ample supply of cheap raw materials or abundant labour, companies can simply rest on these advantages and often deploy them inefficiently. But when companies face a selective disadvantage, like high land costs, labour shortages, or lack of raw materials, as the case of Japanese companies they must innovate and upgrade to compete (Levy, 1990; 1993). Moreover, in the sophisticated industries, a nation does not inherit but instead creates the most important factors of production-such as human resources or scientific base. The stock of factors that a nation enjoys at a particular time is less important than the rate and efficiency with which it creates, upgrades, and deploys them in particular industries (Porter, 1990; Teece et al., 1997; Ngowi and Rwelamila, 1998).

However, to innovate, companies must have access to people with appropriate skills and have home-demand conditions that send the right signals. In addition, they must have active domestic rivals who create pressure to innovate; and company goals that lead to sustained commitment to the industry.

Against this background, this paper highlights the importance of close links among the various sectors of the construction industry in a nation and using Botswana construction industry as a case study shows how it may affect the competitiveness of the construction firms based in that nation.

HOME BASE ENVIRONMENT

A nation may be considered the home base for a company if it is either a locally owned, indigenous enterprise or managed autonomously although owned by a foreign company or investors (Porter, 1990).

Porter (1990) put forward four determinants that create the national environment in which companies are born and learn how to compete. These determinants are arranged in a diamond of national advantages and include: factor conditions; demand conditions; related and supporting industries; and firm strategy, structure and rivalry. Each point on the diamond and the diamond as a system affects essential ingredients for achieving international competitive success: the availability of resources and skills necessary for competitive advantage in an industry; the information that shapes the opportunities that companies perceive and the directions in which they deploy their resources and skills; the goals of owners, managers and individuals in companies; and most important, the pressures on companies to invest and innovate (Porter, 1990). To support competitive advantage, a factor must be highly specialized to an industry's particular needs.

The quality of the local business environment strongly influences the sophistication with which companies compete in a particular location. Companies cannot employ advanced logistical techniques, for instance, without a high quality transportation infrastructure. Nor can companies effectively compete on sophisticated service without well educated employees.

Companies that operate in the same business environment are related to one another either directly or indirectly. This relationship may be formal or informal because companies that are in the same location and have repeated exchanges among themselves, foster some degree of co-ordination and trust. However, formal relationships through such mechanisms as networks, alliances and partnerships have inflexibility that often lead to management problems. Such problems could be mitigated by clusters of independent and informally linked companies and institutions that represent robust organizational forms offering advantages in efficiency, effectiveness and flexibility. Porter (1998) defines a cluster as a geographic concentration of interconnected companies and institutions in a particular field that encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure; and often extend downstream to channels and customers and laterally to manufacturers of complimentary products and to companies in industries related by skills, technologies, or common inputs.

THE CONSTRUCTION INDUSTRY

The construction industry contributes significantly to the Gross Domestic Product (GDP) of all countries. In the UK and the European Community, for instance, the construction industry contributes about 10% of the GDP (DETR, 1998; Raftery et al.,1998), while in Botswana this percentage is about 15 (NDP 8, 1997). Traditionally, the construction industry has been substantially influenced by the public sector, which in many developing countries is the major employer.

However, a general trend that has been brought about by globalization is the larger share of the private-sector participation in the construction industry. Although private-sector participation has been prominent in building construction for many years, it now includes the construction of infrastructure projects that were previously considered the preserve of the public sector. Judging from recent trends in Asia (Raftery *et al.*, 1998) there is a shift from both the limited domestic budget resources and foreign aid for infrastructure projects to private financing, which is considered resourceful and efficient.

One important aspect of private financing for construction projects is that project sponsors form consortia of contractors, developers and financiers in order to tap into the expertise of the members in technology, project management and financing, and to share project risks. Since no one sponsor would like to shoulder all project risks on its own, and as construction projects, especially infrastructure ones, become more complex, formation of consortia is gradually becoming a norm in private-sector financing. The formation of such consortia calls upon a wide range of both formal and informal relationships among the various direct and indirect participants in the construction industry as noted by Porter (1998) in the definition of a cluster. Using the basic elements of a cluster, a survey was carried out in the Botswana construction industry to determine the types of existing links among the various participants in the industry.

The Construction Industry in Botswana

Botswana is a sparsely populated country with a total area of 582000 square kilometers and a population of 1.4 million people (Census, 1992). The country has experienced rapid economic growth since independence in 1966, and development of the infrastructure has been one of the country's priorities. Construction companies in the country are registered with the Central Tender Board (CTB, 1992) under the Ministry of Finance and Development Planning. The CTB has six categories of contractors namely Opportunity Class (OC), and classes A, B, C, D, and E which are based on the maximum value of a single project that a company can handle (Table 1).

Table 1: Categories of construction companies in Botswana

Class	*Maximum contract value (Million Pula*)*	*Total number of contractors in the class*
OC	0.15	220
A	0.45	115
B	0.90	91
C	2.00	65
D	4.00	18
E	Unlimited	12

From 1984, the end of the period when Botswana faced a severe drought and construction activities were suspended, the construction industry enjoyed a steady growth which culminated in a boom in 1988-92. This period witnessed the emergence of several citizen-owned construction companies, as well as entry of a number of international companies to the local market. Between the end of 1992 and the beginning of 1996 the volume of construction work drastically fell, causing many citizen-owned companies to close down and some of the international companies to relocate to other countries. From the end of 1996 the volume of construction work picked up again and at the moment (1999) the industry is experiencing another boom. Companies that survived the construction slow down were the target of the interview.

THE STUDY

This study targeted citizen-owned companies that have been in operation for more than ten years. It examined the types of relationships that the companies have established with the other key players in the construction industry, namely: material suppliers, plant hirers, financial institutions, research and development (R&D) institutions, education providers, and government policy makers.

Methodology

Ten large citizen-owned construction companies, all of which were registered in class B more than 10 years ago, were selected from a list of contractors registered with the Central Tender Board as shown in Table 2. The firms are named A, B, C, D, E, F, G, H, I, and J for anonymity, which was agreed upon during the study.

Due to the notoriety of local construction companies in responding to postal questionnaires, the information-gathering technique adopted for this study entailed semi-structured interview with each chief executive of the selected companies. Each company was visited after prior appointment and interview with each chief executive lasted for about forty five minutes in their offices. Where visits could not be arranged (two cases) the interviews were carried out by means of telephone.

Table 2: Construction companies selected for the study

Class	*Number of citizen contractors selected*	*Total number of citizen contractors in the class*
E	2 (A and J)	2
D	5 (B, E, F, G and I)	5
C	3 (C, D, and H)	32
B	0	154

Citizen-owned construction companies were selected for this study because it was assumed that they have similar backgrounds and that they have interest in a strong and sustainable construction industry. All the selected companies are involved in building projects although the majority (70%) claimed to be general contractors. There was no evidence of this claim, as none of these companies has carried out infrastructure projects other than minor site roads. Class B companies were not included in the study because most of them have not operated for more than 10 years, and there was no reliable information at the CTB on this category of companies.

Interview Findings and Discussions

The interviews were carried out by introducing the basic relationships in the construction industry in the form of questions and allowed the respondents to express their views and experiences on each item. The points raised during the interviews are now discussed.

Material Suppliers

The respondents were asked to indicate the type(s) of relationship that they have with material suppliers and the responses are summarized in Table 3.

*Table 3: Relationships between construction companies and material suppliers**

Type of relationship	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Direct purchase	1	1	1	1	1	1	1	1	1	1
Holding of shares	0	1	0	0	1	0	0	0	0	1
Joint production & sale	0	0	0	0	1	0	1	0	0	0
Just-in-time delivery	1	0	1	0	0	0	0	0	1	0
Subsidiary company	0	0	0	1	0	0	0	0	0	0

* “1” indicates a valid relationship, while “0” indicates no relationship

Efficient material suppliers are key to successful construction projects. Besides direct purchase of materials from the suppliers, which is done by all the companies interviewed, such arrangements as production of precast or prestressed concrete components by companies E and G and sale by their appointed material suppliers/distributors have been entered to. Another type of relationship that has been established by companies B, E and J is holding of shares in a material supply company or vice versa.

Companies A, C and I have unique relationships with their respective material suppliers in which the latter mobilizes materials for specific projects and store them in their warehouses until the exact time when they are required for incorporation into the structures. This arrangement, which is unique in Botswana, requires careful coordination as a slight mistake may result in long delays. It is important to note that in direct purchase, the suppliers have no obligation to store the materials once they are purchased. All respondents who practice this type of arrangement said that they have made substantial savings on site storage and are quite happy with it as it also brings the suppliers to the management of the projects. Company D owns a material supply subsidiary company.

Plant Hirers

Responses to the question on "What type of relationships do you have with plant hirers?" as shown on table 4 established that all the companies hire plant of one type or another from specialized plant hirers. Often this is done in situations where the plant is specialized like tower cranes, or when the project site is too far away from the company headquarters. Like in the case of material suppliers, companies H and I hold shares in plant hire companies, while company A has a subsidiary company that hires out construction plant. Joint training of plant operatives and plant maintenance personnel is one of the most important relationships between construction companies and plant hirers. All interviewed companies pointed out that they have participated in this type of training, which is normally organized by the Association of Plant Hirers.

*Table 4: Relationships between construction companies and plant hirers**

Type of relationship	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Direct hiring	1	1	1	1	1	1	1	1	1	1
Holding of shares	0	0	0	0	0	0	0	1	1	0
Subsidiary company	1	0	0	0	0	0	0	0	0	0
Joint training	1	1	1	1	1	1	1	1	1	1

* "1" indicates a valid relationship, while "0" indicates no relationship.

Financial Institutions

The question on the type of relationship between construction companies and financial institutions determined that either the companies underutilize the potential of financial institutions or the latter do not intend to make use of the opportunities that can be created in the construction industry.

While studies of the Japanese construction industry (Levy, 1990; 1993; Abdul-Aziz, 1999) and those of other developed countries (OECD, 1992) have shown how the Japanese and American banks have enabled construction companies in their countries to create competitive advantages, in Botswana the only significant relationship between the industry and the financial institutions, according to the responses to the interviews are short-term loans. It is only three cases, i.e., companies C, F and H that banks have given long-term loans for estate development (Table 5). Although there are several financial institutions in Botswana, namely the National Development Bank (NDB); Botswana Building Society (BBS); Botswana Cooperative Bank (BCB); Botswana Development Corporation (BDC) and several commercial banks, none of them has equity in construction companies or is keen in giving long-term loans for infrastructure development. Similarly, none of the local financial institutions has participated in consortia for infrastructure development as practiced in the Build Operate and Transfer (BOT) mode of construction procurement.

*Table 5: Relationship between construction companies and financial institutions**

Type of relationship	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Short-term loans	1	1	1	1	1	1	1	1	1	1
Long-term loans	0	0	1	0	0	1	0	1	1	0
Participation in Consortia	0	0	0	0	0	0	0	0	0	0
Equity	0	0	0	0	0	0	0	0	0	0

* "1" indicates a valid relationship, while "0" indicates no relationship.

The respondents were of the opinion that the financial institutions consider construction to be a high-risk investment, the return from which is not predictable. To a large extent, this view is the result of the poor performance of the construction industry recently (*Daily News*, 1996).

Research Institutions

The respondents were asked to describe the relationships they have with the institutions that carry out research in the country, namely: The University of Botswana (UB), The Botswana Technology Centre (BOTEC), Rural Industries Innovation Centre (RIIC) and the Road Materials Laboratory. Table 6 summarizes the responses elicited.

*Table 6: Relationship between construction companies and research institutions**

Type of relationship	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Attachment of staff	1	0	0	0	0	0	0	0	0	0
Joint research	0	0	0	0	0	0	0	0	0	0
Funding of specific projects	0	0	0	1	0	0	0	0	0	0
Provision of equipment	0	0	0	0	0	0	0	0	0	1

* "1" indicates a valid relationship, while "0" indicates no relationship.

The summary shows that only three of the ten companies have established relationships of some kind with the research institutions in Botswana. In the case of company A, a staff member who was researching on the suitability of Kalahari soil for construction of the various layers of the pavement structure was attached to the BOTEC for a period of one year. The response from company D shows that it made a cash donation to BOTEC for research in energy-efficient lighting systems and company J provided special equipment for research in water retaining structures at RIIC. None of the companies said it has a relationship with either the research activities at the University of Botswana or the findings of those researches.

Research that leads to the development of unique construction technologies has enabled big American and Japanese construction companies to create and sustain competitive advantages for several years (OECD, 1992; Levy, 1990; 1993). Research that is intended to provide new ways of doing things takes a long time and large investment, and requires dedicated and qualified researchers. Japanese companies, which are renowned for developing technologies, for instance, spend about 3% of their revenues on research and have well-equipped laboratories and qualified staff (Levy, 1990). Those companies that do not undertake research activities directly collaborate with research institutions to get access to the findings that could enhance their performance.

The responses to this question showed that, in Botswana, construction companies generally neither participate in direct research nor establish the necessary relationships to ensure that research findings from research institutions easily find their way in the companies' operations.

Educational Institutions

The respondents were asked to indicate the types of relationships they have with the education institutions in the country. Companies A and F indicated that they offer annual sponsorship to selected members of their staff for studies at the University of Botswana and other training institutions. Response from company C indicated that the company has held some seminars at the university and schools whereby the students were informed about the operations of the company. The ultimate aim of such seminars was to recruit the potential students to the company on completion of their studies. None of the companies either have arrangements to allow university staff to work in the company for a short period, or to attach its own staff at the university as a staff member for a short period. However, all companies pointed out that they have taken in student form the University of Botswana for short periods of industrial placement.

*Table 7: Relationship between construction companies and educational institutions**

Type of relationship	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Sponsorship of staff	1	0	0	0	0	1	0	0	0	0
Attachment of staff	0	0	0	0	0	0	0	0	0	0
Secondment of UB staff	0	0	0	0	0	0	0	0	0	0
Seminars	0	0	1	0	0	0	0	0	0	0
Student placement	1	1	1	1	1	1	1	1	1	1

* "1" indicates a valid relationship, while "0" indicates no relationship.

The importance of close relationship between the construction industry and education institutions, particularly technical institutions hardly needs to be emphasized. While the education institutions provide general education, the industry should complement this by offering job specific training that will enable the student to relate the theoretical knowledge to practice. This also applies to staff members who should receive regular exposure to practical experience in order to hone their teaching abilities. Of equal importance is the participation of industry in formulating programmes that should be taught at the educational institutions. This will ensure that programmes are relevant to the continuous changes in the industry and that the basic training needs of industry are met.

There was no evidence from the responses to this question that the firms have been involved in the development of educational programmes.

Government Policy Makers

Policies that are made at various ministries have direct and indirect effects on the operations of the construction companies. A policy like empowerment of citizen contractors has the direct effect of ensuring that such contractors get preference in job allocation, but has an indirect effect of making the companies complacent and not develop the skills that are required to participate in a competitive environment.

Several methods may be employed to ensure that there is a close relationship and constant interaction between policy makers and the construction industry. These include, among others: appointing key individuals to represent the industry in the policy making bodies, electing members of the construction industry as policy makers and participation in the policy making process which may include consulting stakeholders and debates in various forums.

The responses to the question "What types of relationships do you have with policy makers?" established that no specific relationships are established with policy makers other than lobbying them for specific policies when a need arises.

CONCLUSIONS

The aim of this paper was to highlight the importance of close relationships between companies operating in the same environment to their competitiveness. The review showed that close relationship among all the companies and institutions operating in the same environment such as financial institutions, research and development (R&D) institutions, educational institutions and policy-making bodies are necessary whether their operations have direct bearing on the activities of one another or not.

The study showed that construction companies in Botswana form reasonably close relationships with the companies that are directly involved in their operations, in this case material suppliers, plant hirers, and financial institutions, but do not bother to form relationships with companies or institutions that are not directly involved in related operations. Although the interviewed companies are the ones that survived the slowdown in the construction industry in early 1990s, there was no evidence to show that the hard times made them to forge closer and stronger relationships among themselves.

The study was based on a selected sample of ten companies and selected types of relationships. It is recommended that further studies involving a larger number of companies and a wider range of relationships be carried out.

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Claims Resulting from Inappropriate Construction Procurement Methods: The Ugandan Case

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Abstract

This paper considers how clients and their representatives choose a procurement method and the resulting consequences such as claims and other project problems. It forms part of a larger research investigation on construction procurement strategy in Uganda. The research was carried out with a questionnaire survey and interviews of clients, consultants and contractors in Uganda.

Major findings are that there is no guide to the selection of an appropriate construction procurement method; and about 54% of construction problems arise from the use of inappropriate procurement methods. TGC and DB are quite popular in Uganda, and a guide has been proposed on how to arrive at an appropriate method.

Keywords: Construction claims, procurement methods, Uganda.

INTRODUCTION

There appears to be a hood over how construction team members arrive at the selection of a procurement strategy for their projects. It is also believed that inappropriate strategies have led to several project problems. The construction industry in Uganda is characterized by many claim situations. Some are settled amicably while others end up in litigation (Tutesigensi, 1997). Several factors give rise to claim worthy situations. It has been recognized that some of these are as a result of a procurement method employed in the formulation of contracts.

This paper seeks to: (i) evaluate how knowledgeable the clients, contractors and client's representatives are about procurement strategies (generic or common ones); (ii) ascertain which ones are available in Uganda and how they have arrived at selecting the right ones and matching them with the right conditions of contract and contract type; (iii) ascertain what claims have arisen in the past and how they are linked with the type of procurement strategy used; and (iv) understand the role of procurement strategy as it links claims and their resolution(s).

Research scope and objectives

The scope of this investigation is the construction industry in Uganda and it is limited to investigating the following variables:

1. types of contract procurement methods used in particular situations; and
2. claims that have been encountered as a result of the procurement method used and how they have been resolved.

This paper presents part of a larger research project on “An investigation into procurement strategies in the construction industry in Uganda”. This part of the study looks solely into the link between the procurement method used and the resulting problems such as claims.

The objective of the larger research was to develop a guide to procurement method selection in Uganda. It is believed that this will:

- help in creating a proper framework for reasoning, and or criteria for selecting an appropriate procurement method for a given type of project;
- help to investigate the common procurement methods used in the Ugandan construction industry; and
- create a database of common situations of use of inappropriate procurement methods and claims and how to avoid such occurrences in future.

RELEVANT LITERATURE

Naoum **(**1998) concluded that time overrun is not determined solely by the payment methods used and that projects can overrun owing to the selection of an inappropriate procurement method, client variation orders, client inexperience, and industrial factors such as strikes.

Traditionally, clients of construction works have relied on architects/consulting engineers to design and supervise their construction needs, and indeed the system has generally worked satisfactorily. However, in recent times, large projects such as power stations, airports and refineries have proved difficult to manage (Harris & Mccaffer, 1995). This is due to the fact that complexity is an important factor to consider in the procurement methods used.

Clients do not define their needs from the onset with any degree of ease and specificity. To alleviate this, many other contracts and or procurement methods have been adopted such as the design and build (DB), the construction management (CM) and the management contract (MC). These are combined in one way or the other with cost reimbursable, stage tendering, serial contracts, etc (Harris & Mccaffer, 1995). Project organizations usually consist of architects, civil and structural engineers, electrical engineers, and so on. One of the complaints here is that design responsibility and supervision are not at par. Therefore, the overall responsibility for managing design, procurement and construction becomes ambiguous (Harris and McCaffer, 1995). Thus most construction projects containing the phases typified require a clear decision on the part of the client on what focus should be placed on structural designs, procurement and contracting. Certain factors influence this decision as listed by Mccaffer (Mccaffer, 1995):

1. Type of work
2. Certainty of cost
3. Availability of finance
4. Managerial and technical resources of the owner
5. Forward workload
6. Aspects of the project requiring specialists
7. Desirability of early contractor involvement
8. Extent to which competition is desirable
9. Manpower availability
10. Sensitivity of project variability to time and cost

11. Interaction and interacting between contracts and contributors.

Mccaffer and Harris (1995), have also advised that to be able to manage this efficiently, there is need for proper project definition, organizational structure, programmes, design control, budget and contract control, control of construction management claims, and quality.

Procurement methods selection and use in Uganda

A few cases of procurement methods application in Uganda have been studied. Tindiwensi (1997) noted that TGC which assumes that coordination is the responsibility of the contractor is the most widely used option in Uganda despite its short comings. Hughes (1992), in his paper to the 5th annual conference clearly indicates these shortcomings.

In Uganda today, although DB is desirable, these types of contractors are not readily available and therefore CM and DB are not well used. Tutesigensi (1997) noted that most people use TGC because it can accommodate the client's variation orders. Also, Tutesingesi (1997) concluded that:

1. The construction industry is dominated by building professionals and they have reduced it to a state of mere conspiracy against the employer. This has led to the encouragement of direct labour instead of outsourcing.
2. There is a wide range of disputes with a few in arbitration and litigation and a great majority is never resolved. Blames have tended to be leveled on contractors unnecessarily.
3. The problem has been lack of representation of the employer in deciding the team the client wants.

Mururu (1997), also shed some light on claims in his paper at Uganda on Common Claim Situations. He noted that complications arise from the way claims are visualized by the employer and this has led to pitching them at a higher level. Also, he noted that change of mind of the client, incomplete designs and site investigations have all led to claims.

RESEARCH METHODOLOGY AND RESPONDENTS

Research methodology

Three main groups were selected for the research and they are: the contractors, the consultants, and the clients. International consultants could not be reached. The research stretched across government ministries, the central government works department, parastatals, the private sector and the non-governmental organizations.

The questionnaire targeted familiarity levels and use of the various procurement methods in section 1,the conditions of contracts in section 2, and types of contracts in section 3. Section 4 targeted project problems such as claims, delays, disputes cost and time overruns and how the resulting claims and disputes are resolved. Most questions were multiple choice, with a few ranking and some were open-ended questions. Open-ended questions on areas envisaged to be confusing were used for interviews. The list of contractors who have engaged in jobs greater than 1 million shillings for the last ten years was obtained from the Contractor's Association, while that of the consultants was obtained from the Association of Consulting Engineers in Uganda. The data was analyzed using the Statistical Package for Social Sciences (SPSS).

Respondents

The overall response rate was 73.5% (61 out of 83) and 10 organizations were interviewed. Foreign construction firms were 18% while consultants were 25.4%. Oil marketers were 6% and oil industry contractors were 15.7%. Municipal councils were also 15.7% and parastatals and central government was

19.2%. In all, consultants were 25.3%, contractors were 33.7% and clients were 41%. Most of the respondents were construction managers, clients or principal partners for consultants or client representatives. Others were chief executives or senior officials in the client organization relating to construction contract procurement.

Data analysis

In the question relating to the organization's level of familiarity with the various procurement methods, as shown in Table 1, TGC is 86.9% while MC is 57.4% and DB is 59% while CM is 36.1%. Only 6.6% are not familiar with any of the methods.

Consideration in choosing a procurement method, in Table 2, included complexity as the greatest factor with 84.7% followed by clarity of price, 76.3% and time for completion of the project from inception to finish with 66.1%. Capacity for variations and clients involvement follow with 52.3% and 47.5% respectively.

Table 1: Organization's level of familiarity with various procurement methods

	Contractors		*Consultants*		*Clients*		*Total*	
	F	%	f	%	F	%	f	%
Traditional General Contracting	18	85.7	11	91.7	24	85.7	53	86.9
Management Contracting	10	47.6	7	58.3	18	64.3	35	57.4
Design and Build	13	61.9	7	58.3	16	57.1	36	59.0
Construction Management	8	38.1	6	50.0	8	28.6	22	36.1
None of the above	2	9.5	0	0.0	2	7.1	4	6.6

f- Frequency
Total % =f value x 100/61.

Table 2: What is considered when choosing procurement methods

	Contractor		*Consultant*		*Client*		*Total*	
	F	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Certainty of price	17	81.0	6	54.5	22	81.5	45	76.3
Clients involvement	12	57.1	6	54.5	10	37.0	28	47.5
Time from inception to finish	12	57.1	6	54.5	21	77.8	39	66.1
Complexity of project	19	90.5	9	81.8	22	81.5	50	84.7
Capacity for variations	13	61.9	5	45.5	13	48.1	31	52.5
Clarity	8	38.0	3	27.3	7	25.9	18	30.5
Separation of design from management	2	9.5	3	27.3	4	14.8	9	15.3

Table 3: .Procurement methods used by the organizations

	Contractor		*Consultants*		*Clients*		*Total*	
	f	*%*	*F*	*%*	*f*	*%*	*f*	*%*
Traditional General contracting	18	85.7	10	83.3	22	84.6	50	84.7
Management Contracting	2	9.5	1	8.3	3	11.5	6	10.2
Design and Build	6	28.6	0	0.0	2	7.7	8	13.6
Construction Management	1	4.8	3	25.0	2	7.7	6	10.2

In this study, from Table 3, 84.6% of respondents used TGC and 10.2% used MC. In addition, 13.6% used DB while 10.2% used CM.

In order to link choice of procurement methods with project problems, in Table 4, incomplete designs and payment terms ranked highest with 61.5% each. This was followed by improper site investigations with 51.9%. The use of procurement methods scored 53.8%.

In a ranking exercise of project problems (Table 5), respondents believed that delay contributed 34.4%. Cost overruns contributed 32.8% and bad quality jobs contributed 21.3% while claims contributed 14.8%.

Table 4: Most common causes of project failures

	Contractor		*Consultant*		*Client*		*Total*	
	f	*%*	*F*	*%*	*F*	*%*	*f*	*%*
Site investigation	10	62.5	6	54.5	11	44.0	27	51.9
Incomplete design	7	43.8	9	81.8	16	64.0	32	61.5
Payment terms	14	87.5	6	54.5	12	48.0	32	61.5
Wrong Procurement method	11	68.8	3	27.3	14	56.0	28	53.8
Wrong cond. of contract.	6	37.5	4	36.4	9	36.0	19	36.5
Wrong types of contract.	4	25.0	3	27.3	8	32.0	15	28.8
Contractor org.	0	0.0	2	18.2	1	4.0	3	5.7
Poor supervision	0	0.0	1	9.1	0	0.0	1	1.9

Table 5: Relative position of project problems as ranked 1st

	Contractor		*Consultant*		*Client*		*Total*	
	f	*%*	*f*	*%*	*F*	*%*	*f*	*%*
Cost overruns	8	38.1	2	16.7	10	35.7	20	32.8
Disputes	2	9.5	3	25	2	7.1	7	11.5
Delays	5	23.8	5	41.7	11	39.3	21	34.4
Bad jobs	6	28.6	3	25	4	14.3	13	21.3
Bad practices	6	28.6	1	8.3	5	17.9	12	19.6
Claims	1	4.8	2	16.7	6	2.4	9	14.8

CONCLUSIONS

Several conclusions can be made from the study. Inappropriate procurement methods are a major cause of project problems such as claims in the construction industry in Uganda. Although the construction professionals are familiar with some of the procurement methods, conditions and types of contracts, the level of familiarity and use is not deep enough to foster proper selection and matching. Although clients in Uganda seem to be quite aware that a project brief is necessary, it was observed that most briefs are not documented. It is believed that this is because they do not understand in great depths the importance of a brief in the contract strategy selection process.

Projects in Uganda are more of the small ones than major ones and the tilt is towards TGC and DB. No proper risk analysis is done in advance for most projects in Uganda to determine the vulnerability of the strategy and its management. The use of TGC and DB with EAC and FIDIC that is popular in Uganda does not portray that a good match is achieved all the time.

Claims resolutions have been mostly by amicable settlement ranging from quasi-conciliation to mediation. Adjudication, arbitration and litigation are rarely used. While most disputes do not end up in arbitration or litigation in Uganda, it must be emphasized that their potentials abound if the increasing claims are not properly addressed.

RECOMMENDATIONS

A proper risk analysis should be done for all major projects where it is envisaged that by their nature, the works are complex and are of high contract sum. Every procurement strategy should be tested for appropriateness using this analysis which involves quantification and provision for the risks. The criteria outlined below may be of help.

- Payment methods/terms adequacy
- Risk to contractor and client
- Claims/disputes that can occur
- Quality and safety compliance provisions
- Risk arising out of complexity of management of the project

Seminars on ADR should be held periodically to explain the definitions of common terms such as adjudication, mediation, conciliation, etc. This will help to reduce project problems.

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Linking JIT Productivity with ISO 9000 Quality for Construction Industry Development: Lessons for Developing Countries

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Abstract

Achieving high productivity and quality standards is a challenge for construction industry development in developing countries. In so far as quality is concerned in the more developed countries, many construction firms have already established quality management systems (QMS) within their organisations to meet ISO 9000 requirements. Construction firms in the more developed countries are also increasingly adopting the Just-In-Time (JIT) philosophy within their operations to achieve higher productivity. Both the ISO 9000 and JIT systems are, however, treated separately by most, if not all, construction firms where implementation is concerned. This division is undesirable for construction firms in developing countries which are proceeding along similar directions in the near future.

This paper suggests that there are many similarities between ISO 9000 requirements and JIT principles and that these should be taken advantage of in order to implement the JIT philosophy successfully. This can be achieved by extending the template for existing ISO 9000 QMS to incorporate JIT principles. Consequently, by riding on existing ISO 9000 QMS, JIT principles can be operationalised more readily within construction organisations without the need to expend additional resources. This paper presents the ISO 9000 requirements as well as JIT principles and discusses how these two sets of requirements/principles should be integrated using the ISO 9000-JIT Matrix. Construction firms in developing countries who are able to take advantage of this integration can avoid the ISO 9000-JIT division which prevails in the developed world.

Keywords: *ISO 9000, quality, Just-In-Time, productivity, construction, integration.*

INTRODUCTION

The ISO 9000 Standards on Quality Systems were first introduced in Singapore in the late-1980s and in the construction and real estate industries only in the early-1990s (Low, 1998). Third party certification to ISO 9000 Standards is set to play a more important role in the local building industry. This is because the Singapore government has announced that all G6 to G8 construction firms as well as the larger consultancy firms (which are involved in public-sector projects which are worth more than $30 million) will need to be certified to ISO 9000 Standards by 1 July 1999 if they wish to tender for public-sector works after this deadline (Low, 1998).

Consequently, as 1 July 1999 drew nearer, more construction firms in Singapore sought certification to ISO 9000 Standards in order to bid for public sector building projects. Mandatory certification in this direction will hopefully help to raise quality and productivity standards in the local construction industry. It would, however, appear that quality and productivity standards will not be enhanced if construction firms treat the requirements of ISO 9000 narrowly without further exploring how these can be fully exploited to their advantage.

Like ISO 9000, the Just-In-Time (JIT) philosophy has also been proven to be successful in the Singapore construction industry. JIT was applied to a school project (Low and Tan, 1997), a public housing project (Low and Tan, 1997a) as well as for the prefabrication of precast concrete components (Low and Chan, 1997a). In all these cases, there were time and cost savings following the strategic application of JIT in their operations.

It is therefore the contention here that JIT is just as important as ISO 9000 for raising quality and productivity standards in the construction industry (Low and Chan, 1997a; Low, 1998). Hence, adopting the JIT philosophy and ISO 9000 collectively can help to solve productivity and quality problems in the construction industry. The JIT philosophy provides techniques for managing manpower, quality and productivity while ISO 9000 provides a system for JIT to operate on (Hernandez, 1993).

The objective of this paper is therefore to provide an understanding of how JIT can be applied in construction using ISO 9000 as a template. It will explain the JIT principles and ISO 9000 requirements to understand why it is possible to strategically use ISO 9000 to apply JIT successfully. This should provide quality managers with the opportunity to identify the necessary steps to apply JIT through existing ISO 9000 QMS. The successful implementation of JIT in construction should be rendered less cumbersome in the process.

IS INTEGRATION WITH ISO 9000 POSSIBLE?

Experience in the construction industry suggests that it is possible to integrate different management systems to achieve synergy. A good case in point is the ISO 14000 Standards for environmental management which share many similar concepts with the ISO 9000 Standards for quality management. In the former, an environmental management system (EMS) is a formal business process that may be used by organisations to manage environmental issues. The areas which are being developed under the ISO 14000 series of standards include the following:

1. EMS which becomes a part of an organisation's overall management system.
2. Environmental Auditing (EA) which is used to assess the conformance of EMS to various audit criteria.
3. Environmental Performance Evaluation (EPE) which provides the framework for an organisation to identify, select and use a variety of indicators to assess its environmental performance.
4. Environmental Labelling (EL) which provides consumers with an indication of the environmental friendliness of a product or service.
5. Life-Cycle Assessment (LCA) which gives an overall evaluation of the environmental impact of a product or service. The assessment includes raw materials used, production and operation, disposal, recycling and reuse.

An EMS therefore addresses environmental aspects of an organisation's products, services and activities while a QMS addresses quality aspects of the organisation's products or services. Whereas a QMS emphasizes on consistency, an EMS stresses continual improvement of the system to achieve overall improvement in environmental performance. Hence, a QMS tends to be customer-driven while an EMS tends to be stakeholder-driven (stakeholders in this case refer to employees, shareholders, bankers, local and international communities, regulators and other interest groups) (*The Straits Times*, 1998).

It can therefore be seen that both EMS and QMS are essentially management systems which can help a company manage a specific concern within the organisation. In this case, ISO 14000 and ISO 9000 are concerned with environmental and quality issues respectively. Nevertheless, the methodology used by both EMS and QMS is similar. In both cases, for example, there is a need to establish a policy, define roles and responsibilities, provide resources, appoint a management representative and provide appropriate training to staff. In addition, both EMS and QMS must be documented and records kept, internal audits must be conducted and there must be regular management reviews.

Consequently, the similar elements in both ISO 14000 and ISO 9000 standards allow for the integration of EMS and QMS. Common elements such as documentation control, training records, maintenance and calibration of equipment and procedures for non-compliance and corrective action for under-performance can therefore be integrated and addressed jointly in a single document (*The Straits Times*, 1998). This possibility of integrating EMS and QMS suggests that it is also technically possible to integrate the requirements of the ISO 9000 Standards with other management systems, including that of productivity improvement through the JIT philosophy.

QUALITY ASSURANCE BASED ON ISO 9000 STANDARDS

Quality assurance can be defined as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality. These actions serve to inspire confidence in a product or service so much so that the need for inspections and reworks is eliminated completely. The three basic elements of quality assurance are: Say what you do; Do what you say; and Record that you have done it (Lim and Low, 1992).

Within the wider context of the ISO 9000 Standards on Quality Systems, the quality assurance framework will include compliance activities such as third party approvals; systems audits; advanced quality planning; comprehensive quality manuals; use of quality costs; involvement of non-production operations; failure mode and effects analysis; and statistical process control, among others. The 20 clauses set out in ISO 9001 which all organisations will need to fulfil in order to develop their quality manuals are described succinctly by Low (1998) and the PS21 Office in the Prime Minister's Office (PS21 Office, 1998) as outlined below.

1. Management responsibility - Define the organisation's directions, route and crew, provide the means to get there and monitor progress. The following criteria form part of this requirement: establish written quality policy; establish quality objectives; define quality responsibilities and authority; identify and provide adequate resources; appoint management representative; and conduct review of system.

2. Quality system - Document what you know works, do what you know works and plan what you do not know. The following criteria form part of this requirement: document quality manual and procedures; define and document quality planning; and ensure effective implementation of quality system.

3. Contract review - Only make promises which you know you can keep. The following criteria form part of this requirement: establish procedures for review of customers' requirements; conduct review to determine whether customers' requirements can be met; ensure amendments to contracts are identified and transferred to relevant functions; and keep records of contract review.

4. Design control - For a new service or product, analyse the components and interactions, and design a more reliable solution. The following criteria form part of this requirement: establish design plans, activities, responsibilities and functional interfaces; assign design work to qualified people; ensure clear and unequivocal design inputs; ensure design inputs address statutory and regulatory considerations (if any); ensure design review; verify design outputs and conduct design validation; control design changes - and maintain records on design work and activities.

5. Document and data control - Ensure that everyone has the right information to do the job. The following criteria form part of this requirement: establish document control over issue, distribution and changes to controlled documents and data; remove obsolete and/or invalid documents; maintain masterlist or equivalent to identify current status; identify status of all controlled documents; and identify obsolete documents retained for legal and/or knowledge preservation purposes.

6. Purchasing - Use suppliers and subcontractors you can trust. The following criteria form part of this requirement: establish system of assessing and controlling subcontractors; specify clearly requirements of products to be purchased in purchasing documents; and review and approve all purchasing documents.

7. Control of customer-supplied product - If the customer supplies tools or materials, do not take it for granted that they work. Make sure that you return any equipment on loan. The following criteria form part of this requirement: inspect on receipt of the product or material; provide adequate storage; and report to customer on loss, damage or unsuitability for use.

8. Product identification and traceability - Do the right job, on the right terms. The following criteria form part of this requirement: establish system of product identification from receipt and during all stages; and establish system for product traceability and ensure recording on product and batches.

9. Process control - Provide the right environment and ensure the right output. The following criteria form part of this requirement: establish documented work instruction; provide suitable equipment and environment; provide trained personnel for the tasks assigned; ensure compliance with specifications and quality plans; identify and control product and process variables affecting quality; qualify equipment and processes before release; provide acceptance criteria for workmanship; control and monitor variables affecting special processes; maintain records of control; and carry out equipment maintenance.

10. Inspection and testing - Check that what comes in, what is being produced and what has been produced is what was wanted. The following criteria form part of this requirement: conduct incoming, in-process and outgoing inspections; ensure identification of materials if released for urgent production; and maintain inspection and testing record.

11. Control of inspection, measuring and test equipment - Don't forget to test the tester. The following criteria form part of this requirement: establish and maintain a calibration programme; maintain a master list of measuring equipment; ensure that equipment including test software are duly calibrated and traceable to national standards; establish calibration methods for all measuring and test equipment including jigs and fixtures and test software; and identify all measuring equipment and their calibration status.

12. Inspection and test status - Track so as not to miss a key action. The following criteria form part of this requirement: identify inspection status; maintain status to ensure that only products which pass the required inspections are dispatched, used or installed.

13. Control of non-conforming product - Know how to deal with bugs. The following criteria form part of this requirement: mark or segregate non-conforming products; review for disposition of non-conforming products; and re-inspect reworked items before release.

14. Corrective and preventive actions - Banish the known bugs and sniff out lurking ones. The following criteria form part of this requirement: investigate and analyse causes of non-conformance; initiate corrective and preventive actions; ensure actions taken are effective; record changes in procedures; and ensure preventive actions are reviewed by management.

15. Handling, storage, packaging, preservation and delivery - Having built in quality, do not ruin it at this stage. The following criteria form part of this requirement: provide suitable material handling methods; ensure appropriate methods for preservation and storage of products; control issue and receipt at store; assess stocks periodically; provide suitable and adequate packaging for products; and provide protection to products up to destination if contractually required.

16. Control of quality records - Now where did you put that letter? The following criteria form part of this requirement: establish methods for identifying and maintaining all quality records, including computer databases, and microfilms; ensure legibility and easy retrieval of records; provide suitable environment for storing quality records; and specify retention periods.

17. Internal quality audits - How well do your procedures relate to your actions? The following criteria form part of this requirement: establish audit plan and procedures to carry out audits on the quality system to check for compliance and effectiveness; ensure auditor independence; maintain records of audit results; ensure that deficiencies found are rectified and follow-up actions are conducted to ascertain their effectiveness; and review results of audits at management reviews.

18. Training - Develop the people to keep doing the job right. The following criteria form part of this requirement: identify training needs and execute training programmes; and maintain records of all training.

19. Servicing - When the customer comes back, keep him coming back. The following criteria form part of this requirement: provide after-sales servicing if required contractually; provide necessary support for servicing; and verify and report that servicing is done correctly.

20. Statistical techniques - Remember to apply mathematical formulae consistently. The following criteria form part of this requirement: identify needs for appropriate statistical techniques to verify process capability and product characteristics; and implement and control application of statistical techniques. (Low, 1998; PS21 Office, 1998; SISIR 1994).

JUST-IN-TIME PRINCIPLES

The JIT philosophy has been established in the manufacturing sector for many years. This concept is, however, still relatively new in the construction industry. About three decades ago, the idea for the JIT concept was first mooted by Mr Taiichi Ohno, former Executive Vice-President of Toyota Motor Corporation (Lim and Low, 1992). The JIT system used in manufacturing by Toyota Motor Corporation proved to be a success as the cars produced are of better quality and reliability and yet achieved savings in terms of improved productivity and reduction of costs in maintaining inventory levels and storage space. With its proven success at Toyota Motor Corporation, JIT was promoted widely both in Japan and abroad.

JIT is essentially:

a. a series of operating concepts that identifies operational problems systematically; and
b. a series of technology-based tools that corrects problems following their identification.

The successful implementation of JIT is dependent on the suppliers' flexibility, users' stability, total management and employee commitment as well as teamwork. Through the elimination of waste, JIT aims to improve product quality and productivity. Waste is considered as non-value adding to an activity. In any operation, it comprises motion and work. However, only work is a value-adding activity. Hence, motion is regarded as a form of waste. Wastes include over-production of components and products, delays in materials and information, material transportation, unnecessary processing, excess stocks, unnecessary human activities and defects in material and information. The seven principles of JIT used to overcome the above problems are now outlined.

(a) Elimination of waste

The fundamental philosophy of JIT is to eliminate waste and under the JIT concept, construction waste can be classified into the following categories:

1. waste from over-production
2. waste from delays
3. waste from transportation
4. waste from unnecessary processing
5. waste from excess inventory
6. waste from unnecessary motion
7. waste from defects.

(b) The Kanban or Pull System

Methods of production can generally be organised in two ways, namely the pull and the push system. In the pull system, organisations produce on demand whereas in the push system, organisations forecast the demand or maintain stock level. The advantage of the push system is that since the amount of production is known in advance, the scheduling of activities needed is predictable. However, a forecast may be required and therefore there is a possibility of over-production. The advantage of the pull system is that it is less dependent on estimates when compared to the push system. However, in the Kanban system, responding to unexpected demands is not possible.

(c) Uninterrupted workflow

Uninterrupted workflow means that the schedule for the final assembly must be smooth flowing. Hence, rationalisation and simplification of the production process is necessary. Every process should be reduced to its simplest form before considering mechanisation or automation and the aim is to replace a complex and expensive process with one that is simple and cheap.

(d) Total Quality Control (TQC)

In order to achieve zero inventory, errors and defective components must be eliminated in each task. Under TQC, all workers are responsible for ensuring that their work is defect-free before proceeding to the next stage of operation.

(e) Employee involvement

As noted earlier, the success of JIT implementation is dependent to a great extent on the teamwork and commitment of every employee. Each employee should be given adequate training and responsibilities in various areas like timeliness of production and quality assurance. Employees should be able to set up and maintain various type of machinery. Involvement can be extended to suggestion schemes and participation in quality improvement teams.

(f) Supplier relations

Building a good supplier-user relation is no longer a choice but a necessity. The quality of the supplies purchased is a critical factor to the quality of an organisation's finished products. Hence, an organisation must treat suppliers as long-term business partners so that the quality of materials delivered will always be maintained at a high standard. This would greatly reduce paperwork, inventory levels and storage space.

(g) Continuous improvement

An organisation should not remain content with its status quo. To maintain its competitiveness, it should continuously strive to improve operations and the ways in which activities are carried out. Audits and benchmarking are some of the tools which an organisation can adopt to ensure that its operations are improved continuously.

The successful implementation of JIT would require a consideration of the seven principles mentioned above. Once this is achieved, the advantages of implementing JIT would include:

- reduction in inventory level (work-in-progress and raw material)
- reduction in storage space
- reduction in factory overheads
- reduction in production costs
- reduction in rectification works
- improvement in quality
- improvement in productivity (Low and Chan, 1997a)

INCORPORATING JIT INTO ISO 9000 QMS

The comparative review above suggests that there are many similarities between ISO 9000 requirements and JIT principles which make integration possible. The thrust of this paper, as shown in Figure 1, is to attempt to incorporate JIT concepts into existing ISO 9000 QMS to achieve productivity in the construction industry. Having reviewed these requirements and principles, it is possible to match JIT requirements against the ISO 9000 template which consists of the 20 clauses in ISO 9001. This attempt at matching is shown conceptually in the matrix in Figure 2. The outcome of a technical comparison between ISO 9000 requirements and JIT concepts is shown in Table 1 which lists the situations where the relevant JIT principles can make use of an existing ISO 9000 QMS for implementation. JIT and ISO 9000 requirements which are similar are marked with crosses (x) in Table 1. In this manner, there is no necessity to establish a separate framework for the implementation of JIT and incurring in the process, additional resources and costs. Since most construction companies already have an existing ISO 9000 QMS in place or are in the process of developing and implementing one, the ISO 9000 template can help to facilitate the smooth development and implementation of JIT principles within an organisation. It is therefore timely for quality managers in construction firms to familiarise themselves with JIT principles and determine where these principles can be implemented within their organisations through existing QMS without disrupting other existing systems and operations.

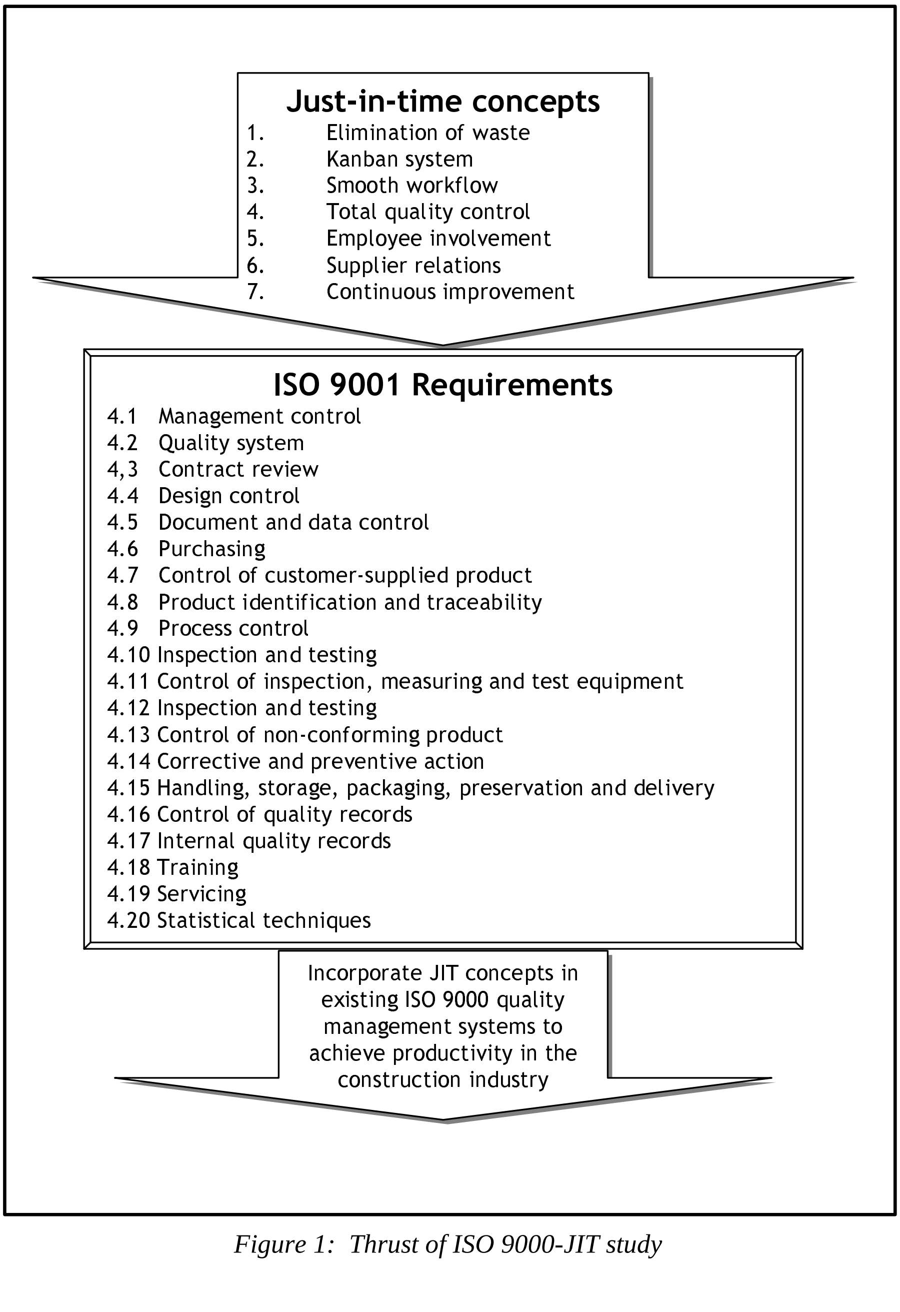

Figure 1: Thrust of ISO 9000-JIT study

		Just-in-Time Concepts						
		Elilmination of waste	***Kanban system***	***Smooth workflow***	***Total quality control***	***Employee involvement***	***Supplier relations***	***Continuous improvement***
ISO 9000 quality management system requirements	4.1 Management responsibility							
	4.2 Quality system							
	4.3 Contract review							
	4.4 Design control							
	4.5 Document and data control							
	4.6 Purchasing							
	4.7 Control of customer-supplied product							
	4.8 Product identification and traceability							
	4.9 Process control							
	4.10 Inspection and testing							
	4.11 Control of inspection, measuring and test equipment							
	4.12 Inspection and test status							
	4.13 Control of non-conforming product							
	4.14 Corrective and preventive action							
	4.15 Handling, storage, packaging, preservation & delivery							
	4.16 Control of quality records							
	4.17 Internal quality audits							
	4.18 Training							
	4.19 Servicing							
	4.20 Statistical techniques							

Figure 2: Matrix for integrating ISO 9000 requirements and Just-In-Time concepts

Table 1: Technical comparison of ISO 9000 requirements and JIT concepts

ISO 9000 requirements		*Just-In-Time Concept*						
		Elilmination of waste	*Kanban system*	*Smooth workflow*	*Total quality control*	*Employee involvement*	*Supplier relations*	*Continuous improvement*
4.1	**Management responsibility**							
4.1.1	Quality policy	x			x	x	x	
4.1.2	Organisation	x			x			
4.1.2.1	Responsibility and authority		x	x	x	x	x	

ISO 9000 requirements		*Just-In-Time Concept*						
		Elilmination of waste	*Kanban system*	*Smooth workflow*	*Total quality control*	*Employee involvement*	*Supplier relations*	*Continuous improvement*
4.1.2.2	Resources	x	x	x	x	x	x	
4.1.2.3	Management representative				x		x	
4.1.3	Management review	x	x	x	x	x	x	x
4.2	**Quality system**							
4.2.1	General				x			
4.2.2	Quality system procedures		x	x	x	x	x	
4.2.3	Quality planning	x	x	x	x	x	x	
4.3	**Control review**							
4.3.1	General				x			
4.3.2	Review	x	x	x	x		x	
4.3.3	Amendment to a contract		x		x	x	x	
4.3.4	Records		x		x		x	
4.4	**Design control**							
4.4.1	General				x			
4.4.2	Design and development planning	x	x	x	x		x	
4.4.3	Organisation and technical interfaces	x	x	x	x		x	
4.4.4	Design input	x	x	x	x		x	
4.4.5	Design output	x	x	x	x	x	x	
4.4.6	Design review	x	x	x	x		x	
4.4.7	Design verification	x	x	x	x	x	x	
4.4.8	Design validation	x	x		x		x	
4.4.9	Design changes	x	x		x	x	x	
4.5	**Document and data control**							
4.5.1	General				x			
4.5.2	Document and data approval and issue		x	x	x	x	x	
4.5.3	Document and data changes	x	x	x	x	x	x	
4.6	**Purchasing**							
4.6.1	General				x			
4.6.2	Evaluation of sub-contractors	x	x	x	x	x	x	
4.6.3	Purchasing data	x			x	x	x	
4.6.4	Verification of purchased product	x	x			x	x	x
4.6.4.1	Supplier verification at sub-contractor’s premises	x			x			
4.6.4.2	Customer verification of sub-contracted product	x			x			
4.7	**Control of customer-supplied product**	x		x	x	x		
4.8	**Product identification and traceability**	x	x	x	x	x	x	
4.9	**Process control**	x	x	x	x	x	x	

ISO 9000 requirements		*Just-In-Time Concept*						
		Elilmination of waste	*Kanban system*	*Smooth workflow*	*Total quality control*	*Employee involvement*	*Supplier relations*	*Continuous improvement*
4.10	**Inspection and testing**							
4.10.1	General				x			
4.10.2	Receiving inspection and testing	x	x		x	x	x	
4.10.3	In-process inspection and testing	x	x		x	x	x	
4.10.4	Final inspection and testing	x	x		x	x	x	
4.10.5	Inspection and test records		x		x	x		
4.11	**Control of inspection, measuring & test equipment**							
4.11.1	General	x			x			
4.11.2	Control procedure		x		x	x		
4.12	**Inspection and test status**							
4.13	**Control of non-conforming product**							
4.13.1	General				x			
4.13.2	Review and disposition of non-conforming product	x			x	x	x	
4.14	**Corrective and preventive action**							
4.14.1	General				x			
4.14.2	Corrective action	x	x	x	x	x	x	
4.14.3	Preventive action	x	x	x	x	x	x	
4.15	**Handling, storage, packaging, preservation and delivery**							
4.15.1	General				x			
4.15.2	Handling	x			x		x	
4.15.3	Storage	x			x		x	
4.15.4	Packaging	x			x			
4.15.5	Preservation	x			x		x	
4.15.6	Delivery	x	x	x	x		x	
4.16	**Control of quality records**		x		x	x	x	
4.17	**Internal quality audits**				x	x	x	x
4.18	**Training**	x		x	x	x		
4.19	**Servicing**	x	x		x	x	x	
4.20	**Statistical techniques**							
4.20.1	Identification		x		x	x	x	x
4.20.2	Procedures		x		x	x	x	x

CONCLUSION

Apart from the technical requirements of ISO 9000 which are explained above, very few studies have examined the non-technical requirements of ISO 9000 which actually form the backbone of the system. Both the technical and non-technical requirements are essential for ISO 9000 success (Low and Omar, 1997; Low and Chan, 1997). On the other hand, JIT is a philosophy which requires a system to operationalise its principles. A systematic approach can help to assist with JIT implementation. However, unlike ISO 9000, the

JIT philosophy lacks standard clauses and guidelines to provide assistance to organisations which are interested in implementing JIT.

While there is evidence to suggest that the application of JIT in construction is beneficial, the inability of local contractors to apply JIT principles consciously can be attributed to their ignorance and reluctance to adapt to changes. Many local contractors appear to lack not only a working knowledge of JIT but also a full understanding of ISO 9000 requirements. The integration of JIT principles with ISO 9000 QMS will also require a change in mindset on the part of the external auditor and quality manager. The quality manager should not regard the incorporation of JIT principles into the QMS as "excess baggage". Likewise, the external auditor should view JIT operations in a QMS as a value-adding activity and not penalise it for riding on the ISO 9000 framework. There will obviously be problems associated with this integration. However, with a proper understanding of its long term benefits, these problems can be ironed out readily.

In conclusion, it is worthwhile to reiterate once again that existing ISO 9000 QMS can be extended to incorporate JIT principles to achieve productivity in the construction industry. After this incorporation, it may also be worthwhile to consider integrating ISO 9000 QMS further with other management systems (for example, safety management system and EMS) to attain a truly Integrated Management System for an organisation. Construction companies in developing countries should bear these lessons in mind in order to achieve synergy when developing their own quality, productivity, safety and environmental management systems in the future.

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A Cost Minimisation Model of Contractor Performance based on European Best Practice

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Abstract

The authors have, over recent years, performed extensive empirical research into European (UK, French and German) construction contractor performance. This paper represents the culmination of that research, by presenting a model for minimising construction labour costs based on European best practice. By removing or neutralising the impact of external factors (such as the procurement method), the research was able to concentrate on contractor practices and their direct impact on construction (labour) cost performance. A variety of European contractor performance data were analysed to identify optimum solutions (i.e. contractors' construction practices) for achieving minimal cost. The principal theme of the paper is graphical presentation and description of *a model for minimising construction labour costs based on European best practice.* Contractors and clients across Europe may wish to consider the characteristics of the model in striving to achieve more cost effective performance.

Keywords: *European contractor performance, best practices, construction labour costs.*

INTRODUCTION

The culmination of four years work, which researched an aspect of European contractor performance, is presented. Specifically, this paper reports one of the principal conclusions of that work; the development of best practice performance models based on data from contractors in France, Germany and the UK. Here, a model for labour cost minimisation is presented and explained. The model embraces several generic construction concepts that were found to have significant positive impact on project (labour) cost performance (Proverbs, 1998a). The 'European' model presented proposes 'best practices' for these generic concepts. Contractors and/or clients seeking to reduce construction project labour costs may consider the best practices presented in the model. First, a snap-shot of earlier construction-performance studies is presented, this being followed by a summary of the research methodology employed in this work. Finally, a description of the model is given.

EARLIER CONSTRUCTION PERFORMANCE STUDIES

Research grants GR/C/551387, GR/C/906387, GR/D/34366, GR/E/66576, GR/J/09635 provided by the Engineering and Physical Sciences Research Council (EPSRC) over the last decade or so, together with substantial funded research supported by the Overseas Development Association, The Leverhulme Trust and industry, have all contributed to greater understanding of construction production performance. The results of such research, including useful planning and estimating data, have been well publicised. For example, refer to Harris *et al.* (1985), Emsley and Harris (1987) and Proverbs *et al.* (1999a).

Measuring the production performance and productivity of construction contractors is a complicated process. This is because in many instances, quantifying performance and output is not easy. Furthermore, because there are so many different products that can be produced in so many different ways. Notwithstanding this dilemma, Thomas and Yiakoumis (1987), Olomolaiye (1988), Horner and Talhouni (1990) and Price (1991) have all successfully carried out studies evaluating productivity levels on construction sites, utilising various research methodologies.

Comparison of contractor performance is further complicated because ‘like-for-like’ building projects, facilitating convenient evaluation of pre-determined contractor performance attributes, do not exist. Even where similar construction products are found, such as in the domestic housing sector, vagaries (for example, site conditions, geographical location and project timing) make comparisons difficult to say the least, and suspect if not carefully designed. The complexities of international comparisons are further compounded by factors such as the different cultures, languages and customs of the countries involved. However, recent reports by Bernard Williams Associates (1993), the Business Round Table (1994) and Cooke and Walker (1994), have demonstrated that such pan-European research is possible, and that results can provide informative, reliable and indicative international information.

None of the previously mentioned international studies have approached the contentious subject of contractor performance in the context of a competitive European construction industry. Whilst some earlier investigations have compared the productivity of international construction industries (Department of the Environment, 1995; Business Round Table, 1994; d'Arcy, 1993), there remains a dearth of research into the performance of contractors internationally. Subsequently, where contractors from different nations are to compete for the same work, it is unclear as to which (if any) are most likely to be successful in terms of being able to satisfy clients’ objectives. This research has sought to address this void whilst simultaneously developing best practice performance models for observation by contractors, clients and other construction professionals.

PRÉCIS OF RESEARCH METHODOLOGY

A desk-based methodology was used. Essentially, this was because it would prove impractical to attempt a field-study methodology without the considerable resources and linguistic skills required for such an international investigation. The methodology employed was designed to extract comparable contractor performance data by using a ‘model’ building project (in the form of a high-rise in situ concrete framed structure). This hypothetical, but realistic building meant that respondents’ contractor performance data could be analysed statistically on a ‘like-for-like’ basis, thus overcoming the problem of bias. Whilst the more critical reader may consider this approach ‘contrived’, it should be noted that such an approach nullified the impact of project specific variables, such as constructability, procurement method and project timing, which normally make unbiased performance comparison onerous and unreliable.

The sample comprised suitably experienced and resourced contractors in France, Germany and the UK. The firms were identified with the assistance of national contractor organisations. A combined total of 55 contractors participated in the study. These contractors’ Planning Engineers were sent the model building documents (appropriately translated) and requested to consider the model project, one for which their company intended to submit a *bona fide* bid. Respondents were asked to provide their own planned productivity rates for three main construction operations, these being: formwork erection, reinforcement fixing and concrete placing; to columns, beams and floor slabs respectively (a total of nine productivity rates). Practical solutions to a number of key construction methods and practices involved in building the model project were also elicited. To avoid repeating previously published details of this research methodology, sample stratification and the like, interested readers may observe Proverbs (1998a) and Proverbs *et al.* (1999b) for comprehensive elucidation.

GENERIC CONCEPTS OF THE COST MINIMISATION MODEL

Significant disparity was discovered in contractor's productivity rates provided for the three main operations involved in construction of the model structure. In summary, German contractors exhibited higher productivity for concrete placing and reinforcement operations, and French firms for formwork operations. The cost implications arising as a result of the productivity variations were also of significance.

Further investigation (using analysis of variance (ANOVA) and tests for association) revealed certain construction practices (i.e. construction methods and labour utilisation) to impact certain productivity rates. Ten such relationships (concepts) were identified and formed the generic concepts of the (labour) cost minimisation model as shown in Figure 1. These concepts include two types of variables, namely, construction methods and labour utilisation concepts.

Concepts 1, 2 and 3: Construction methods (formwork)

Five different formwork methods were identified by contractors, these being: traditional timber; steel; prefabricated; proprietary; and other solutions (the latter were not defined by respondents). The solutions preferred by French, German and UK contractors were found to be significantly different (refer to Proverbs *et al.*, 1998a). ANOVA revealed significant difference between the productivity rates achieved for different formwork [to beams (*F statistic* 3.996, *P value* 0.007), columns (*F statistic* 4.149, *P value* 0.0067) and floor slabs (*F statistic* 5.487, *P value* 0.001)] solutions (Proverbs *et al.*, 1998b). Tables 1, 2 and 3 present the mean productivity rates (MPRs), total hours, labour costs and indices for each of the formwork methods, based on the aggregated (i.e., 'European') sample.

In Table 1 for example, MPRs represent the productivity rates of formwork to beams as indicated by contractors who chose each particular formwork solution. Therefore, the average productivity rate for contractors choosing traditional timber formwork was 2.45 hours per square metre. By multiplying the MPRs with the quantity of formwork to beams contained in the model project (1600.76m²), total labour hours for each formwork solution can be derived. Hence, for traditional timber formwork, total labour hours equates to:

MPR	x	Project quantity	=	Total labour	hours
2.45 hrs/m²	x	1600.76m²	=.	3921.86	hours

To obtain the labour cost for each formwork solution, the total labour hours is multiplied by the all-in rate for skilled labour. In this example, a European rate based on the mean of (recently published) skilled labour rates in France, Germany and the UK, of £16.17 per hour has been used. Hence, for traditional timber formwork, the 'European' labour cost is:

Total labour hours	x	Labour rate	=	Labour cost
3921.86 hours	x	£16.17 per hour	=	£63,416.48

Table 1: European cost implications of formwork method to beams (Concept 1)

Formwork to beams (model project quantity: 1600.76m²)					
Formwork solution	*MPRs (hrs/m²)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Traditional timber	2.45	3921.86	£63416.48	5	1.52
Steel	1.50	2401.14	£38826.43	3	0.93
Prefabricated	1.45	2321.10	£37532.19	2	0.90
Proprietary	1.64	2625.25	£42450.29	4	1.01
Other	1.04	1664.79	£26919.65	1	0.64
Mean	1.62	2586.83	£41829.01	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17per hour (Builder,1994b)

This process was repeated until a labour cost was derived for each of the formwork solutions. Each of the solutions were then ranked in order of cost effectiveness, i.e. in this example *'other'* forms acquired lowest costs and were ranked first. A mean labour cost was also generated, based on the average of the five solutions. Cost indices were then calculated for each solution based on the mean 'norm' value of £48,829.01 (i.e., an index of 1.00). This facilitates a relative cost performance comparison of the solutions. Hence, traditional timber solutions result in labour costs 1.52 times the average, and so forth.

Similar calculations were conducted for formwork to columns and floor slabs as presented in Tables 2 and 3 respectively.

Figure 1: Generic concepts of the (labour) cost minimisation models

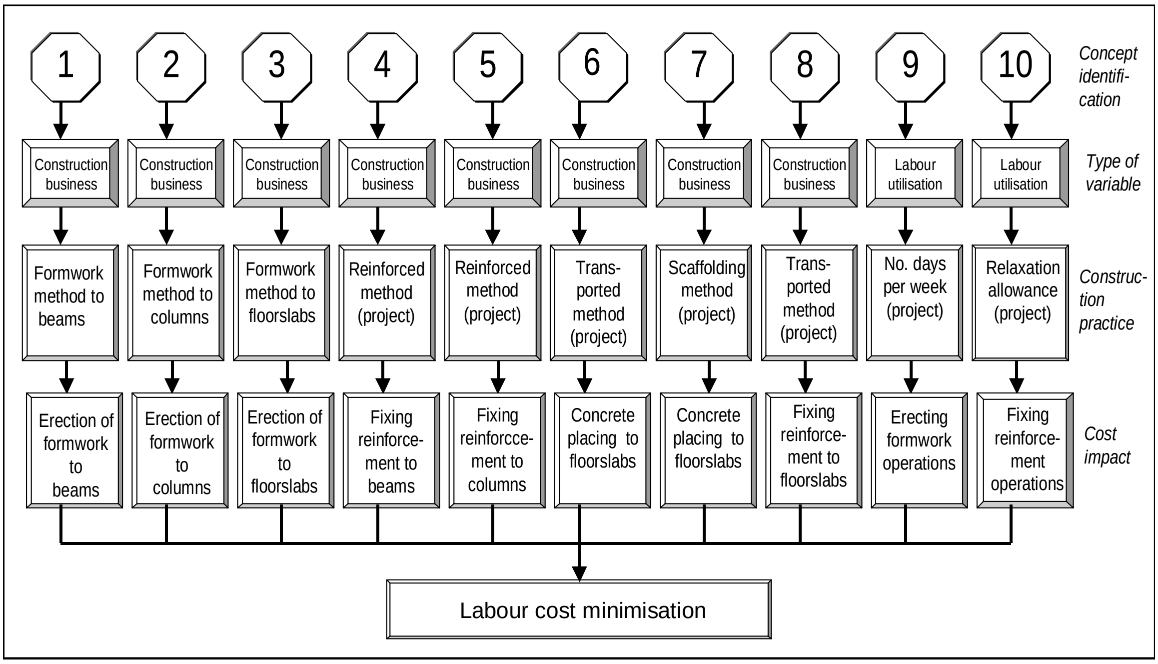

Table 2: European cost implications of formwork method to columns (Concept 2)

Formwork to columns (model project quantity: 977.76m²)					
Formwork solution	*MPRs (hrs/m²)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Traditional timber	1.91	1867.52	£30,197.80	5	1.48
Steel	1.18	1153.76	£18,656.30	3	0.92
Prefabricated	1.01	987.54	£15,968.52	1	0.78
Proprietary	1.09	1065.76	£17,233.34	2	0.85
Other	1.25	1222.20	£19,762.97	4	0.97
Mean	1.29	1259.36	£20,363.79	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17 per hour(Builder,1994b)

Table 3: European cost implications of formwork method to floor slabs (Concept 3)

Formwork to floor slabs (model project quantity: 4037.88m²)					
Formwork solution	*MPRs (hrs/m²)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Traditional timber	1.17	4724.32	£76,392.25	5	1.22
Steel	0.99	3997.50	£64,639.58	4	1.03
Prefabricated	0.91	3674.47	£59,416.18	2	0.95
Proprietary	0.96	3876.36	£62,680.74	3	1.00
Other	0.75	3028.41	£48,969.39	1	0.78
Mean	0.96	3860.21	£62,419.63	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17per hour (Builder,1994b)

Concepts 4 and 5: Construction methods (reinforcement)

Three different reinforcement fabrication methods were identified by contractors, these being: pre-bent; prefabricated; and bent and fabricated on-site. The solutions preferred by French, German and UK contractors were found to be significantly different (refer to Proverbs *et al.*, 1998c). ANOVA revealed significant difference between the productivity rates achieved for different reinforcement fabrication methods to beams and columns only (*F statistic* 3.271, *P value* 0.046 and *F statistic* 3.378, *P value* 0.042, respectively (Proverbs *et al.*, 1998b). Tables 4 and 5 present the mean productivity rates (MPRs), total hours, labour costs and indices for each of the reinforcement fabrication methods, based on the aggregated (i.e., 'European') sample. These were derived using the methodology described previously for concepts 1, 2 and 3.

Table 4: European cost implications of reinforcement fabrication methods for fixing reinforcement to beams (Concept 4)

Reinforcement to beams (model project quantity: 9.59 tonnes)					
Reinforcement fabrication method	*MPRs (hrs/tonne)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Pre-bent	22.82	218.84	£3538.64	1	0.78
Prefabricated	29.82	285.97	£4624.13	2	1.02
Bent & fabricated on-site	35.00	335.65	£5427.46	3	1.20
Mean	29.21	280.15	£4530.08	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17per hour (Builder,1994b)

Concepts 6 and 8: Construction methods (transportation)

Five main concrete transportation groups were identified from respondents as follows: concrete pump; tower crane / skip; tower crane / skip and hoist; tower crane / skip and concrete pump; and tower crane / skip, hoist and concrete pump (Proverbs, 1998b). The solutions preferred by French, German and UK firms were found to be significantly different.

By applying ANOVA (with the transportation method as the independent variable) significant difference between the productivity rates achieved for concrete placing to floor slabs (*F statistic* 3.786, *P value* 0.018) and fixing reinforcement to floor slabs (*F statistic* 2.873, *P value* 0.033) were revealed (Proverbs *et al.*, 1998b). Tables 6 and 7 (Appendix 1) present MPRs, total hours, labour costs and indices for each of these concepts derived using the same methodology.

Table 5: European cost implications of reinforcement fabrication methods for fixing reinforcement to columns (Concept 5)

Reinforcement to columns (model project quantity: 6.16 tonnes)					
Reinforcement fabrication method	*MPRs (hrs/tonne)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Pre-bent	22.32	137.49	£2223.21	1	0.79
Prefabricated	28.24	173.96	£2812.93	2	1.00
Bent & fabricated on-site	34.50	212.52	£3436.45	3	1.22
Mean	28.35	174.66	£2824.20	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17per hour (Builder,1994b)

Table 6: European cost implications of transportation methods for concrete placing to floor slabs (Concept 6)

Concrete placing to floor slabs (model project quantity: 605.68m³)					
Transportation solution	*MPR (hrs/m³)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Concrete pump	0.76	460.32	£6909.40	1	0.63
Tower crane, skip	1.31	793.44	£11,909.53	3	1.08
Tower crane, skip & hoist	0.86	520.88	£7818.41	2	0.71
Tower crane, skip & concrete pump	1.31	793.44	£11,909.53	3	1.08
Tower crane, skip, hoist & pump	1.82	1102.34	£16,546.12	4	1.50
Mean	1.21	734.08	£11,018.60	N/A	1.00

*Labour cost is based on a mean European rate for semi-skilled labour of £15.01per hour (Builder,1994b)

Table 7: European cost implications of transportation methods for reinforcement fixing to floor slabs (Concept 8)

Reinforcement fixing to floor slabs (model project quantity: 78.75 tonnes)					
Transportation solution	*MPR (hrs/m³)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Concrete pump	8.78	691.43	£11,180.42	2	0.69
Tower crane, skip	14.73	1159.99	£18,757.04	4	1.15
Tower crane, skip & hoist	7.95	626.06	£10,123.39	1	0.62
Tower crane, skip & concrete pump	21.30	1677.38	£27,123.23	5	1.66
Tower crane, skip, hoist & pump	11.24	885.15	£14,312.88	3	0.88
Mean	12.80	1008.00	£16,299.39	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17 per hour (Builder, 1994b)

Concept 7: Construction methods (scaffolding)

Four scaffolding options were identified from respondents as follows: traditional tube and fittings; mobile towers; standard proprietary systems; and designed solutions (Proverbs *et al.*, 1998d). The solutions preferred by French, German and UK firms were found to be significantly different.

ANOVA revealed significant difference between the productivity rates achieved for concrete placing to floor slabs (*F statistic* 3.459, *P value* 0.023) depending on the scaffolding system implemented (Proverbs *et al.*, 1998b). Table 8 (Appendix 1) presents the MPRs, total hours, labour costs and indices.

Table 8: European cost implications of scaffolding methods for concrete placing to floor slabs (Concept 7)

Concrete placing to floor slabs (model project quantity: 605.68m³)					
Scaffolding solution	*MPR (hrs/m³)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
Traditional tube and fittings	1.39	841.90	£12,636.92	2	0.87
Mobile towers	2.65	1605.05	£24,091.80	4	1.67
Standard proprietary systems	1.49	902.46	£13,545.92	3	0.94
Designed solutions	0.83	502.71	£7545.68	1	0.52
Mean	1.59	963.03	£14,455.08	N/A	1.00

*Labour cost is based on a mean European rate for semi-skilled labour of £15.01per hour (Builder,1994b)

Concept 9: Labour utilisation (number of days worked per week)

Weekly working schedules were found to be significantly different among the three countries (Proverbs *et al.*, 1999c). On average, UK contractors planned to work 5.4 days per week, while all French and German contractors intended to work no more than five days.

A correlation coefficient of 0.294, at 5 per cent level of significance was found between the number of days worked each week and the formwork erecting *M*MPRs (average MPRs for beams, columns and floor slabs). This indicates that weekly working schedules and the productivity of formwork operations were inter-related, i.e. working schedules exceeding five days per week were counter-productive (Proverbs *et al.*, 1998b). Table 9 presents the *M*MPRs, total hours, labour costs, rankings and indices for the three classifications of working schedules based on the European sample.

Table 9: European cost implications of weekly working schedules and formwork operations (Concept 9)

Formwork to entire project (quantity: 6616.40m²)					
Weekly working schedule	*MMPRs (hrs/m²)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
5	1.37	9064.47	£146,572.48	1	0.82
5.5	1.69	11181.72	£180,808.41	2	1.01
6	1.96	12968.14	£209,694.82	3	1.17
Mean	1.67	11071.44	£179,025.24	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17 per hour (Builder, 1994b)

Concept 10: Labour utilisation (relaxation allowance)

The time allocated for official breaks during the working day was found to be significantly different in the three countries (Proverbs, *et al.*, 1999c). On average, allowances per hour equated to 5.64, 6.24 and 7.44 minutes per hour worked in UK, Germany and France.

The relaxation allowance significantly correlated with the reinforcement fixing *M*MPRs (correlation coefficient of 0.305, at 5 per cent level of significance), indicating that extended relaxation allowances are counter-productive (Proverbs *et al.*, 1998b). Table 10 presents the cost implications and indices for the three classifications of allowance (as identified from the sample response).

Having explained the ten generic concepts of the cost minimisation model, now follows presentation of the model.

Table 10: European cost implications of relaxation allowances and reinforcement fixing operations (Concept 10)

Reinforcement to entire project (quantity: 94.50 tonnes)					
Relaxation allowance (mins/hr)	*MMPRs (hrs/tonne)*	*Total labour hours*	*Labour cost**	*Rank*	*Index*
< 6	19.86	1876.77	£30,347.37	1	0.82
≥ 6 < 7	24.90	2353.05	£38,048.82	2	1.03
≥ 7	27.67	2614.82	£42,281.64	3	1.15
Mean	24.14	2281.55	£36,892.61	N/A	1.00

*Labour cost is based on a mean European rate for skilled labour of £16.17 per hour (Builder, 1994b)

COST MINIMISATION MODEL

'European', French, German and UK variants of the model were derived using appropriate data sets. For the ‘European’ version aggregated data accrued from all the sample (as previously described) was used. For the French, German and UK models, aggregated data were substituted with data specific to each country, as appropriate. Similar calculations to those described above were performed for each of the concepts. Here, only the ‘European’ cost minimisation model is presented. Readers interested in the country-specific variants of the model are referred to Proverbs (1998a).

‘European’ cost minimisation model

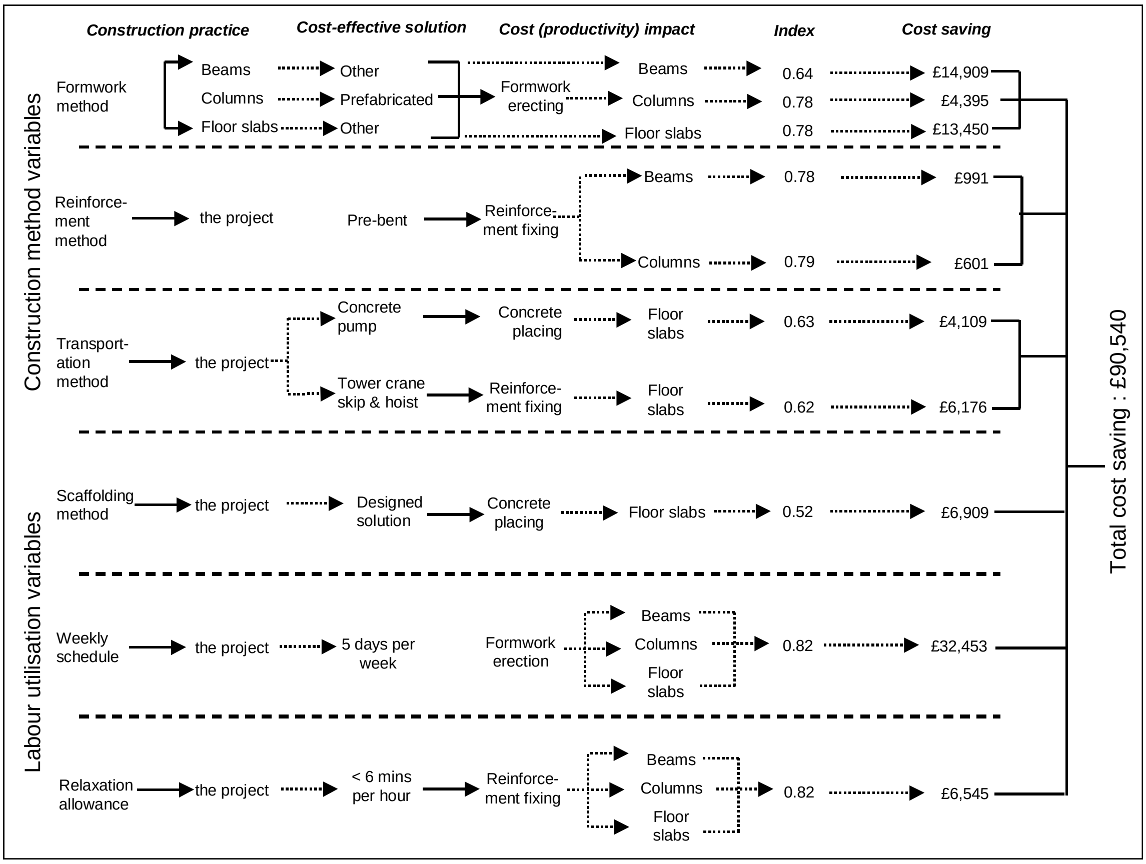

Figure 2: European construction cost minimisation model

Applying the above generic principles and based on the ten concepts presented in Figure 1, labour costs and indices were derived for the ‘European’ cost minimisation model. This model is presented graphically in Figure 2. Data used as inputs to the model are extracted from Tables 1 to 10. The solution / category ranked in first place (i.e., the most cost effective) for each of the ten concepts, together with associated indices and (labour) cost savings (as compared to the mean for each concept) are presented graphically in the model. Total cost savings exceed £90,000 sterling (i.e. when the savings from all concepts are considered jointly).

The most valuable construction practice (in the context of construction labour cost saving) is the weekly schedule. Working no more than 5 days per week results in a cost saving of £32,452.76 (i.e. 36 per cent of total labour savings) when compared to the mean cost. Choosing the appropriate formwork method also has considerable financial implications. Considered collectively, cost effective solutions for formwork to beams, columns and floor slabs (concepts one to three) return total cost saving of £32,754.87 (i.e. 36 per cent of total labour savings) when compared to mean costs. It is important to note that these cost savings would increase substantially when compared to the most costly solutions for each of the ten concepts.

It is pertinent to acknowledge the fact that the model is theoretical, based on foregone analyses. In reality, such a simultaneous combination of solutions might not be possible! Nonetheless, this theoretical model serves as ‘benchmark’ to which contractors can aspire.

SUMMARY

Construction practices found to be significantly related to construction labour costs formed the generic concepts of the cost minimisation model. Ten construction practices (concepts) were identified and classified as either construction method or labour utilisation variables. Explanation of how these were used as inputs to the cost minimisation models have been explained.

Using appropriate data, ‘European’, UK, French and German versions of the models were developed, and here, the European variant presented. Valuable cost savings were derived following implementation of the optimum solutions for the five concepts.

In striving for continuous improvement, contractors across Europe may wish to consider implementation of those construction practices identified in the model. For UK contractors, this may help acquire the annual target of 10 per cent reduction in construction costs set by the Construction Task Force (Egan, 1998). Contractors from developing countries may consider the model as a useful guide, in that it is based upon the experiences of contractors from developed countries.

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Application of Product Modelling Technology in Building Plan Checking Systems

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Abstract

CORENET (COnstruction and REal Estate NETwork) is a major Information Technology (IT) initiative undertaken by the Ministry of National Development of Singapore to propel the construction and real estate sector into the next millennium. Plan Checking Systems is one of the projects in CORENET. Its aim is to automate the process of checking of building plans for compliance with the Regulations and Codes of Practices (CoPs) stipulated by various government agencies. In order to capture the data from the building plans and to aid the data interpretation by plan checking engine, the emerging technology, namely product modelling technology, has been adopted.

The paper describes how the contents in the CoPs were transferred to the plan checking models and how these models are constructed to bridge the building plans and plan checking systems. The paper also highlights the current data integration problems existing in the construction industry.

Keywords: P*roduct modelling; code of practices; building plan checking; data integration.*

INTRODUCTION

Most information of a building originates from the design stage. This information is used for different purposes, is shared and processed by many parties at every stage of the construction process. But it is always not an easy task to capture and interpret the design information. It could be more difficult if the information is generated by more than one party and is presented in more than one format.

This paper discusses how product modelling technology is applied to extract information which is generated during the design stage for plan checking. The information needed for plan checking is specified in the various Code of Practices (CoPs) and government Regulations. These models are built to facilitate the information transfer from digital design files to building plan checking systems.

BACKGROUND

The development of the Automated Plan Checking Systems is one of the key activities of CORENET, which is one of the major IT initiatives identified under the Information Technology Master Plan of Singapore (IT2000) by the Ministry of National Development for the construction industry (http://www.ura.gov.sg/corenet/). These systems aim to automate the checking process of the various building-related drawings submitted by designers. With these systems, regulatory requirements can be checked more consistently and comprehensively. Areas of non-compliance with respect to Building Codes and Regulations can be detected and addressed during the early stages of the design process rather than during the approval phase. This will result in fewer re-submissions of plans without compromising on the safety aspects of the building.

Three plan checking systems have been identified to cater for three main design disciplines, namely, architects, structures engineers and M&E engineers. The respective plan checking systems are:

- Integrated Building Plan Checking System (IBP);
- Integrated Structural Plan Checking System (ISP); and
- Integrated Building Services Plan Checking System (IBS).

This paper mainly focuses on the IBP. IBP checks information or design plans mainly generated by architects against various government agencies' requirements, such as those listed below:

- Building Control Division (BCD)
- Fire Safety Bureau (FSB)
- Ministry of Environment (ENV)
- Land Transportation Authority (LTA)
- Housing Development Board (HDB).

PRODUCT MODELS FOR PLAN CHECKING SYSTEM

As a pioneer project in this area, no precedent pattern can be followed to capture the abundant information needed for plan checking, which is encapsulated in a number of CoPs and Regulations, from various government agencies. Therefore, product modelling technology was adopted because of its proven track record in modelling of the building construction industry and increasing popularity among software vendors who are targeting the industry.

Objectives of the Models

Product Models for plan checking systems is to ensure consistent interpretation of the building plans submitted by designers. It is used as a data exchange standard between CAD systems and plan checking engine.

These models will be useful for two groups of users:

- Application developers of Plan Checking Engine; and
- CAD vendors.

Applications of the Plan Checking Models

Generally speaking, these models serve documented user requirements or system specifications. Therefore, they can be used:

- by application developers of the Plan Checking Engine, to provide a static data model capturing all building plan data at high semantic level in order to perform the compliance checking; and
- by CAD vendors, to customise their respective CAD systems for compliance with the plan checking requirements. *Product Modelling*

Product modelling is a way of communication on a high semantic level. In a product model, information on the product is stored as objects with attributes, representing the product and its properties (Zhong, 1998). The product information is stored in a standardised format, which is independent of the application that may use it. A product model is a particular type of conceptual schema (Bjork, 1995).

The product modelling concept was first introduced during the late eighties in CAD systems for integration purpose after geometric modelling concept, represented by IGES, was found inadequate to support the design tasks (Luiten, 1994). Currently both STEP ([ISO TC184/SC4], 1997) and IAI (1997) have adopted the Product Modelling methodology in their corresponding modelling and implementation approach towards the building construction industry.

Modelling Principles

Principles below have been followed during the modelling exercise:

- To adopt the bottom up approach.
- To construct stand alone models according to each clause or each chapter in the CoPs and regulations first, and then harmonise these models into an integrated view model.
- To comply with the IAI.

Model Harmonisation

As there is a large quantity of information encapsulated in a number CoPs and regulation documents, to avoid the risk of missing data, the bottom up approach was used to start off the modelling exercise.

Stand-alone models are built according to each clause or requirements from CoPs or regulation document within one agency. These models are then integrated through a harmonisation exercise (see Figure 1).

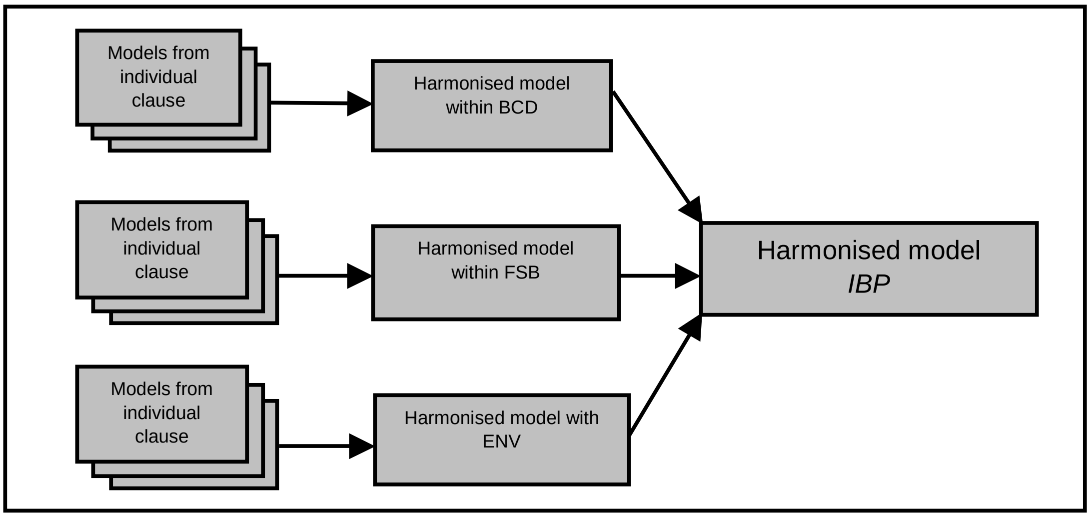

Figure 1: Model Harmonisation

Data Structure

Each agency requires a specific domain of information for its plan checking needs. Some objects, such Building, Space and Wall, are needed by all the agencies. On the other hand, some other objects are only needed by one agency, such as *Hydrant* by FSB. This same principle is also applied to the attributes. For example, only in FSB extension models is *HabitableHeight* associated with Zone.

The product models for plan checking have been defined in two layers (see Figure 2):

- Common Model Layer; and
- Extension Model Layer.

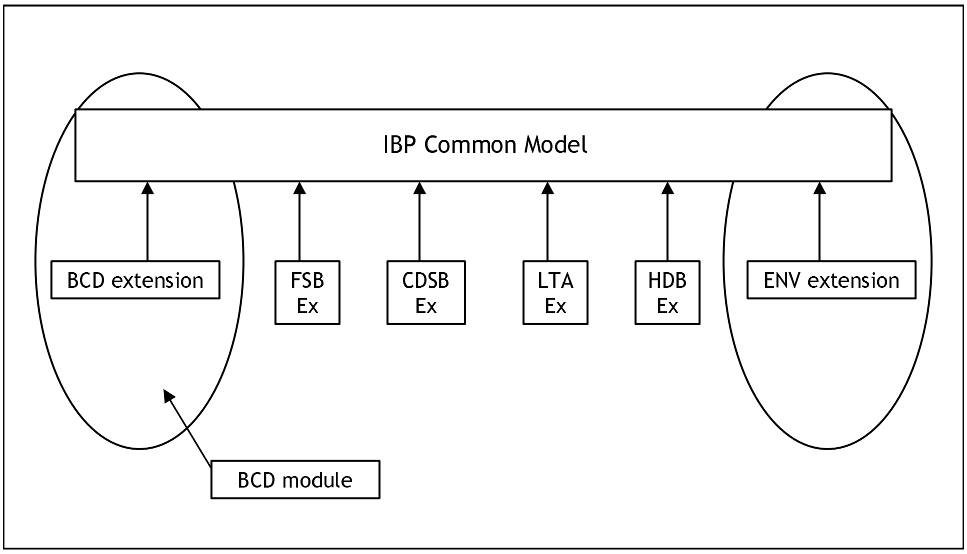

Figure 2: Two Layers of Models for Plan Checking

Compliance with IAI

Product models developed for plan checking systems are based on consideration of IFC Pre-release v 1.5 models.

Schematic Diagram of Plan Checking Process

As indicated in the first section, product models are constructed to facilitate the information transfer from digital design files to building plan checking systems. These are shown schematically in Figure 3.

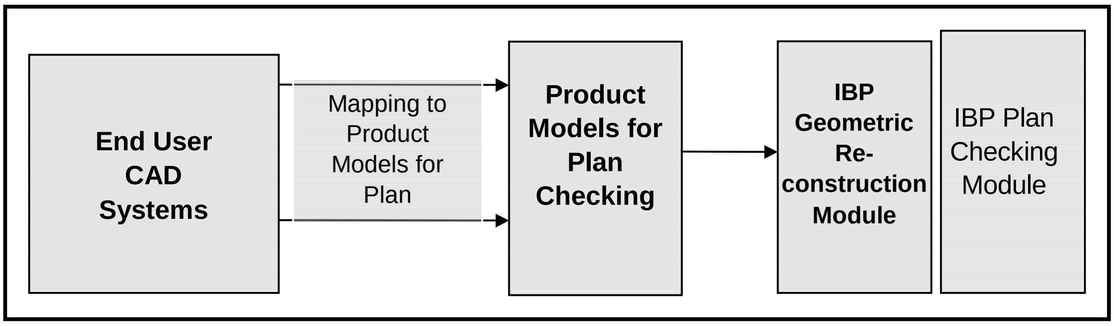

Figure 3: Schematic Overview of the Plan Checking Process

Digital CAD files are submitted by designers to government agencies for code compliance. As each CAD system has its own native file format and semantic data structure, in order to maintain consistent interpretation of the Code of Practices and Regulations, the following practices have to be enforced:

- Submitted CAD files from designers must semantically comply with the definition of Product Models for Plan Checking; and
- Submitted CAD files from designers must syntactically comply with a predefined CAD file format, such as STEP Physical file format, or DXF, DWG format.

After mapping, CAD files will be processed by the Plan Checking System. Areas of non-compliance with respect to Building Codes and Regulations can be detected and addressed during the early stages of the design process if it is used for self checking or during the approval phase if it has been submitted to the government agencies for approval.

Example of Models Developed to Capture the Information for Plan Checking

EXPRESS Definition

Plan Checking Models are presented in both lexical EXPRESS and graphic EXPRESS-G formats.

Take *Staircase* for example, object, *Staircase*, in *Common Layer* has attributes needed by more than one *Extension Layers* while in *Extension Layers* it has attributes only needed by a specific domain. EXPRESS definitions are:

```
SCHEMA common;

ENTITY CnStaircase
        SUBTYPE OF (CnElementAssembly);
        Headrooms : LIST [1:?] OF CnLengthMeasure;
        Pitchlines : LIST [1:?] OF CnBoundedCurve;
        HasLandings : LIST [2:?] OF CnBuildingElement;
        StaircaseType : StaircaseType;
        HasFlights : LIST [1:?] OF CnFlight;
 DERIVE
        NoOfRisers : SET [1:?] OF INTEGER := FlightHeight/StepHeight;

END_ENTITY;

END_SCHEMA;

SCHEMA FSBext;

    ENTITY    CnFSBStaircasePropeties;
              PropertiesForStaircase : CnStaircase;
              IsScissor : BOOLEAN;
              IsPressurised : BOOLEAN;

 INVERSE
        ConnectsToPassagesays : SET[0:?] OF CnPassageway FOR ConnectsToStaircase;

END_ENTITY;

END_SCHEMA;
```

Data Dictionary

In order to assist in understanding the connotation of the models, a data dictionary is produced for every object and attributes associated with the object.

The dictionary is defined as two levels with different views. *Level 1* comprises general information including the definitions, corresponding CoPs clauses, illustration drawings and attributes in *Common Layer*. *Level 2* comprises information in all *Extension Layers*. *View* defines information particular to each *Schema* in context of EXPRESS language, such as Common Schema, BCD Schema, or FSB Schema, etc.

See Figures 4, 5, and 6 for exemplary data dictionary for *Staircase* in both Level 1 and Level 2 with different views.

CnStaircase	Data Sheet Type : Level 1 Version : 1.1 Date : 11 August 1997 Page : 1 of 4
Super Classes : CnObject | CnProduct | CnElement | CnElementAssembly	Author : Zhong Qi
Standard/Clauses : <B> for BCD <F> for FSB <L> for LTA <E> for ENV <C> for CDSB <H> for HDB	**Definition** Construction that comprises a succession of horizontal stages (steps or landings) that make it possible to pass on foot to other levels. **IFC Definition** Not available in v1.5. **BSI Definition** **(**or stair) Construction that comprises a succession of horizontal stages (steps or landings) that make it possible to pass on foot to other levels.
<Drawing illustration>	**Functional Views**
<Express-G diagram>	<Express Codes>

Figure 4: Exemplary Data Dictionary For Staircase in Level 1

CnStaircase		Data Sheet Type : Level 1 Version : 1.15 Date 11 August 1997 Page 2 of 4
Super Classes : CnObject | CnProduct | CnElement | CnElementAssembly		Author : Zhong Qi
Common View		
Attributes	**Type (Optional)**	**Definition**
• HasFlights	LIST [1,?] of CnFlight	List of relationships to the flights forming part of the staircase
• HasLandings	LIST [2,?] of CnBuildingElement	List of relationships to the building elements, which function as landing, i.e. landing and floor
• Headroom	LIST [1:?] of CnLengthMeasure	List of headrooms above a staircase
• NoOfRisers	SET [1:?] of INTEGER (derivable)	Set of relationship, which define the number of risers and which can be derived from tread width and horizontal run.
• Pitchline	LIST [1:?] of CnBoundedCurve	Notional line that touches the nosings of a flight on the walking line.
• Type	StaircaseTypes ENUMERATION [Circular, Geometric, Spiral, Straight]	Geometric type of staircase.

Figure 5: Exemplary Data Dictionary For Staircase in Level 1 With Common Views

CnFSBStaircaseProperties	Data Sheet Type : Version : Date : Page :	Level 2 1.1 11 August 1997 3 of 3
Super Classes : N.A.	Author :	Zhong Qi

FSB View

Attributes	**Type (Optional)**	*Definition*
• ConnectsToPassageways	SET[0:?] of CnPassageway	Set of relationship to passageway, to which this exit staircase is connected.
• IsPressurised	BOOLEAN	If the staircase is pressurised
• IsScissor	BOOLEAN	If the staircase is a scissor staircase
• PropertiesForStaircase	CnStaircase	Extended attributes of staircase from common model for FSB domain.

Figure 6: Exemplary Data Dictionary For Staircase in Level 2 With FSB Views

CONCLUSIONS - PROBLEMS TO BE FACED IN IMPLEMENTATION

This paper discussed the modelling of information needed for code compliance. Actual implementation in may be much more difficult, however, this is beyond the scope of this paper. Some issues of concern include the following:

- Ensuring that CAD systems are able to generate files which are rich enough to capture all the objects and relationships needed for code compliance.
- Ensuring that CAD systems are able to generate files which comply semantically and syntactically with the models.
- Ensuring that the models are able to capture all the information identified in CoPs.
- Ensuring that Plan Checking engine are able to accept CAD files.

Finally, for a system like this to succeed, it is very important to get the relevant people to support such a change of process, as it has a dramatic impact on all parties in the industry.

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A Comparative Study of Artificial Neural Networks and Multiple Regression Analysis in Estimating Willingness to Pay for Urban Water Supply

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Abstract

This paper describes a study that was carried out to estimate willingness to pay 'WTP' for urban water supply. The study looked at three types of consumers typically found in urban areas in developing countries. Those who receive water through existing connections; stand posts; and water wells. To estimate WTP, two forecasting techniques are applied, namely, Artificial Neural Networks (ANN) and Multiple Regression (MR). The former is a state-of-the-art technique while the latter a conventional one. A comparative study was carried out to determine whether the estimate for WTP with the application of the ANN technique can produce better predictions than with the MR method. A comparison was made between the ANN and MR models, in terms of their forecasting accuracy, by using a relative measure known as the mean absolute percentage error (MAPE). The forecasting error of the best ANN model was found to be about half of that of the best MR model. From the MR models, it was seen that the significant variables that determine WTP differ depending on the type of consumer, and from those variables typically considered as significant for WTP by urban consumers in developed countries.

Keywords: Water supply; willingness to pay; price; artificial neural networks; regression; benefits; costs.

INTRODUCTION

Many countries are beginning to consider urban water supply as a strategic resource, not only due to its scarcity and wastage, but also due to its impact on the environment and equity related issues. Pricing of urban water supply is therefore not simply a matter of raising revenues to ensure continued operation of the enterprise concerned, although this is a major function of pricing. What is of strategic concern is the role of pricing in ensuring that the expansion of capacity and consumption is at the correct level.

A pricing approach that ensures the expansion of capacity and consumption is at the correct level places the burden on the consumer to reveal willingness to pay (WTP) (Warford, 1994) and, hence, value of water consumed. If the price paid is at least equal to the cost of providing additional supplies, investment in additional capacity is warranted; if not, existing capacity should be rationed (Warford, 1994). This forward-looking approach to pricing can provide the test for project justification in urban water supply.

The objectives of this paper are to describe a study that was carried out to estimate WTP for urban water supply in Trincomalee, the harbour city in the North East of Sri Lanka and to carry out a comparative study to evaluate the forecasting performance of Artificial Neural Networks (ANN) technique and Multiple Regression (MR) method in estimating WTP.

The ANN is considered as a state-of-the-art technique while MR is the conventional one. A comparative study should determine whether the estimate for WTP with the application of the ANN technique can produce better predictions than with the MR method. In the field of construction management, several ANN applications have already been made in areas such as sequencing, simulating and optimising construction processes (Flood, 1989, 1990; Flood and Kartam, 1993), and predicting tender bids (Gaarslev, 1991).

The WTP is an indicator of the strength of an individual's preference for a good or service. The price estimated as a result of this study can be used to estimate benefits to determine whether additional capacity is warranted, or existing capacity should be rationed in Trincomalee. It has been established that the old water supply scheme is unable to meet the water requirements of the city and surrounding areas (Barathithasan, 1997).

The study looked at three types of consumers typically found in urban areas in developing countries: those who receive water through existing connections; stand posts; and water wells (i.e., persons with no access to urban water supply). This study can provide the basis for future surveys and estimation of WTP for urban water supply projects.

Willingness to pay (WTP) for water supply

A number of questions arise when water utilities in developing countries attempt to study consumption patterns of households (HHs) (Barathithasan, 1997). For example, some common questions are: Where do HHs obtain their water? How much water do different types of HHs consume? What do they use the water for? How much do HHs pay for water (if anything)? What does that payment represent as a proportion of HH income? What is their WTP for water services? Unfortunately, water utilities do not know the answers to such essential questions.

Consequently, new systems and expansions are planned and designed with little understanding of HH water demand behaviour. Hence, urban supply schemes often fail to achieve the expectations of the consumer, the goals set for the number of HHs to be connected to the water system, the amount of water that should be produced, and the recovery of the revenue (Barathithasan, 1997). For example, the public investment programme for Sri Lanka (PIP, 1996) estimates that the "non-revenue water", a term referring to production loss when water is distributed by the utility, is about 50%. Barathithasan, (1997) identifies the main cause of these shortfalls as the lack of useful and adequate data on HH water demand and WTP for water.

The value of an environmental resource, like water supply, arises because people (either as individuals or as society) wish to consume it, and is due to its “use value” as well as its “non-use value”. The use values arise from physical personal use while non-use values arise from non-physical non-personal use of the environmental resource. The basic measures of use values and non-use values are an individual's: maximum willingness to pay (WTP) to prevent environmental damage or realise an environmental benefit; and/or minimum willingness to accept (WTA) compensation for accepting a specific degradation in environmental quality (ADB, 1996).

The maximum price an individual is willing to pay for a good or service is a measure of how much that good or service is valued. In other words, WTP is the maximum amount a person would be willing to pay to obtain an improvement in or avoid deterioration of an existing environmental condition. WTP is typically influenced by several factors, such as an individual's income, gender, cultural preferences, education, and age (ADB, 1996).

The study by Whittington et al. (1989) established that a rapid reconnaissance survey of water vending activities in Onitsha, Nigeria, and WTP gave valuable information on whether the poor can afford water, for water supply planning. However, it is generally accepted that the contingent valuation method (CVM) can be used to value both the use and non-use value of an environmental resource (ADB, 1996).

Whittington et al. (1990) showed that contingent valuation survey is a feasible method for estimating the individual's WTP for improved water supply services based on a study in southern Haiti. This research suggested that the contingent valuation survey may prove to be a viable method for collecting information on the individual's WTP for a wide range of public infrastructure projects and public services in developing countries.

Martin and Wilder (1992) found a relatively strong inverse relationship between HH income and delinquency in payment of water bills. Low income HHs are much more likely to be in arrears than higher income HHs because delinquency can lead to service cut-off. This causes a dilemma in the pricing of water services, as income elasticity of demand is low and economic growth does not bring large revenue growth for the water system.

In addition, as the elasticity of demand with respect to marginal price is relatively low, the supplier has an incentive to increase the marginal price when there is a need to increase revenue. This can lead to increased cut-offs of low income HHs that not only leads to substandard living conditions but also raise public health concerns. Martin and Wilder (1992) state that it has some characteristics of a public good in the sense that "if my neighbour's service is cut-off both of us suffer".

Warford (1994) defined an efficient policy as one which maximises the net benefits accruing to a community from a given course of action, with no consideration paid to the way in which those benefits are distributed. According to Warford (1994), a proposition stemming from this definition is that the price of a good or service should be equated to the cost of producing an additional unit of it or to its marginal or incremental cost. If consumers are willing to pay a price that exceeds marginal cost, it means that they place a value on the marginal unit at least as great as the cost to the rest of society of producing that unit. Therefore, output and consumption should be expanded when the system's capacity is reached (Warford, 1994).

Data on WTP

As noted earlier, a pricing approach that ensures the expansion of capacity and consumption is at the correct level places the burden on the consumer to reveal WTP (Warford, 1994) and, hence, value of water consumed. To collect primary data necessary to establish the WTP, surveys were conducted using prepared questionnaires in the Trincomalee (TDSA) and Kantale Divisional Secretary Area (KDSA).

For the WTP surveys, three types of consumers were interviewed in the study area; namely, those having existing water supply connections (WSCs), those who use stand posts (SPs), and those who use water wells (WWs) because they have no access to urban water supply. A different questionnaire was used to interview each group of consumers.

In developing these questionnaires, socio-economic, production and functional variables that typically influence WTP for a good or service (ADB, 1996) and those found in the pilot study (Barathithasan, 1997) to be relevant in the local situation were included. For example, unlike in WTP surveys in developed countries where the owner of the house is generally defined as the chief occupant (CO) (ADB, 1996), house owners in the study area were not necessarily the main contributors to the household income.

The pilot study showed that the CO (house owner)'s income did not reflect the true economic picture of the HH. Besides, secondary income sources (i.e., schoolteachers conducting extra classes after hours of school, or low salaried employees earning income from retail shops or other businesses) of the members of the HHs were found to be as significant as, or larger than their primary source (monthly salary). Such factors found in the pilot study to be relevant to the local situation were included in the main questionnaires.

The variables on which data were collected to estimate the WTP are given in Table 1. The primary income source from employment of the COs had four categories: white collar jobs (WC); blue collar jobs (BC); businessmen/women (BS); and pensioner (PE). The other variables and their symbols are shown in Table 1.

To estimate the WTP, the following environmental changes were specified. For those who had existing WSCs, it was the additional amount to obtain an improvement in existing water supply from 12 hours to 24 hours of supply by replacing smaller pipes with bigger sized pipes. For those who used SPs, it was the possibility that the utility may be forced to close some of the SPs because of prohibitive costs. For those using their own WWs, it was the possibility of obtaining piped water.

Table 1: Variables and their symbols in the questionnaires for different types of consumers

Independent Variable	*WSC*	*SP*	*WW*
Type of employment of CO	WC,BC,BS,PE	-	WC,BC,BS,PE
Ownership of house	OWN	OWN	OWN
House is permanent	PER	PER	PER
Number of rooms	ROM	ROM	ROM
Value of the CO's vehicle	VEC	VEC	VEC
Water flow from connection	FLW	-	-
Monthly payment for water	PAY	-	-
Hours of water supply	SHR	-	-
Change to continuous water supply	CHN	-	-
Household monthly income	INC	INC	INC
Age of CO	AGE	AGE	AGE
Educational level of CO	EDC	EDC	EDC
Number of occupants	OCC	OCC	OCC
No. of families using water from SP	-	FAM	-
Distance between house and nearest SP	-	DIS	-
Time spent per day to collect water	-	TIM	-
Interest to get connected	-	INT	INT
Amount afford to pay for connection	-	AFF	AFF
Get connection and to pay monthly	-	FNC	FNC
Number of monthly instalments	-	INS	INS
Dependent Variable			
Willingness to Pay (where applicable in addition to current water bill)	WTP	WTP	WTP

Responses to the questionnaires were obtained from three random samples of 200 chief occupants (CO) of, HHs (i.e. 100 respondents from each DSA) having existing WSCs, HHs using SPs, and HHs using WWs. Some variables were common, and others different, depending on the classification of the CO as shown in Table 1. The responses to various socio-economic, production and functional variables relevant to the CO were binary (categorical, yes/no), discrete (rooms, occupants, no. of monthly instalments) or continuous (amount, years, hours, metres) as shown in Table 2.

The same interviewer interviewed all of the 600 CO respondents. This was to reduce the bias that may be included if different people conducted the interviews. It also meant that the number of HHs that could be used for the survey was curtailed due to the lack of time (Barathithasan, 1997).

Artificial Neural Networks (ANN)

Artificial Intelligence (AI) forecasting techniques such as neural networks have been receiving much attention lately. They have been cited to have the ability to learn like humans, by accumulating knowledge through repetitive learning activities. Their application in the prediction of economic indicators and financial indices has been demonstrated (White, 1988; Varfis and Versino, 1990; Windsor and Harker, 1990; and Goh, 1996). However their ability to estimate WTP for urban water supply remains to be seen in this study.

In order to gauge the success of applying such techniques, a comparison needs to be made. Conventional regression techniques have often been used to establish WTP for urban water supply and sanitation (Whittington et al., 1990; Whittington et al., 1992; Barathithasan, 1997). This conventional method can, therefore, serve as a benchmark against which to judge the performance of the ANN technique in estimating WTP for urban water supply projects in developing countries.

Table 2: Characteristics of data for different variables

Independent Variable	*Value type/range*	*Type of data (Number)*
Type of employment of CO	Categorical	Binary
Ownership of house	Yes/no	Binary
House is permanent	Yes/no	Binary
No. of rooms	Numbers (1-7)	Discrete
Value of the CO's vehicle	Amount (Rs.)	Continuous
Water flow from connection	Yes/no	Binary
Monthly payment for water	Amount (Rs.)	Continuous
Hours of water supply	Hours	Continuous
Change to continuous water supply	Yes/no	Binary
Household monthly income	Amount (Rs.)	Continuous
Age of CO	Years	Continuous
Educational level of CO	Years	Continuous
No. of occupants	Numbers	Discrete
No. of families using water from SP	Numbers	Discrete
Distance between house and nearest SP	Metres	Continuous
Time spent per day to collect water	Hours	Continuous
Interest to get connected	Yes/no	Binary
Amount afford to pay for connection	Amount (Rs.)	Continuous
Get connection and to pay monthly	Yes/no	Binary
No. of monthly instalments	Numbers (1-12)	Discrete
Dependent Variable		
Willingness to Pay (where applicable in addition to current water bill)	Amount (Rs.)	Continuous

Note: Rs. is the rupee currency

Learning algorithm and architecture of the ANN Model

Back propagation is one of the most widely used learning algorithms. It is a supervised learning procedure adopting the error-correction rule. It is capable of learning internal representations involving the presentation of a set of pairs of input and output patterns. Using only internal computation, it can be applied to multi-layered neural networks with hidden units. The application of the generalised delta rule (Rumelhart et al., 1986) to back propagation allows the weights of the interconnections to be adjusted to enable learning to take place.

A typical three-layered back propagation neural network architecture was chosen for building the three ANN models, i.e. WSC, SP and WW. Each architecture consisted of an input layer, a hidden layer and an output layer. For WSC and WW models, 16 nodes were used in the input layer, 12 nodes for the hidden layer and one node for the output layer to represent WTP. The SP model was designed with 15 input nodes, 11 hidden nodes and 1 output node. Although there are no rules governing the design of ANN architecture, the rules of thumb adopted in the study are, firstly, to adopt the number of independent variables to determine the size of the input layer and, secondly, to ascertain the size of the hidden layer by using 75% of the size of the input layer (Goh, 1996).

The data used to train an ANN can greatly affect its effectiveness and performance. It has been mentioned that “the character of a neural network is as much determined by the data in its experience as by the algorithms used to build it” (Crooks, 1992). There are three distinct ways of classifying data for ANN: continuous; binary (nominal numbers); and symbolic (for descriptive variables) (Lawrence, 1991). The ANN treats the first type (both continuous and discrete variables) as real numbers, taking into consideration their magnitude and variability. The second type is used as arbitrary numerical codes. Based on the survey data collected, Table 2 explains the nature of the input data used to train the ANN models.

Besides selecting appropriate data for the ANN, there is a need to create an encoding and decoding scheme. The encoding algorithm converts the input data into a form suitable for presenting to the network while the decoding function performs the reverse. They entail the process called normalisation. In this study, the NeuroForecaster (version 4.1a) software was used and the normalisation was performed automatically, converting the values to 80% of their global maximum and minimum range.

The MR model

Nine multiple regression analyses were carried out. The first six analysed the classifications of consumers for the two areas. The next three analysed the types of consumers by pooling the data from the two areas. The significant variables in the WTP equations are selected based on the standardised t statistic at a 5% significance level. The regression equations and coefficients of multiple determination (R^2) for the nine analyses are given in Table 3.

WTP results for the ANN model

Using the NeuroForecaster (version 4.1a) software, the ANN models were built based on the back propagation algorithm. In the training process, each network was first randomly assigned weights in its input links. Then each set of inputs and output was presented to the network one at a time. By repeating this process many times, the network was eventually trained and ready to be tested. Each training data set comprised 190 cases while the remaining 10 cases formed the test data set. Table 4 shows the results of the forecasts generated by the ANN models for WSC, SP and WW.

Table 3: Regression equations for WTP and coefficients of multiple determinations

Type	*Area*	*Regression Equation*	R^2
WSC	TDSA	WTP = - 18.26 + 43.46 CHN + 5.9 ROM	0.23
	KDSA	WTP = 36.5 + 0.22 PAY - 5.18 OCC - 0.97 SHR	0.28
	Both	WTP = - 4.93 + 37.64 CHN	0.19
SP	TDSA	WTP = 53.61 + 0.004 AFF + 54.56 INT - 81.29 OWN - 23.63 FNC	0.49
	KDSA	WTP = - 67.61 + 0.007 AFF + 0.003 INC + 4.97 EDC + 4.22 OCC	0.72
	Both	WTP = - 32.94 + 0.004 AFF + 39.36 INT + 0.003 INC	0.45
WW	TDSA	WTP = 34.27 - 33 BC + 0.012 AFF	0.39
	KDSA	WTP = - 14.27 + 0.005 AFF + 34.39 INT + 0.003 INC	0.46
	Both	WTP = - 0.59 - 26.34 BC + 0.005 AFF + 34.38 INT + 0.003 INC + 2.85 EDC	0.37

WTP results for the MR model

The regression equations for WTP for the three types of consumers show that variables which are significant to those who have water supply connections and those who do not (i.e. SPs and WWs) are completely different. The R^2 values show that relationships for those who do not have water supply connections (37% to 72%) are more reliable than for those who have connections (19% to 28%). Therefore, one has to therefore be cautious in arriving at conclusions. Notwithstanding that, we can make some observations.

The variables that are significant are those variables that one would normally expect to see as significant variables. The signs for most of these variables are correct, meaning that they do not lead to intuitively incorrect interpretations. The most significant variable to those who have WSCs is the change in hours of supply (continuous) from limited supply at present. The low R^2 values do not give much confidence on the relationship as an estimator of WTP.

The exceptions to intuitively correct signs are those for OWN and FNC in TDSA relationship for SPs. When both TDSA and KDSA responses were pooled, both variables were no longer significant. The KDSA relationship for SPs has the highest R^2. Hence, the WTP equation for SPs can be considered to be a reliable estimator of WTP.

Table 4: Results of the forecasts obtained by the ANN models

Type	*Actual WTP*	*Forecast 1*	*% Error*	*Forecast 2*	*% Error*
Water Supply Connection (WSC)	20	29.5	-47.5	34.5	-72.5
	150	37.5	75.0	35.4	76.4
	100	28	72.0	42.6	57.4
	30	28.4	5.3	40.2	-34.0
	75	24.5	67.3	39.5	47.3
	20	27.4	-37.0	40.3	-101.5
	150	46.2	69.2	105.1	29.9
	100	35.5	64.5	106.2	-6.2
	30	20.4	32.0	30.5	-1.7
	75	22.5	70.0	26.2	65.1
Stand Post (SP)	50	44.5	11.0	40.5	19.0
	40	44.8	-12.0	41.2	-3.0
	45	58.0	-28.9	56.6	-25.8
	40	47.4	-18.5	43.3	-8.3
	50	47.6	4.8	44.4	11.2
	50	53.5	-7.0	51.4	-2.8
	75	54.9	26.8	54.4	27.5
	50	50.4	-0.8	44.6	10.8
	50	51.0	-2.0	50.5	-1.0
	60	48.5	19.2	48.7	18.8
Water Well (WW)	60	69.4	-15.7	66.0	-10.0
	100	105.1	-5.1	96.1	3.9
	150	150.6	-0.4	111.7	25.5
	100	108.0	-8.0	98.9	1.1
	100	159.9	-59.9	105.3	-5.3
	70	65.8	6.0	60.5	13.6
	35	58.8	-68.0	49.8	-42.3
	40	59.2	-48.0	60.9	-52.3
	20	47.9	-139.5	48.7	-143.5
	45	51.0	-13.3	49.6	-10.2

The significant variables of WWs for TDSA and KDSA all appeared in the pooled analysis. In addition, EDC, which was not significant in either, becomes significant in the pooled situation. In WSCs and SPs there was a reduction in the number of significant variables when the data was pooled. In the case of WSCs, five variables became one, while in SPs, seven variables became three.

While some of the variables which are supposed to influence WTP, such as income and education (ADB, 1996) appeared as significant variables. Some others such as change in hours of supply, interest in getting a connection, and affordability also became significant in urban water supply. The forecasts generated by the MR models for WSC, SP and WW are shown in Table 5.

Results of comparative study

The forecasting results of the ANN and MR models for WSC, SP and WW were compared using relative measures of forecasting accuracy dealing with percentage errors. The measures used in the comparative study are mean percentage error (MPE) and mean absolute percentage error (MAPE). These measures and their application to forecasting have been discussed by Makridakis et al. (1983) and Goh (1996). The results of the comparative study are given in Table 6.

In short, the MAPE is a good measure of the magnitude of the errors incurred by the forecasts and the MPE gives an indication of whether a model has a greater tendency to over (negative sign) or under (positive sign) forecast. From Table 6, the forecasting accuracy of the models can be reflected by their MAPE values. Four inferences can be drawn from the results.

1. The ANN models for WSC, SP and WW have consistently outperformed the respective MR models in terms of having lower MAPE values.
2. The ANN and MR models for SP have been consistently the most accurate compared to those for WSC and WW.
3. It has been observed that the MAPE values for the WSC and WW models were generally high, exceeding the acceptable limit of 10 to 15%. It could be attributed to the poor quality of data used to build the models since both the ANN and MR techniques did not perform well. It could be also due to more extreme values being present in the test data sets. Despite all these, it was clearly demonstrated that the ANN models could still produce more accurate forecasts than the MR ones could. The power of the ANN lies in its natural ability to act as an associative memory to retrieve stored information from incomplete, noisy, or partially incorrect input data. The inherent capability of the ANN to learn and generalise from imprecise data has been proven in this case.
4. It has been shown that the ANN models for WSC, SP and WW could achieve internal validity based on the small difference between their MAPE values of Forecasts 1 and 2. Each of the models was trained twice and after each training cycle, it was used to generate a set of forecasts. The two sets of forecasts were tested for consistency using the MAPE. As explained earlier, a detection of inconsistent performance may be a sign of the network being stuck in local minima in either one or both sessions of the training.

Table 5: Results of the forecast obtained by the MR models

Type	*Actual WTP*	*Forecast*	*% Error*
Water Supply Connection (WSC)	20	37.7	-88.5
	150	36.0	76.0
	100	34.2	65.8
	30	36.0	-20.0
	75	34.2	54.4
	20	37.7	-88.5
	150	36.0	76.0
	100	34.2	65.8
	30	36.0	-20.0
	75	34.2	54.4
Stand Post (SP)	50	41.8	16.4
	40	48.6	-21.5
	45	71.9	-59.8
	40	41.8	-4.5
	50	46.0	8.0
	50	71.3	-42.6
	75	58.6	21.9
	50	62.3	-24.6
	50	58.1	-16.2
	60	45.5	24.2
Water Well (WW)	60	53.3	11.2
	100	78.9	21.1
	150	121.2	19.2
	100	86.8	13.2
	100	92.8	7.2
	70	69.9	0.1
	35	60.5	-72.9
	40	66.3	-65.8
	20	59.6	-198.0
	45	64.6	-43.6

Table 6: Results of the Comparative Study

Type	*Measure*	*Forecast 1 by ANN Model*	*Forecast 2 by ANN Model*	*Forecast by MR Model*
WSC	MPE	+ 37.04%	+ 5.98%	+ 17.56%
	MAPE	54.0%	49.22%	60.89%
SP	MPE	- 0.81%	+ 4.65%	- 9.84%
	MAPE	13.12%	12.8%	23.93%
WW	MPE	- 35.19%	- 21.94%	- 30.85%
	MAPE	36.38%	30.76%	45.25%

CONCLUSIONS

This paper has described a study to estimate WTP for urban water supply. It compared the accuracy of the traditional regression technique and the state-of-the-art ANN. The comparative study has shown that ANN models can generate more accurate forecasts than the MR models. In relative terms, the most accurate ANN model, i.e. the one for SP, generated only half of the forecasting error of the MR model. This finding has re-affirmed past studies (McKim, 1993; Goh 1996; Goh 1998) on ANN which found that they can outperform traditional statistical methods owing to their ability to capture non-linear relationship between the input and output variables automatically, without having to specify non-linear terms to fit the data. Refining the definitions of variables and expanding the survey to a larger sample size can increase the reliability of regression models. In conclusion, the study has, therefore, achieved its broad objective of demonstrating the accuracy and versatility of ANN by its successful application to estimating WTP for urban water supply.

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LIST OF NOTATIONS

ANN	Artificial Neural Networks
AFF	Amount affordable to pay for connection
AGE	Age of CO
BC	Blue collar job
BS	Businessmen/women
CHN	Change to continuous water supply
CO	Chief Occupant
CVM	Contingent valuation method
DIS	Distance between house and nearest SP
EDC	Educational level of CO
FAM	Number of families using water from SP
FLW	Water flow from connection
FNC	Get connection and to pay monthly
HH	Household
INC	Household monthly income
INS	Number of monthly instalments
INT	Interest to get connected
KDSA	Kantale Divisional Secretary Area
MAPE	Mean Absolute Percentage Error
MPE	Mean Percentage Error
MR	Multiple Regression
OCC	Number of occupants
OWN	Ownership of house
PAY	Monthly payment for water
PE	Pensioner
PE	Processing Elements
PER	House is permanent
ROM	Number of rooms
SHR	Hours of water supply
SPs	Stand Posts
TDSA	Trincomalee Divisional Secretary Area
TIM	Time spent per day to collect water
VEC	Value of the CO's vehicle
WC	White collar job
WSCs	Water Supply Connections
WTA	Willingness to Accept
WTP	Willingness to Pay
WWs	Water Wells

Scenario Building: A Suitable Method for Strategic Construction Industry Planning?

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Abstract

This paper is primarily about the Scenario Method. It discusses how scenario building, planning or learning exercises can profitably be used to identify, develop and test alternative plans, policies and practices that might be proposed in exploring and preparing for strategic decision-making in the construction industry. The method has been widely used in business, industry and government for over thirty years as an unrivalled technique to learn about the future before it happens. The paper examines the principles, practice and pitfalls of Scenario Building with the prime aim of presenting the technique as one singularly relevant to the study of the construction industry. It also identifies some of the driving forces, societal issues and policy strategies that confront Ireland in devising a suitable approach towards learning about and planning for the future.

Keywords: *scenarios; construction; driving-forces; strategic; planning*.

INTRODUCTION

The construction industry worldwide designs, produces and maintains the physical infrastructure for the functioning and welfare of society and the continuing growth and development of the economy. Its basic structure reflects the three main components of operation: the design of buildings and facilities; the manufacture and importation of the necessary materials and components; and the on-site construction process. The product of the construction process includes all surface buildings for uses such as housing, industry, commerce, health, education, leisure, public utilities, underground installations, transportation routes and facilities, drainage, water supply and waste disposal. Strategic thinking and planning is, therefore, central to the future wellbeing of all societies.

In the Republic of Ireland, the current profile of the construction industry can be characterised as follows:

- Output in 1997 was IR£7 billion, representing 17.5% of GNP and 62% of fixed capital formation.
- Direct employment was 90,000 persons or 7% of the workforce.
- Exports were IR£800 million and imports, IR£1,000 million.
- Funding was apportioned roughly into 35% public sector and 65% private sector.
- It comprised some 6,000 geographically dispersed firms of which 60% employ less than five people and the top 34 companies account for a third of the output.

Currently this profile places the industry in prime position in the Irish economy ahead of agriculture and tourism in output terms.

In the above context, this paper has two prime aims:

1. To explore and promote the use of Scenario Building as a general method for researching future planning and development policies for the construction industry.
2. To identify some of the driving forces of change, the societal issues and the strategic policies that emerge from a first exercise in a Scenario Building process for Ireland.

The contents are essentially those of the author in respect of scenario building in general, and those of the Enterprise Ireland Technology Foresight team with regard to the specific application of the approach to the Irish construction industry.

SCENARIO BUILDING AND LEARNING

Nothing is more obvious than the unpredictability of the future. Uncertainty has become so pronounced as to render futile, if not downright counterproductive, the kind of planning traditionally employed by governments and corporations – forecasting based on probabilities. Experience has shown us that no unique forecast can be relied upon. Yet, however good our research methods may become, we shall never be able to escape from the ultimate dilemma that all our knowledge is about the past, whilst all our decisions are about the future. Indeed, studying futures is not really a question of knowledge and facts at all, but rather one of conjectures.

A special approach towards projecting potential futures, so as to improve present decisions, is thus required. Scenario building, and the learning process that goes with it, is such a technique. This paper, therefore, suggests that scenario building offers a methodology for understanding the whole range of forces, factors and possibilities that present themselves in planning for the construction industry. By learning to use and develop such a scenario approach, all those organisations and agencies involved in construction can take actions to make a desirable future occur; quickly adapt to unfavourable environments; and efficiently implement strategies that will succeed in a variety of social, economic and political circumstances.

Origins

Scenario building has enjoyed a rich, though somewhat chequered, history over the past thirty years or so, in business, government and the military. The technique was developed, with much enthusiasm, by the legendary Herman Kahn, first when working at the RAND Corporation in the 1950's, then as founder of the Hudson Institute during the 1960's, when he coined his trademark phrase "thinking the unthinkable".

No paper on scenario building would be complete without mention of the pioneering work performed by Royal Dutch Shell during the 1970's and thereafter to the present day. The little known role played by Shell in constructing and exploring the alternative scenarios facing South Africa during the period of political transition between 1992 and 1996 cannot be underestimated.

Successive champions of the methodology included Ted Newland, Pierre Wack, Arie de Geus and Kees van der Heijden (Schwartz, 1996). Also during the 1970's, the consulting firm SRI International (formerly Stanford Research Institute) devised a structured approach to scenario writing that supported strategic planning under the leadership of such luminaries as Willis Harman, Arnold Mitchell, Oliver Markley and Marie Spengler. Other consulting firms and agencies offering scenario planning services sprang up, most notably Battelle, Datar, The Futures Group, Global Business Network and Northeast Consulting. Public attention towards the use of scenarios was initially drawn by the publication of the highly contentious *The Limits to Growth* by Dennis and Donella Meadows (1967); early professional impetus was provided by Jay Ogilvy, Paul Hawken and Peter Schwartz in their seminal text *Seven Tomorrows* (1980); and wider acceptance gained by the work of such leading figures as Michel Godet (1986) in France, Martha Garrett (1966) in the US and James Robertson (1983) in the UK.

More recently, scenario building has been used in a variety of situations such as European Commission future planning, the global telecommunications industry, East Asian economic emergence, the French iron and steel industry, the US defence industry, new business models, British Airways, Cable and Wireless, ICL, United Distillers and the UK National Health Service, which are described elsewhere (Ringland, 1998).

What stands out, however, is that while the scenario approach has spread throughout many fields of industry, commerce and government over the past thirty years, virtually no serious use has been made of the method in the related worlds of city planning, construction or real estate development.

Purpose

The prime purpose of scenarios and scenario building is to enable decision makers to detect and explore all, or as many as possible, alternative futures so as to clarify present actions and subsequent consequences. They should, thus, be prevented from making strategic decisions before they have done some strategic thinking!

According to Michel Godet (1987), scenarios should aim to detect the key variables that emerge from the relationship between the many different factors describing a particular system, especially those relating to the particular actors and their strategies. In doing so, they provide a context for thinking clearly about the otherwise impossible complex array of factors that affect any decision; give a common language to decision-makers for talking about these factors and encourage them to think about a series of 'what-if' stories; help lift the 'blinkers' that limit creativity and resourcefulness; and lead to organisations thinking strategically and continuously learning about key decisions and priorities (Schwartz, 1996).

Ultimately, however, the purpose is not just about constructing scenarios; it is about informing decision makers and influencing, as well as enhancing, decision-making. In this context, it has been suggested that the purpose of scenario building is to (Fahey and Randall, 1998):

- Augment understanding by helping to see what possible futures might look like, how they might come about, and why this might happen.
- Produce new decisions by forcing fresh considerations to surface.
- Reframe existing decisions by providing a new context within which they are taken.
- Identify contingent decisions by exploring what an organisation might do if certain circumstances arise.

In this way, scenario building can create a learning organisation. But that organisation must have the will, the insight and the stamina to undertake such a learning process, as well as making available the resources to make the necessary investment to develop the skills required to construct and employ those scenarios to identify, analyse and manage uncertainty. Good scenarios, moreover, always challenge and surprise – bad ones merely confirm current conceptions and perpetuate personal prejudices.

Process

A variety of processes by which scenarios are constructed have been developed over the years, but certain common characteristics and elements can be discerned. The methodology, for example, shares several important premises:

- The scenarios should be focused on the needs of some issue, decision, strategy or plan.
- The scenarios should be logically structured and internally consistent.
- The process should be highly flexible and capable of adaptation to the needs of the given situation.
- There should be a high degree of 'ownership' of the final product.

The methodology employed in this exercise comprises a seven-stage process which has evolved from a number of different sources. The terminology varies and the number of stages differs in alternative models, but the basic elements and process remains the same.

Stage 1: Task Identification and Analysis
Stage 2: Key Decision Factor Appraisal
Stage 3: Driving Forces
Stage 4: Ranking
Stage 5: Alternative Projections
Stage 6: Scenario Development
Stage 7: Interpretation

Operation

Methods of projecting and analysing possible futures are invariably received with more than a little scepticism, and over the past couple of decades the use of scenarios has met with mixed results. Experiences drawn from a wide range of applications in diverse industry, business and policy fields has produced some common recommendations and warnings as to the operation of scenario building. These are now summarised.

Participants. Scenario building is essentially a team exercise, and it is important that team members are drawn from a representative cross-section of the organisation. Top management must be supportive, fully involved, subscribe to the logics evolved and committed to the outcome. A balance of line and staff personnel should be achieved, with staff confined to supporting line managers in shaping the scope and focus of the scenarios. Specialist or exceptional outside inputs should be invited. Experts on particular topics can be involved at specific stages of the scenario building process, and the part played by 'remarkable' persons intermittently or throughout cannot be understated. A diversity of views is a prerequisite. Participants' individual roles must be made clear at the outset, and a core group, with supporting players, is normally established at the beginning. An author, or pair of authors, should also be assigned to write the scenarios at the start. Ideally, authorship should be the task of an internal decision maker, and not an outside facilitator or consultant.

Expectations. Scenarios will not work if they are seen as a gimmick. The expectations must be realistic. Understanding is a more likely outcome than a plan, and it often takes time for an organisation, especially a large one, to learn that the future will not resemble the past. Appropriate time frames should be set, both for the horizon of the scenarios, as well as time taken to build them. Many organisations find it hard to look far enough ahead, and most underestimate the resources required to conduct the process properly. A particular problem frequently encountered in scenario building is getting decision-makers to confront the key beliefs, challenge conventional wisdom and look at the prospects of 'breaking-out-of-the-box'.

Number of Scenarios. It has already been stated that between two and four is the normal bracket of scenarios sufficient to explore the possible futures within which decisions will have to be taken, but there is the danger of always ending up with three scenarios (though, in practice, this is often the case). Inexperience with scenario building tempts those involved to generate a 'good' and a 'bad' at the extremes, and an 'average' in the middle, with a tendency to drift towards the middle, and treat it as the 'most likely' single-point forecast. All the advantages of a multiple-scenario method are then lost. At the same time, it is important to avoid drafting several scenarios that are simply slight variations on the same theme. An underlying danger, moreover, is that the participants endeavour to construct the 'right' answer in a single scenario. The true value of the scenario building exercise is stressed as being the experience of exploring a set of distinct and plausible futures that could unfold (Schwartz and Ogilvy, 1998).

Naming Scenarios. It is important to choose an evocative and memorable name for each scenario which succeeds in portraying the essential logic or story driving it. Vivid and meaningful titles stand a much better chance of becoming accepted and used within the decision-making and implementing parts of an organisation. Good names become useful shorthand when planners and managers meet in groups; they also stimulate interest and lead to better questions being asked. Each of the scenarios constructed, however, should attract the same degree of imagination and creativity in finding a name, so that the most picturesque is not necessarily the most preferred.

Policy. It is vital that the scenario building process is not an isolated one, but is firmly linked into existing planning, managing and budgeting processes within the organisation. At the same time, the distinction between the use of scenarios as thinking and learning frameworks, as opposed to employing them as a means of evaluating actual proposed projects needs to be drawn, and requires careful control. Again, it cannot be overstated that the stories told in the respective scenarios must be relevant to the key policy makers. The main objective, after all, is to alter the mind-set of decision makers about future possible opportunities, threats and actions, so that they are not caught by surprise.

Process. It has been found that the scenario process may start to drift if participants do not have what has been called a "clear road map" (Shoemaker, 1998). This should set definite milestones and deliverables for the process together with the relevant dates, tasks and people concerned. A preoccupation with trends should be avoided as it simply projects the past forwards and fosters tunnel vision. The main focus should be placed upon examining the drivers of change, and great care taken to avoid internal inconsistencies that might otherwise arise in the scenarios. One of the most problematic areas concerns quantification. It is difficult, but essential, if the scenarios are to be taken seriously within an organisation for numbers to be attached wherever possible. However, quantification can easily reduce the scenario exercise to a simple sensitivity analysis unless there are highly significant qualitative differences between the scenarios (Schwartz and Ogilvy, 1998). Nevertheless, probabilities should not be assigned to the scenarios, nor should they be identified or ranked as 'least' or 'most likely' too early in the process.

Conflicts. A well-crafted set of scenarios is said to lure the decision-makers outside the comfort and familiarity of their traditional mind-set and mode of operation. In so-doing, a number of conflicts are described by Fahey and Randall (1998), which tend to characterise scenario building:

- **Present versus Future –** decision makers have to respect and reconcile simultaneously present realities with the logic of plausible futures which demands a thorough understanding and analysis of the driving forces of change**.**
- **Closed versus Open-Ended –** scenarios can be constructed with very specific strategy decisions in mind, or they may be developed to ascertain which strategy decisions should be analysed.
- **Grounded versus Imaginative** – good scenarios are both thoroughly researched and thoroughly imagined, whilst bad scenarios rely too much on uninformed speculation and are poorly researched. A balance between detailed study and unfettered creativity needs to be struck.
- **Intellectual versus Emotional –** in similar vein, scenarios are necessarily an intellectual or analytical activity, but they must also capture the emotions of those who develop and implement them.

- **Advocacy versus Dialogue** – good scenarios are likely to be forged when individuals advocate their point of view, argue how a plot might evolve, demonstrate the logics that underpin it, and illustrate its implications for the organisation's current and future strategies. Once scenarios have been selected, however, a reasoned dialogue among all those concerned is required to secure effective strategic planning.
- **Scepticism versus Expertise** – expertise is naturally essential in the analytical process of scenario building, but because the future can be so different from the past, a healthy scepticism should be maintained about the pronouncements, judgements and assessments of experts. This scepticism compels decision-makers critically to reflect upon each scenario's logic and its strategic implications.
- **Quantitative versus Qualitative** – as essentially constructs of the imagination, scenarios are fundamentally qualitative in nature, but some estimate of the extent of quantitative differences between scenarios is important if strategy is to be correctly calibrated.
- **Probability versus Plausibility** – one of the most contentious debates concerning the use and development of scenarios rages around the assignment of probability to the final scenarios. One school of thought (Battelle Management Consulting, for example) argues that not assigning probabilities is a 'cop-out' because probabilities give decision makers important information on which to base their strategies. Another school (Global Business Network and SRI, for example) believes that assigning probabilities is a 'hangover' from the days when forecasters really thought they could predict the future (Fahey and Randall, 1998). This author views probability assignment as a "dressing-up of prejudices" which can lead to a distortion of the process and a detraction from the basic purpose and function of the scenario building.

SCENARIOS FOR IRELAND

As part of a Technology Foresight exercise for studying the future planning and development of the Irish economy, three alternative scenarios have been constructed by Enterprise Ireland. These are very simply described below to give some idea of how they emerge:

Scenario 1: Island Ireland – The Sustainable European – (Equality)

***2015**: Europe has expanded to the East. Ireland, now a net contributor to EC coffers, suffers mild paranoia about peripherality. Payback time has arrived for some of the short-termism of the former 'Tiger Economy'. The social divide continues to widen, with high levels of exclusion and unemployment.*

However, since 2012 we have had a pragmatic government with the political will to do something about all of this. The platform is to upgrade our national capacity to participate fully in the European opportunity. This mainly through self-help. Among other things this recognises that the creation of a sustainable quality physical infrastructure underpins our ability to become contributing citizens of Europe. After all next year is the centenary of the Easter Rising!

Scenario 2: Ireland – Keystones in Fortress Europe – (Liberty)

***2015**: Europe on the defensive. The weakened American and Asian economies tried to use Europe as an economic dumping ground. Europe raised the drawbridge. Selective trade barriers, a halt to economic migration from outside, the expansion of the community to the east halted and administrative decentralisation to mark the boundaries. After all this is the bicentenary of the treaty of Vienna where Europe's boundaries were redefined after Napoleon left.*

Ireland is seen as a good citizen of Europe – a contributor to the Community's technology, culture and sustainable development. The new eurocredits system means we remain a nett financial beneficiary. Construction and infrastructural development is now a networked European activity. The government can afford to be laissez faire.

Scenario 3: Ireland – The Global European – (Fraternity)

2015*: An enlarged and confident Europe goes global. Capitalism with an evolving conscience, aid and trade, an open economy, partners of the world. Since 2011 the Community was operating in a sustainable manner and quality of life issues are to the fore – in the global village a dawning awareness that most of the villagers are not doing anything like as well. In the developed world post materialistic fluidity is setting in and with it comes an economically acceptable conscience. Europe's skills and resources could develop the social and economic infrastructures of the second and third worlds. Trade could follow aid. After all it's 60 years since the Marshall Plan started to rebuild Europe after the war!*

In the exercise itself, very much more detailed pictures of these alternative scenarios are painted, against which various policies, proposals or possibilities related to the construction industry can be tested.

Issues And Driving Forces

The following issues and driving forces were identified and are listed in approximate order of perceived importance in each category.

Economic

- Cycles in national economy
- Competitiveness, speed, sustainability and value
- Joint public/private finance
- Security/replacement of EC funding interest rates, EMU, convergence
- Growing investment in repairs, maintenance and rehabilitation
- Affordable housing
- Mobility of capital
- Change emphasis from first cost to life cycle cost (low cost ownership)
- Growing markets leisure/tourism
- Energy costs of construction process and building use
- External competition from EC partners
- Design/construction management a tradable commodity
- Remote geographic location in Europe
- Industry to become more involved in socio-economic policy debate
- Future ownership of Irish construction companies
- Potential involvement in the third world.

Operational

- Increased client expectations and in particular, those of multinationals and funding institutions
- Competition and partnering
- Client as part of team and process
- Quality and total quality management
- Integration of contractor and design team
- Skills availability
- Integration of design, build, maintain, operate
- Claims/litigation culture inhibiting design and innovation
- Partnering for skills, scale, competitiveness
- Entry standards to contracting
- Registration of professionals, technicians and skilled operatives.

Regulatory

- Physical planning policy and efficient operation of planning system
- Integration of regulatory process for infrastructure

- Development of regulatory environment associated with full implementation of EU Construction Products Directive
- Registration of contractors, architects, engineers, surveyors and skills
- Public procurement regulations.

Technological

- IT in design, manufacture, construction management, procurement and operations
- IT in partnering and integration of process
- Apparent low level of R&D in industry
- Integrated training and education for industry from clients to crafts
- Efficiency in provision of infrastructure
- Differentiate between R&D and innovation and learning
- Recognition of design as having a high R&D component
- Information on technology developments
- Building services proportion of construction to increase.

Social

- Environmental impact of process and end product carbon dioxide emissions
- Health and safety on construction sites
- Increasing urbanisation
- Construction waste management/recycling
- Commercial and industrial building to cater for 30% to 50% of all jobs which do not exist today
- Destruction of rural scale
- Affordable housing
- Safety, security, vandal proofing of buildings
- Buildings for ageing population, disabled and socially excluded
- Growth in population – economic migration
- Mobility of work force
- Consumer-orientated performance-based markets
- Home working – change from industrial to information society
- Transportation issues.

Uncertainty

All strategic planning is bedevilled with uncertainty and the following factors were identified as possessing a potential future impact:

- Changes in structural funds
- EC legislation and regulatory environment
- Changes in demand
- Land use zoning and availability
- Population and demographic change
- Impact of IT on construction
- Ability to recognise and implement technological change and opportunity
- Changes in national economy
- Skills and labour availability
- Changes in EC economy
- Impact of essential sustainable requirements
- Social/customer expectations
- Rural/urban balance
- Balance of public/private and public and private funding
- The industry’s choice between gradual progression (more of the same) and significant strategic change
- North/South Ireland economic integration
- Political/industrial will to implement radical strategies for change
- Transportation policy and developments

- A significant proportion of 2015 technology does not exist
- 2015 buildings to cater for 20% to 50% of jobs that do not exist
- Changing client base
- Energy costs.

Strategic Questions

Two strategic questions were addressed in the exercise.

(a) *How best can the Irish construction industry meet the requirements of the market together with the economic, social, environmental and regulatory conditions of the world of 2015?*

The basic elements of strategy required were identified as the need to:

- Prepare and maintain a SWOT analysis of construction and infrastructure in the run up to 2015.
- Undertake market studies to establish customer profiles needs and expectations and the associated regulatory environment in the run up to 2015.
- Identify and develop niche quality capability skills and products and networking and partnering skills for domestic and European markets.
- Develop quality, competitiveness and international tradability of the knowledge-based activities of the industry (such as design and management).
- Create and market more development partnerships between the construction and financial services sectors.
- Develop the capability to integrate the construction process to the extent appropriate to the project type.
- Make the process of compliance with the planning and regulatory process more efficient and user friendly.
- Implement state of the art operating and business systems and provide the associated construction-related education and training programmes.
- Implement IT application in all sectors of construction from marketing to maintenance in an integrated manner.
- Progressively reduce construction costs in real terms by 25% by 2015.
- Improve the on-site working environment particularly in terms of health, safety, job satisfaction and social esteem.

(b) *How best can the Irish construction industry make strategic use of technology and product possibilities, including those from other industries to develop and sustain a competitive market in the world of 2015?*

The basic elements of strategy required were identified as the need to:

- Source and adopt the new technologies where relevant such as smart materials and products based on new sciences (such as biotechnology).
- Use virtual reality in the design, building and marketing of construction and infrastructure.
- Assess and transfer appropriate processes and technologies from other large-scale assembly industries such as shipbuilding.
- Develop leading edge, niche, globally certified products and specialisations.
- Develop and use technologies for low energy and high recyclability construction processes and products.
- Develop customised dedicated electronic data interchange (EDI) for the industry.
- Improve safety and job enrichment on site by increasing off-site prefabrication starting with design. More brain less brawn on site.
- Develop technologies and practices for safety and sustainability in construction and infrastructure.
- Encourage innovations in the construction product and process by increasing incentives for R&D and technology acquisition.
- Develop stronger operational and commercial links between third level research and education
- Provide integrated education, training and technology dissemination programmes including an infrastructure element in school curricula.
- Establish a joint industry, government and third level research innovation and information centre for construction and infrastructure.

CONCLUSION

The future will always be unpredictable, but it has been shown that by adopting the right approach and by using appropriate techniques it can be imagined, planned for and managed. Scenario building, in all its forms, has proved to be a powerful and effective component in the strategic planners tool-kit. Scenarios generate a distinctive kind of knowledge and promote organisational learning; they provide a process for enhancing decision-makers' understanding of how to prepare for and manage change; they increase the comprehension and acceptance of uncertainty by engaging all concerned in creative thinking; and they demonstrate to 'stakeholders' in an issue, activity or organisation how they and it could thrive in future environments that may be strikingly different from the present.

This paper concludes, therefore, where it commenced, by proselytising the role of the scenario approach in learning about, and planning for the future of the construction industry, and predicting that scenario building, or variants of it, will become the principal behavioural technique for determining public and private sector strategy within the next few years.

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Improving Construction Education by Sharing Learning Resources Over the World Wide Web

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Abstract

Construction engineering is heavily grounded in practical, real-life experiences, which range from construction methods, techniques, planning, and cost estimating to managing productivity, quality, people, and contracts. Current pedagogies and teaching tools in construction education system are unable to include sufficiently complex, realistic design and construction problems and to contribute for retention of knowledge. Artificial Intelligence (AI) techniques, and information and communication technologies are perceived to have immediate potential for building high-value learning tools aimed at providing students with knowledge, experience and practice in skills needed by real professionals in the construction industry.

This paper describes a research project to develop and validate an integrated platform for delivering just-in-time construction engineering learning resources over the World Wide Web whenever a user needs them. This platform comprises a multi-agent system which integrates well-proven instructional/learning theories with techniques and solutions of Artificial Intelligent and Web technology. The system is aimed at having three main instruction roles: (i) a teacher's role; (ii) a motivating role; and (iii) a supportive role. To perform these roles, the system will use a client/server integrated architecture with multiple intelligent agents that can interact with clients, and with a case-based reasoning knowledge-base.

Keywords: A*rtificial intelligence, construction engineering, case-based reasoning, pedagogy, world wide web.*

INTRODUCTION

This paper describes a research project to develop and validate an integrated platform for delivering just-in-time construction engineering learning resources over the World Wide Web (WWW) whenever undergraduate students need them. This platform comprises a multi-agent system and a case-based reasoning (CBR) knowledge-base aimed at supporting undergraduate students in the construction engineering curriculum.

Construction engineering is often defined as a production science that is closely related to industrial manufacturing engineering, in addition to being dependent upon civil and architectural engineering. It takes experience-based judgement to recognise and realise the true worth of construction, and to see where and how it objectively and correctly fits within engineering and architectural disciplines. Construction engineering is heavily grounded in practical, real-life experiences, which range from construction methods, techniques, planning, and cost estimating to managing productivity, quality, people, and contracts (Singh, 1993). Current pedagogies and teaching tools in construction education are unable to include sufficiently complex, realistic design and construction problems and to contribute to the students' effort to improve their learning processes and retain knowledge. In consequence, typical students in construction engineering have difficulty in envisioning design details, design behaviour, construction site layouts, construction sequencing and construction methods. Experience in teaching construction engineering disciplines has shown that the wide diversity in individual differences for learning and the very broad range of topics and matters that need to be learned require a wide range of methods and approaches for effective teaching, learning and communication. Current leading edge Artificial Intelligence (AI) techniques, and information and communication technologies are perceived to have immediate potential for building high-value learning tools aimed at providing undergraduate students with knowledge, experience and practice in skills needed by real professionals in the construction industry.

TEACHING/LEARNING SYSTEMS IN ARCHITECTURAL AND CONSTRUCTION DISCIPLINES

Currently, there are at least three methods used by academic institutions to deliver teaching materials to undergraduate students: in the classroom with one computer; in the classroom with multiple computers; or outside the classroom through desktop computers by individual students (Hotchkiss, 1994). A number of academic institutions have implemented a set of both off-line and on-line multimedia-based instruction tools to deliver teaching materials at course level of Architectural, Construction and Engineering (ACE) disciplines. This section describes some of these projects.

Cornell University developed “Aedificium” (Deierlein et al., 1993), a MacIntosh-based multimedia case studies system in structural engineering which includes more than 1,500 construction photos of bridges, buildings and other structures. Ohio State University (Hotchkiss, 1994) developed a set of courseware modules that simulate road construction problems for students in engineering and landscape architecture. Students may view the tutorials in any order and even use them to simulate the effects of changes they make on roadway alignments. University of Nebraska (Hotchkiss, 1994) introduced a self-paced, interactive multimedia module that highlights stream discharge measurements implemented in upper division/graduate water resources and hydraulic engineering courses. This module was designed to be driven by the student. Oxford Brooks University (Davey-Wilson, 1994) implemented a self-teaching, interactive computer simulation program, ShearDelight, which models geotechnical laboratory calculation of the angle of shearing resistance of coarse soils, using shear box test. Columbia University (Webster, 1995) developed the “Farnsworth House Volume” module. It is a multimedia instructional tool within the Internet’s World Wide Web, into classroom analysis/design projects for architectal and engineering classes. Students use the Farnsworth module in the analysis and design of building closure systems, focused around thermal performance. California Polytechnic State University (Pauschke and Ingraffea, 1996) introduced a set of computer-generated lectures and student testing materials into the transportation engineering course. These materials enable students to visualise linkages between theory, mathematical models, and physical systems. Vanderbilt University (Pauschke and Ingraffea, 1996) implemented a traffic engineering microcomputer software used in the traffic engineering course as follows: students manually solve a problem; the solution is critiqued, graded, and returned; students rework the corrected problem using software and perform sensitivity analysis. Southern University and A&M College (Pauschke and Ingraffea, 1996) introduced a courseware module on dam safety, which integrates materials from several media and captures guest lectures in dam safety courses. Texas University (Pauschke and Ingraffea, 1996) implemented a computer-aided instruction, which integrates data, graphics and textural material to design highway system components for the transportation engineering course.

Although the combination of AI techniques with multimedia technology to build educational software is a relatively new research topic, some researchers are exploring its potential for building intelligent multimedia instruction/tutoring systems. Examples of such efforts for ACE disciplines include: Memorabilia (Oxman, 1993) a tutoring system uses a case-based teaching architecture for teaching design students. It stores architectural design cases that have the status of precedents and makes them available to students who are learning architectural design. Design Case Libraries (Guzdial et al., 1996) are being developed by Kolodner’s case-based design group at Georgia Tech to support authentic problem-solving activity by students. These case libraries hold records of the experiences and outcomes of others involved in problem situations similar to those posed to students. The examination of others’ cases can help students discover issues they need to address, provide suggestions about how to proceed in problem solving, suggest viable solutions, and help with projection of the effects of proposed solutions.

Applications presented in this review show a diversity of methods for solving the problems of instruction across different domains of the ACE disciplines. These applications reflect a broad spectrum of approaches and methods for both the style of learning and use of the technology. They demonstrate the enormous importance of technology as a catalyst for change in higher education. However, these approaches and methods are not broad enough to encompass effective learning environments that enable flexible learning, wider access and teaching efficiency of construction engineering disciplines.

USER NEEDS ADDRESSED

This research and the resulting platform serve the aims of the current curriculum of the "Instituto Superior Tecnico" and address the needs and expectations of all stakeholders (academic institutions, curriculum managers; teachers; students; and industry) in the current construction engineering education. In the long term, the scope of the proposed project is to introduce the system at curriculum level of the construction engineering education. At the level of this research, the scope of resulting platform will focus on the instruction of construction technology. However, the system will be designed to scale to curriculum needs and large numbers of students. New discipline topics can be easily added or linked to the system's knowledge-base. The user needs and nature of the problem that this project is seeking to address are to: provide greater and wider access just-in-time to individual instruction on practical knowledge, skills and competencies; improve the quality of students' learning throughout assisted problem-solving activity, using a technique called "scaffolding", in which one starts gradually with simpler cases and builds up to the full level of complexity; enable flexible learning, transfer and retention of authentic knowledge and experiences students need with a variety of problems, situations, topic matters of construction engineering projects; and provide a shared memory of real-world case problems solved by individual students to allow them to share their experiences in solving related problems and interact with other students' work.

PEDAGOGICAL FOCUS OF THE RESEARCH

Education has two major processes: *teaching* and *learning*. Teaching is the sum of the processes a teacher uses to present teaching materials and tools. Learning is the sum of the processes used to acquire knowledge. Students that improve their learning processes end up learning more with relatively less effort. *Pedagogy* is defined to be the means of transmission of professional knowledge, skills and culture to the students and affects how students retain the knowledge and culture they need. Teaching, learning and pedagogies must be submitted to the imperative wholeness of professional life within construction engineering. Effective teaching of construction engineering discipline topics requires the connection between the theory taught and real-world practice. Recently, a number of attempts were made to introduce new pedagogies and tools for teaching construction engineering disciplines. Guzdial *et al*. (1996) suggested that for AEC knowledge to be flexible and transferable, students need experience with a variety of related problems and situations. A pedagogy that has recently gained attention in the teaching of construction engineering disciplines is to use case studies to bring current construction project issues into the teaching environment (Scott et al., 1996; Grigg, 1995; Aldridge, 1994; McCullough and Gunn, 1993; Singh, 1993). These authors claim that practical and real cases of construction projects provide a learning environment whereby the students actively participate in the learning process. The cases raise student interest levels and give students a sense of participation in real-world situations. Scott et al. (1996) emphasises the need for students to visualise complex conditions at the construction sites when teaching project management issues using cases. McCuen and Chang (1995) emphasised the need for the simulation capability to enable the student to experience a wider array of professional oriented problem-solving situations.

The resulting platform can be characterised not only as a learning resource but also as a instructional strategy because it carries strategies for its use and to improve quality of students learning. Therefore, the platform is supported by an instructional model that considers: (i) learning theories and concepts in construction engineering education; (ii) the pedagogies that apply to those concepts; (iii) the pedagogical issues concerning the use of the technology. Pedagogies, are used to refer to instructional approaches that the system will apply to transfer knowledge, experience and skills students need. Main features of this instructional model are as follows: (a) it provides just-in-time knowledge students need to solve their problems or answer their questions in a variety of situations; (b) it supports students' learning through assisted problem solving of authentic case problems that require them to look at the situations from a variety of perspectives and to consider a variety of alternative solutions; (c) it provides students with real experiences (real-world construction project cases) in a variety of problems and situations of construction engineering topic matters and a reason to examine them, understand and analyse the decisions made by others; and (d) it provides students with assignment-type problems to be solved, and a shared library of problems solved by individual students. These instructional models may be refined through successive iterations at each stage of the platform validation process.

MODELLING APPROACH

The modelling framework used to describe the system reflects a convergence of task-oriented approaches (Chandrasekaran et al., 1992), the ontological analysis methodology (Fernández et. al., 1997 and the CASE-METHOD (Kitano and Shimazu, 1996). The modelling framework categorises the system into three levels. These levels are:

1. **The Object-level:** This level comprises manifold information and knowledge sources, ranging from machine-readable formal representation to human-readable informal representation.
2. **The knowledge-level description:** At the knowledge level, the system is described in terms of the tasks, problem-solving methods, primitive inferences, knowledge types and goals. This level also describes the structure of the knowledge needed by the problem-solving methods through the ontological analysis of the domain. The product of this level is a task-method structure and the domain specific ontologies.
3. **The symbol-level:** At the symbol level, the system is implemented using a selected programming environment. The products of this level are; (i) the *skeleton* system; (ii) the *demo* system; and (iii) the *working* system.

According to this framework, each level of description is a self-contained model of the system. In this methodology the $level_n$ implements the structure of the $level_{n-1}$.

TASK METHOD ANALYSIS OF THE SYSTEM

The goal of the multi-agent system deployed in the integrated platform is to assist undergraduate students in their learning processes using the case-based teaching method. This system integrates an instructional model that supports three key instructional roles: (a) a *teachers' role* by delivering just-in-time construction engineering experts' resources as students need them, and answering students' questions across different topic matters; (b) a *motivating role* by generating goals that will motivate students to explore the system's resources, providing authentic construction engineering context cases in which to situate knowledge for students to access, providing students with feedback and challenging students' solutions and decisions; and (c) a *supportive role* by teaming up with the students to find the information they need.

The task-method structure is the result of the task-method analysis carried out, in the context of the characterisation of the teaching domain. Its principal elements are tasks, problem solving methods, primitive inferences, and goals The task-method structure provides a specification of the multi-agent system in terms of *what* the system should do and *how* the system accomplishes its goals. Therefore, the task structure of system consists of:

- Tasks – *a task is specified by: the task definition; and its initial and goal states*
- Problem-solving methods – *a problem-solving method is specified by a problem space where the search for the solution takes place; a set of sub-tasks or inferences that can be used to transform the initial state of a task to the goal state; and the types of knowledge it uses.*

Figure 1 presents a top view of this task-method structure. Rectangles represent tasks/subtasks and circles represent methods. At the highest level, the task-method structure sets up three semi-autonomous knowledge-based software agents, each one corresponding to an instructional role described above: the teacher agent; the motivating agent; and the supportive agent. At the lower level each agent uses the case-based method to accomplish its task and role.

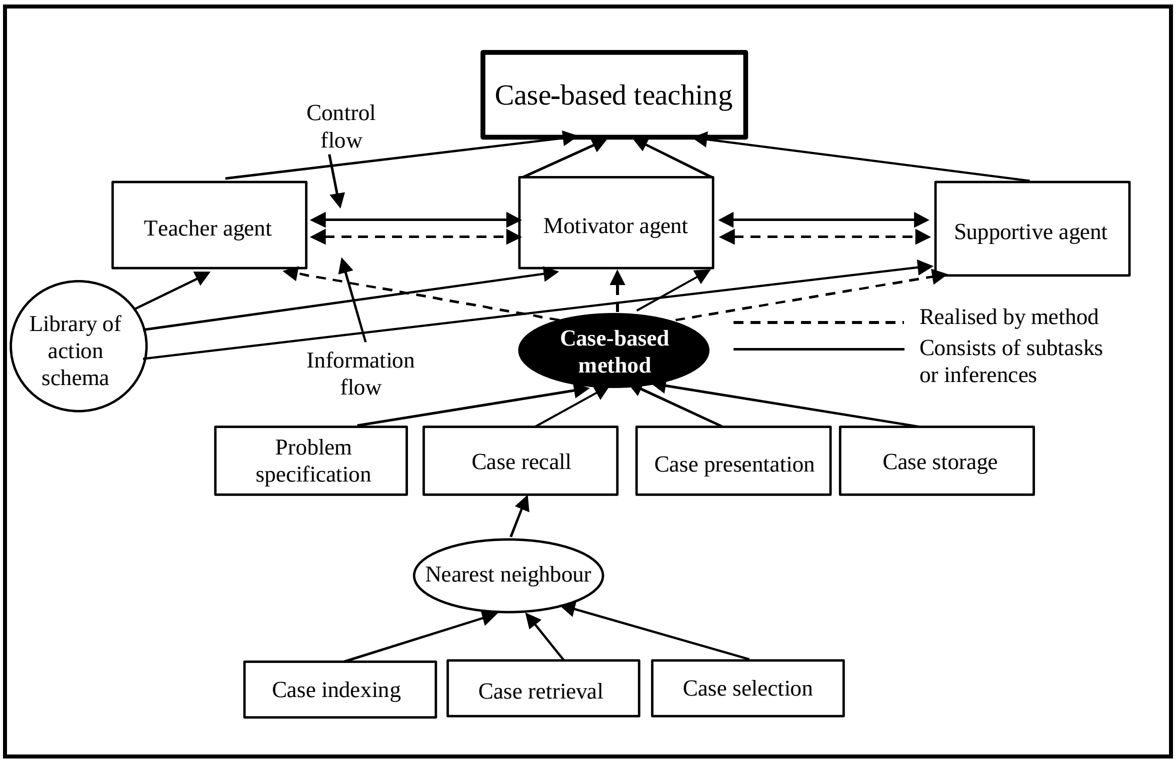

Figure 1: Partial view of the task-method structure

THE AGENT’S MODEL

Lander (1997) pointed out that in creating a multi-agent application, the developer must describe both an agent set and a model of how agents will interact. The agent’s model of the system is based on Norman’s (1986) reference model of semi-autonomous agents (see figure 2). Norman characterises the human-computer interaction as the problem of bridging the twin gulfs of *execution* and *evaluation*. The execution side of the cycle involves translating a goal into a sequence of actions for achieving the goal. The evaluation side involves using feedback from the domain to compare the result of the action with the goal. Norman’s model provides a useful reference to build human-computer interaction programs because it identifies the cognitive processes, and the linkages between them that must be supported for each agent to succeed. The agent model lies in automating the execution side to achieve a goal, leaving evaluation as a task for the user. It describes *which* agents should be included and *how* they accomplish their tasks. Thus, it comprises the following tasks: (i) translating of a user’s goal into an intention to act; (ii) translating this intention into a sequence of internal commands (action plan); (iii) executing this sequence of commands; (iv) presenting the results to the user for evaluation. The use of goals as input and action plans as agent primitives makes the system’s agents consistent with the definition of an agent as a process automating stages of this model (Lewis, 1998).

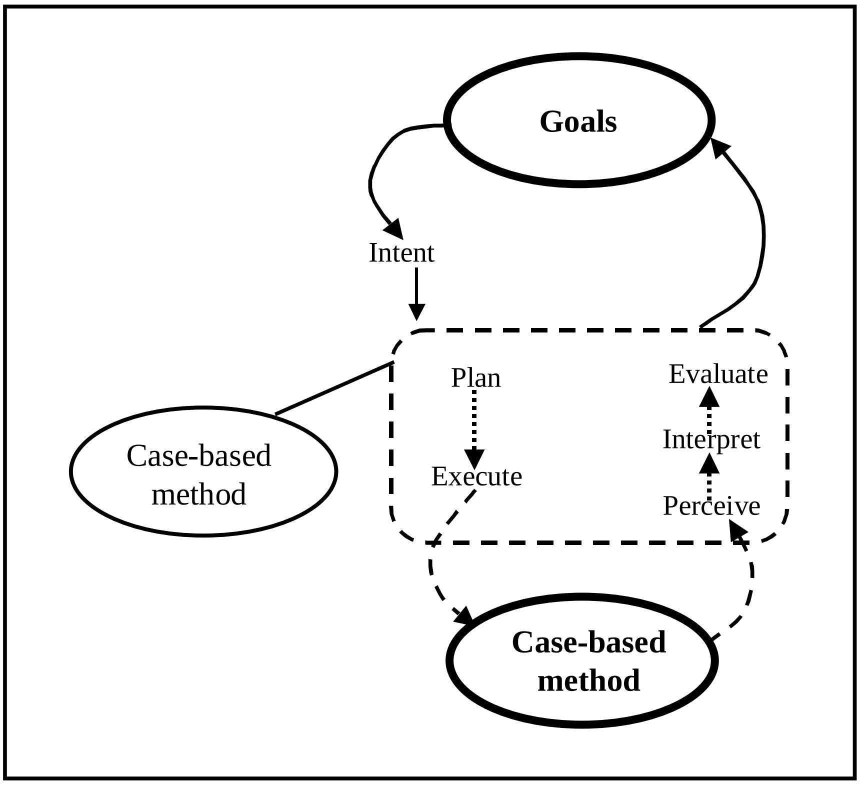

Figure 2: The Norman' reference model of semi-autonomous agent

OVERVIEW OF THE INTEGRATED PLATFORM

The integrated platform consists of three main components: the client interface; the multi-agent system server; and the network learning resources *CBR processes* (figure 3). According to figure 3, the *client interface* consists of a learner-centred and problem-driven Java client application from where students access the multi-agent system and the network learning resources. The *multi-agent system server* is comprised of a multi-agent system with three intelligent agents each one with a specific mandate and role and a WebLogic application server. Finally, the *network learning resources* component is the repository of all the contents of construction engineering learning resources that the multi-agent system provides just-in-time. It comprises a CBR knowledge-base. The CBR knowledge-base consists of the CBR processes, and a library of authentic construction project cases and library of construction problems solved by students.

PROGRAMMING AND DEPLOYMENT TOOLS

The key concerns in the early stage of the development process were how to enable students to access the network learning resources through a learner-centred and problem-driven interface, how to assemble, deploy and manage the multi-agent system, how to represent and access the construction project cases, and how to store and organise diverse teaching material. Taking into account these issues, the following tools were chosen: the VisualCafé Enterprise Suite from Symantec; the WebLogic Application server from BEA Logic; and the ART*Enterprise Version 2.0 from Inference Corporation. VisualCafé Enterprise Suite uses Java technology to build and deploy distributed applications. The BEA WebLogic is a Java application server for developing, integrating, deploying, and managing large-scale, distributed Web, network, and database applications. ART*Enterprise provides a very powerful programming environment that allows developers to build hybrid applications. ART*Enterprise offers a variety of representational paradigms including: objects supporting multiple inheritance, encapsulation and polymorphism; rules; and cases. The

CBR components in ART*Enterprise provide facilities to quickly develop case-bases, the nearest neighbour matching method and the impressive text handling.

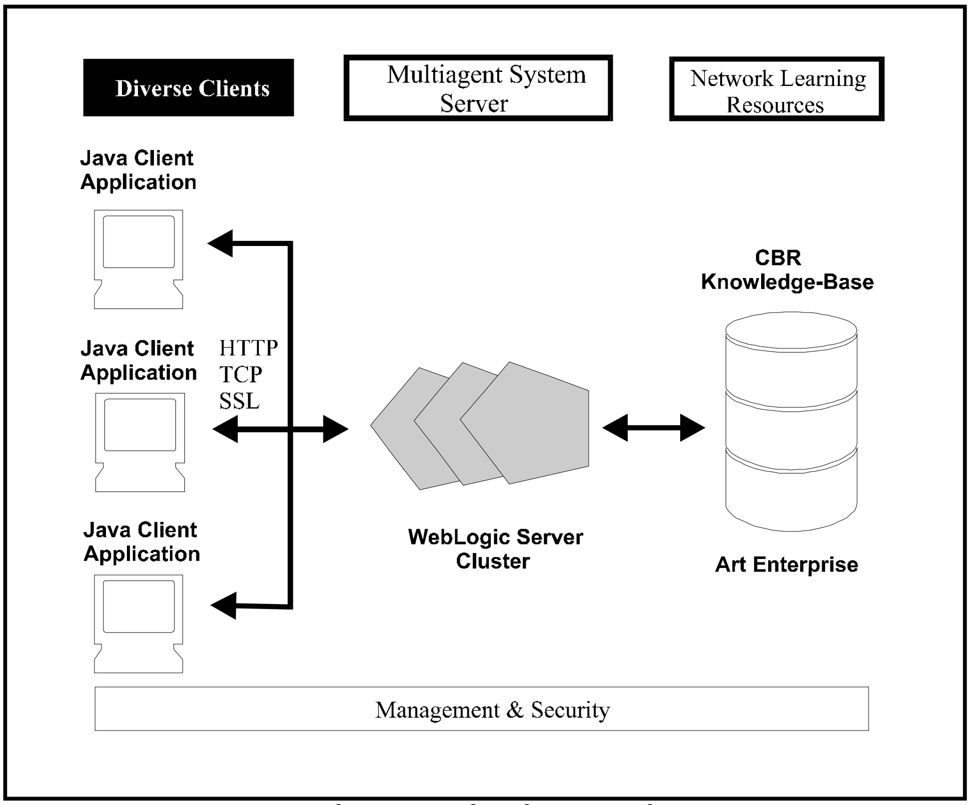

Figure 3: The integrated application architecture

BRIEF DESCRIPTION OF THE PLATFORM

Client interface

The student can access the multi-agent system and the learning resources through a learner-centred and problem-driven user interface with visualisation and multimedia tools for input, doing tasks, editing, presentation, dialogue control, and authoring. This user interface is a Java application, which can be accessed by any Web browser.

WebLogic application server

The WebLogic application server is an integrated platform for assembling and deploying the multi-agent system. It is an extensible framework that allows the multi-agent system to be "snapped in" and transparently shared by many client applications across the network. The WebLogic application server allows the multi-agent system to access and update the CBR knowledge-base. The WebLogic application also allows the CBR knowledge-base to be plugged into the WebLogic framework, automatically wrapped with a Java class.

The multi-agent system

Each agent is being implemented as a knowledge-based Java program using VisualCafé Enterprise Suite. Each agent takes the student's goal as an input, and searches the agent's case base for an action plan to generate a sequence of actions achieving the goal. The agent's case base contains plans (cases) that are indexed by user's goals and can be retrieved according to the input parameters. Agents in the WebLogic can negotiate by exchanging messages concerning their resource information requirements. Java is the language of choice for multi-agent systems in the World Wide Web (Wong et al., 1999). Java has several features not found in any other language that directly support the implementation of agents for the net.

Case base organisation

The CBR knowledge base comprises three case bases: the case base of construction project cases; the case of problems solved by students; and the case base of action schema plans. Each case base consists of a memory of cases describing specific knowledge. For each case base, a distinct structure was implemented. For the case base of valuation rationale cases, this structure was gleaned from existing project documentation (designs, specifications, reports and schedules). For the case base of construction engineering problems and of action schema plans, this structure was engineered by interviewing teachers. We followed this structure in organising cases into each case base. The construction project case's size was an important consideration in choosing the organisation of its case base. Because a construction project is a record of a complex set of experiences and decisions we divided construction project cases into smaller chunks –sub-cases- and their parts linked as a hierarchy. Therefore, the case base for construction project cases uses a hierarchically structured organisation. The memory organisation of the other case bases is a list of pointers to cases. Each case base is an ART*Enterprise object instance of the object case-bases. It comprises the case base object and a case base index. The case-base index stores the information needed for matching cases.

Representation of construction project cases

The CBR paradigm assumes that there is a concept of "a case" which is a contextualised piece of knowledge representing a lesson (Kolodner 1993). The CBR knowledge base contains three kinds of cases: construction project cases; problem-solved cases; and *action schema plans*. A construction project case is simply an ART*Enterprise object instance whose attributes constitute features of the case. It is represented in the CBR knowledge base as a *partonomic hierarchy* because a construction project is a complex set of information and experiences. A partonomic hierarchy of a construction project case is a decomposition of valuation information into a hierarchy of subcases. Therefore, a valuation rationale case in the case base is represented as a hierarchy of subcases. This decomposition allows the search and match to focus only on the relevant parts of a construction project. Processing only some knowledge linked to a case lets reasoning become more efficient.

Case recall

ART*Enterprise gives one mechanism for retrieving cases: the *nearest neighbour matching* method to find the best matching case. The CBR knowledge base integrates search and match. It uses two retrieval algorithms for searching the case base: the hierarchical search for searching the case base of construction project cases; and the serial search algorithm for searching the other case base. Both algorithms are combined with the nearest neighbour matching method to retrieve the best matching cases in the case base memory. The CBR knowledge base uses the output of the problem specification task as a probe into the case base to search for construction project cases that match the current problem as closely as possible. In particular, it searches the construction project cases using the hierarchical search algorithm, first looking for construction project cases exactly matching the specified problem, and then for partial matches.

CONCLUSIONS

This research will address in detail the needs and expectations of all stakeholders of the current education system in construction engineering such as academic institutions, curriculum managers, teachers, students and industry. A review of recent work on teaching/learning systems in construction education has been carried out illustrating the different approaches advocated by several researchers. Within the limits of this paper, an integrated platform using the case-based teaching method in support of the learning process was presented. This platform supports a multi-agent system with three different roles: the teacher' role; the motivating role; and the supportive role. The multi-agent system and its CBR knowledge base implements an innovative instructional model which is grounded in current learning theories and which strikes a proper balance among different instructional approaches appropriate to the construction engineering curriculum. Several leading edge AI techniques are being used to develop the system. AI provides essential enabling techniques for components of the system in order to provide a learning environment with teacher-like competence. Much work remains in order to obtain a finished learning infrastructure. Future work items include: acquiring and storing more construction project cases; refining the representation structure of construction project cases; refining the case indexing; improving the retrieval and matching mechanisms; and finishing the knowledge-based agents within the WebLogic architecture.

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Management Contracting in South Africa

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Abstract

Despite global and economic trends toward management contracting, South Africa has tended to remain with more traditional construction systems. This paper investigates whether the tendency of the construction industry in South Africa is in line with the global inclination toward construction management.

Structured interviews and a questionnaire survey were conducted to assess the extent to which the increasing use of sub-contractors has affected organisational structures of construction companies. This helped to deduce that a management contracting service is required in South Africa. Finally, recommendations as to who could offer the service are made.

*Keywords***:** *management contracting, South Africa, sub-contractors.*

INTRODUCTION

Procurement systems are being diversified from traditional methods whereby a client had to commission the services of a designer to prepare drawings and a quantity surveyor had to prepare estimates and documentation on the basis of which contractors could compute prices before being appointed. Although many believe this traditional approach is sound, there is a general feeling that it places too much emphasis on costs and not enough on time and management. Therefore, other procurement systems have been introduced to meet clients' changing requirements.

The primary purpose of this research is to assess the extent to which the increasing use of sub-contractors has affected the organizational structure of construction companies. By assessing whether companies are employing fewer direct employees and using more sub-contractors than in the past, it is possible to deduce whether construction companies are playing more of a managerial function, thereby indicating a trend toward a management contracting procurement approach.

Research Methodology

A literature study on management contracting and the use of sub-contractors was first undertaken. Structured interviews and a questionnaire survey were designed and conducted to assess the extent to which the increasing use of sub-contractors over the past six years has affected organizational structures of construction companies. Finally, conclusions as to whether a management contracting service is desirable in South Africa were drawn. The research methodology is shown diagrammatically in Figure 1**.**

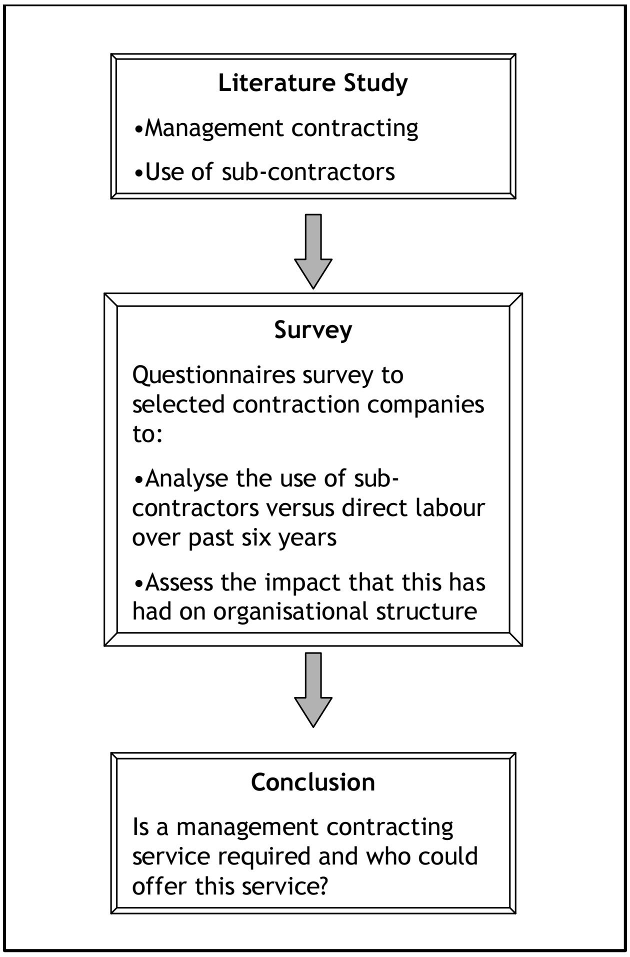

Figure 1: Research methodology flow char

MANAGEMENT CONTRACTING

The construction manager adopts a consultant role with direct responsibility to the client for the overall management of the construction of the project, including liaison with design consultants, to meet agreed objectives. All construction is carried out by means of work packages which are subject to direct contracts between the client and the package contractors (Masterman, 1992). This obviates the need for a main contractor. Management contracting differs from project management. According to Kwakye (1991) project management is the arrangement where the client appoints a professional consultant/advisor to assume the role of project leader and is responsible for the management of the design and construction functions. Figure 2 shows the professional team structure for management contracting.

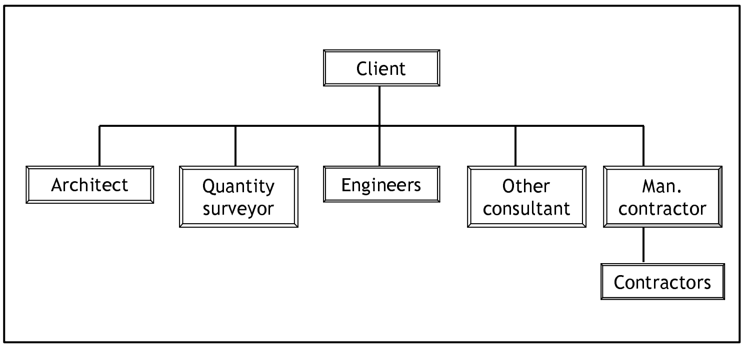

Figure 2: Professional team structure for management contracting

Several advantages are claimed for this method "over the more usual contracts and tendering procedures". Some of the advantages of management contracting, as provided by McKinney (1983) are now outlined.

First, the managing contractor, as a professional agent of the client retained on a fee basis, works in the client's interests. This approach overcomes the contract barrier and removes the basis for traditional adversarial relationships that often exist between the contractor and other members of the team.

Second, the involvement of an experienced contractor performing the role of the management contractor at the design and planning stages provides the client and designers with a source of information on matters concerning cost, buildability, productivity, programmes, schedules, market conditions, and labour and materials availability. Thus, designers can design to suit the prevailing conditions.

Third, competitive tenders can be obtained for 100% of the work, because the management contractor, from his own experience, knows how to sub-contract work on a secure basis. From this experience and list of sub-contractors, he will also be able to select on the basis of quality as well as price.

Fourth, Moore (1984) suggests that the contractor is in a position to control the tendering for work elements thus obtaining maximum price benefit by recognizing market conditions and influences. There is also no unwanted mark-up on sub-contractors who constitute a large portion of the work. Moore goes further to suggest that there may well be savings in the overall time from the initial brief to completion due to the omission of time spent on preparing design/ tender documentation and tendering periods. He argues that such reductions reduce total costs, while the client has the use of the facility sooner.

ASSESSMENT OF USE OF SUB-CONTRACTORS AND IMPACT ON COMPANY STRUCTURE

The sample selection

The required information was obtained by completing a pilot study and sending questionnaires to selected construction companies.

The companies were randomly selected from a list of the Master Builders Association (MBA) comprising 215 companies. The MBA is an employer's association of notable construction firms in South Africa. The companies on the list were numbered from 1 to 215 (the list was originally sent in alphabetic form and was not numbered). A random number table from Hanke and Reitsch (1994) was then used to choose numbers between 0 and 216. The starting point on the table was randomly chosen. From the starting point, moving from left to right; three consecutive digits were taken to represent one number. The random number table was thus used from left to right, top to bottom and then from right to left in this way.

This process was repeated until 75 different numbers had been listed. The five companies that were used for the pilot study were taken from this selection and then removed from the list. The five firms were chosen on the basis of their willingness to participate in the pilot study and assist in refining the survey questionnaire. Of the 70 companies left on the select list, 20 expressly declined to participate in the study. Twenty-seven firms out of the remaining 50 responded to the questionnaire survey.

Changes in the use of sub-contractors

The first objective of the questionnaire was concerned with establishing if the use of subcontractors by construction companies had increased over the past six years.

The percentage of the total value of work that was sub-contracted in 1990 was compared to that in 1996. The percentage values obtained from the respondents are shown in Table 1.

Table 1: The percentage of work sub-contracted in 1900 and 1996, as a percentage of the total value of the contract

Company	1990	1996	Change
	%	%	%
1	80	90	10
2	70	70	0
3	50	50	0
4	50	80	30
5	50	50	0
6	80	95	15
7	57	52	-5
8	70	70	0
9	55	65	10
10	60	75	15
11	95	95	0
12	60	30	-30
13	30	70	40
14	30	60	30
15	20	65	45
16	50	70	20
17	30	35	5
18	43	55	12
19	50	80	30
20	40	73	33
21	60	60	0
22	10	50	40
23	75	90	15
24	50	50	0
25	55	70	15
26	40	60	20
27	20	27	7

Once the tabulation was completed a bar graph of the results was produced showing the number of companies that had experienced an increase, a decrease and no change in subcontracted work.

Figure 3 shows the number of companies that experienced change in the amount of work subcontracted comparing the years 1990 and 1996. It is possible to see from the bar chart that only two companies used fewer subcontractors for projects in 1996 than they did in 1990. There were seven companies that had, over the last six years used a constant amount of subcontractors. The majority of the companies that responded to the questionnaire showed that they had increased the amount of work that they subcontracted. In other words, 66% of the respondents had increased the amount of subcontracted work.

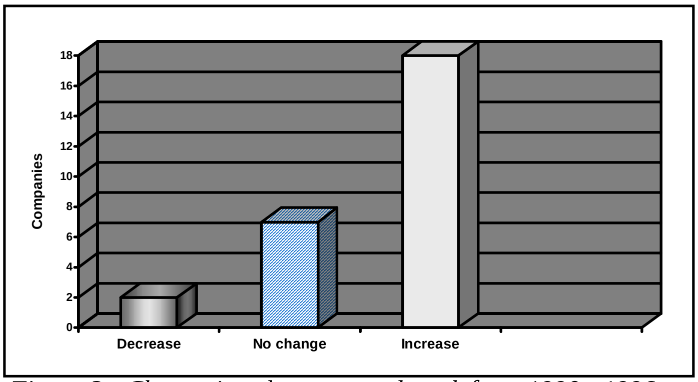

Figure 3: Change in sub-contracted work from 1990 - 1996

Changes in company structure

The second objective of the survey was to determine if company structure had changed over the past six years. Possible change in structure was measured in terms of the number of people that had been directly employed by the respective companies. The results from the questionnaire relevant to change can be seen in Figure 4.

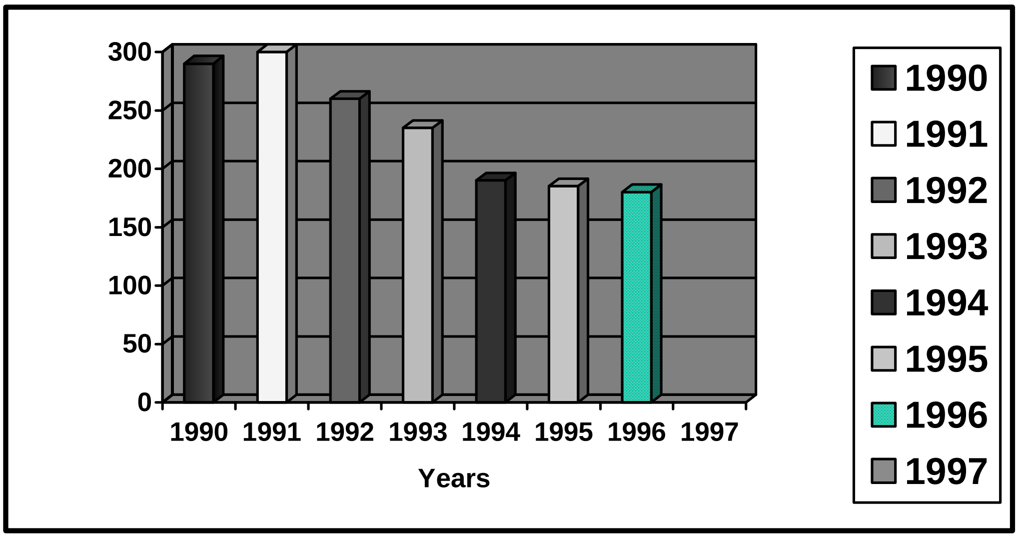

Figure 4: Average number of employees per year

It is clear from the graph that there has been a proportionate decrease in the number of employees of construction companies over the past six years. It can be calculated from Figure 4 that there has been a 34% decrease in the average number of direct employees from 1990 to 1996.

Further results of the study indicate that 52% of the respondents agreed that their companies were more involved in the management of a contract rather than the actual construction in 1996, compared to only 15% of respondents that believed the same statement to be true in 1990. A significant 48% of respondents specifically indicated that the proportion of their directly employed artisans relative to site management staff has decreased over the same period. This indicates a tendency to manage or sub-contract work rather than direct involvement in the process.

CONCLUSION

It has been found that there is a definite trend in the South African construction industry concerning the retrenching of direct employees and replacing those employees with sub-contractors. At the same time, it has been determined that there has been a significant increase in the number of companies that manage more of their projects and do less construction themselves. The South African construction industry, in general, is moving in the direction of management contracting. The indication is that this procurement option will continue to gain significant grounds in the new millenium.

The question as to who could offer a management contracting service in South Africa now arises. Professional project management firms have the skills required and therefore could play a role either by offering the service themselves or by lending their services to main contractors. A combination of management contracting and project management services could also be a possibility. However, conflicting interests could be a problem. According to a study by Goodman (1997) most clients feel that this combination of services is specifically suitable for refurbishments. Nevertheless, the question as to who, and exactly how, the service could be offered in South Africa is an area for further research.

A further implication of these results is that more training in construction management will be required in South Africa in the new millenium. This is especially interesting when one looks at the notable 30% drop in the number of students entering the BSc Building degree (specifically for the training of construction managers) at the University of the Witwatersrand over the last few years. We are informed that the numbers for similar construction management degrees at other universities in South Africa have also dropped. Therefore, while there is an apparent increase in construction management skills required by the industry, there is unfortunately a decrease in the number of construction management graduates. South African universities which offer construction management programmes, should direct their efforts toward increasing the student intake into Building degree programmes in the new millenium. The industry as a whole should be directing their efforts toward increasing construction management skills.

Furthermore, employees with experience who are currently co-ordinating other less experienced employees should be encouraged and trained to be able to start their own sub-contracting companies. This would also give people from previously disadvantaged communities the opportunity to be educated in owning and managing their own businesses.

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Improving Construction Productivity by Management

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Abstract

Despite the extensive development of Singapore's construction industry, productivity in the industry is below the national average and that of many developed countries. In order to improve productivity, several measures have been taken by the construction industry in Singapore. This paper highlights the topic of improving productivity by construction management especially through performance measurement and benchmarking for various construction operations and activities. A case study of ready mixed concrete (RMC) placing, is presented to show how these could be used to improve the RMC placing productivity.

Keywords: Construction productivity, construction management, performance, benchmark.

INTRODUCTION

The construction sector in Singapore is perceived as a low productivity sector due to its low-technology image and visible employment of a large number of foreign workers. In order to raise the level of construction productivity in Singapore, it is recommended that construction projects should have the following features (CIDB, 1992):

a) a high degree of standardisation in grid layout and sizes of components;
b) building systems and installation details which are simple, easy to construct and repetitive;
c) a design which uses or facilitates the use of a high degree of prefabrication or pre-assembled forming systems;
d) architectural details which minimise the use of wet trades, replacing them with dry components or semi-dry trades;
e) well managed construction with proper planning and supply of adequate working details;
f) high level of mechanisation and good housekeeping; and
g) skilled workers in the relevant trades, entering and leaving the project on schedule.

Of the above features, the first four are design-related, which make a construction project more buildable. The last three are construction-related, and involve construction management and workers' skills. The construction-related factors that contribute to low productivity can be further outlined as (CIDB, 1992):

a) shortage of suitably trained skilled workers and the presence of a large unskilled foreign workforce;
b) a poorly developed subcontracting sector;
c) general lack of professional site management; and
d) inadequate mechanisation and automation in some sectors of the industry.

Insufficient fundamental research and development (R&D) on the industry is also a key factor. The two universities in Singapore with support from related government authorities such as the Building and Construction Authority (BCA), the Housing and Development Board (HDB) and the Ministry of Manpower (MOM), and professional bodies such as the Singapore Contractors' Association Limited (SCAL) could contribute more to solve these problems should they pay more attention to and conduct more fundamental R&D. Performance measurement of benchmarking for various construction operations and activities is one of such research projects which will be of help to improve the productivity of these operations/activities and then the productivity of the whole industry.

The following sections will firstly describe in general where and how construction management can improve construction productivity and then consider in detail how performance measurement and benchmarking can do so with RMC placing as a case study.

CONSTRUCTION PRODUCTIVITY AND ITS CHARACTERISTICS

As is well known, productivity is a ratio between input and output. It is important to specify the input and output to be measured when calculating productivity because there are many inputs, such as labour, materials, equipment, tools, capital, and design, to a construction system. The conversion process from inputs to outputs associated with construction operations is also complex, influenced by the technology used, by many externalities such as government regulations, weather, unions, economic conditions and management, and by various internal environmental components. Nevertheless, productivity is often related to only a single input (*eg*, worker-hour) and a single output (*eg*, floor area in m^2), and the simple productivity ratio/index of this input and output is calculated. That is, it has been assumed as a closed system with all factors held constant except for the known input and output. This simplified model can be quite useful, as long as one does not lose sight of the complexity of the real world. For example, a company’s records show that the productivity index for a specific type of concrete pour should be 3.50 m^3/worker-hour (m^3/wh). If on a specific day, 202 m^3 of concrete were placed by 9 workers in a 7.5 hour shift, then the productivity index = 202/(9x7.5) = 2.99 m^3/wh, and the productivity decrease = (3.50 - 2.99)/3.50 = 14.6%.

Neither the productivity index nor the model will provide an explanation for the loss in the productivity. The model, however, does indicate that the change in productivity may be due to one or more internal or external influences including undefined disturbances. In addition, there could be different productivity indices for different purposes and these productivity indices are related to time and place.

A further clue for the change in productivity is provided by the work-time model shown in Fig. 1. The basic work content A is the minimum time required to complete an operation if working conditions are perfect, design and specifications at an optimum, and if there is no time loss. This is an idealised condition that may never occur. The basic work content is increased by the conditions illustrated in sections B, C, and D of Fig. 1.

Fig. 1: Work-time model - Breakdown of total operation time
Source: Drewin (1982)

Total Time of Operation	Total Work Content	"**A**": Basic work content (Ultimate goal is make this plus "B" the total time of operation.)
		"**B**": Work content added by unavoidable externalities (weather, suppliers, *etc*)
		"**C**": Work content added by poor designs, inadequate specifications, lacking of standardisation, government over-regulations, and excessive material and quality requirements.
		"**D**": Work content added by inefficient methods, obsolete equipment, and poor layout.
	Total Ineffective Time	"**E**": Ineffective time due to management's shortcomings, design changes, lack of equipment, lack of manpower, lack of materials, and poor working conditions.
		"**F**": Ineffective time due to shortcomings of worker, absence, lateness, idleness, careless workmanship, and accidents.

The time required to complete the work is further increased by the addition of ineffective time, which may be due to management's shortcomings (E) or shortcomings of the workers (F). Productivity can be improved by reducing any of the time segments B, C, D, E and F shown in Fig. 1. Construction management must be attentive to all sections, the designers can help by producing more buildable design and the government can help by sensible regulations and code requirements. In a word, the BCA's measures will work.

From the example and Fig. 1, it can be concluded that productivity measurement also means comparison: we can compare current levels with historical productivity, between different productive indices and factors, and against target productivity. Often, productivity is compared with standards or benchmarks that were established through productivity measurement and benchmarking, or in more broad terms, performance measurement. We can also arrive at standards/benchmarks by measuring operation times. We can also use activity sampling to measure productivity/performance and then establish standards or benchmarks.

IMPROVING CONSTRUCTION PRODUCTIVITY BY MANAGEMENT

Where construction management is concerned, good planning, scheduling and controlling can improve productivity on a construction project. Several other components related to construction management must also be considered when a purposeful effort is made to increase productivity. Some of these components are now discussed (Chao, 1997).

a) Assign or recruit the right people to do the job or provide training to improve workers' ability and skill.
b) Adopt motivational or personnel management measures to boost workers' morale. For example, tie compensation to performance; ensure that pay, fringe benefits, safety, and working conditions are all at least adequate; and enlarge the jobs to include challenge, variety, wholeness, and self-regulation.
c) Use project scheduling techniques such as computer-aided construction project management (CPM) to optimise the times of related activities and make sure that works, tools, and materials allow continuous task performance so as to reduce the idleness of the labour force to a minimum.
d) Keep simple and efficient the communication among employees as well as with related parties.
e) Make the employees know that they are important to the organisation and involve them in the making of decisions affecting their jobs such as method improvements.
f) Conduct productivity/performance study at the activity/operation level to produce benchmarks and to develop scientific models as part of the study to describe the detailed tasks performed for an activity/ operation by individual or group in order to find out problem areas and propose ways to improve.

It is doubtful that a transient construction worker will respond to all above measures, leading to an increase in productivity. All these components have, however, strong points as well as weaknesses but the greatest opportunity for the construction industry to increase productivity is found in the areas covered by measures (e) and (f). Performance measurement and benchmarking is a concentration on these two components, helping to increase productivity through methods improvements and productivity study.

BENEFITS OF PERFORMANCE STUDY AND BENCHMARKING

Although there is already information about the productivity situation in the construction industry, most of the information is in broad terms for the whole industry. There is little definite or fundamental information available on construction productivity especially related to on-site construction operations in the context of Singapore. Another recognised major limitation is the lack of accepted productivity benchmarks against which improvements over time can be gauged and comparisons made among different projects and countries.

Some questions may be posed: Is it true that productivity of construction crews is substandard? What are acceptable standards? What are the contributing factors (especially related to construction management) having an influence on productivity? What are the required skills? How are the workers managed? What processes are used in planning the projects? How do the individuals know what their jobs are? How hard do they work? These are such fundamental questions should be answered and can only be answered through fundamental on-site R&D. Performance measurement and benchmarking would be among the relevant such R&D subjects.

Performance measurement and benchmarking will provide management with invaluable feedback to guide daily decision-making. By regularly using such feedback, management will become more competent. Measurements help turn even average managers into exemplary performers merely by supplying them with better information, such as benchmarks. This kind of R&D also embodies the principles and philosophy discussed above and hence should be encouraged. The next section shows in detail a case study of performance measurement and benchmarking for ready-mixed (RMC) placing in Hong Kong and how they can used to help improve RMC placing productivity.

CASE STUDY - CONCRETE PLACING

Introduction

Concreting which consists of concrete batching, transporting and placing, is a major construction operation in most of countries. Study of concreting is of direct value to the productivity improvement and of wider international interest. A study was then undertaken in the early 1990s of the utilisation of labour and equipment resources in the in situ concreting of buildings in Hong Kong. The site-based study was concerned only with RMC supplied to multi-storey building sites. Some of the objectives were: (a) to measure the productivity being achieved by site labour and equipment in the concreting of buildings and by RMC plants and truck mixers; (b) to compare the resource utilisation of the different concrete placing methods in use and to produce performance benchmarks for future use; and (c) to find out factors affecting concreting productivity and ways to improve it.

The bulk of the observation work comprises the study of a sample of 154 pours on building sites, each observed from beginning to end: 33% of the pours were pumped, 28% placed by crane and skip (craned), 28% by hoist and barrow (barrowed), and 11% by tremie and direct tip (tremied). In terms of concrete volumes those percentages become 40%, 21%, 24%, and 15%, respectively. These percentages are believed to approximate industry-wide figures quite well. The study sample is not too dissimilar in its composition (Anson *et al*, 1998).

Data and Information Collected On-Site

Detailed data as shown in Table 1 were collected on-site for each of the 154 pours, which were observed from beginning to end of the pour. The mean pour size in the sample was 120 m^3. The results and inferences presented here therefore probably apply only to pours at the larger end of the spectrum. They are likely to receive more management attention than the lesser pours and productivity is therefore likely to be higher.

As shown in the bottom row of Table 1, even though the mean pour duration was 7.02 hours, on average 10.2 truck-hours (th) were actually provided on-site. In spite of this significant over-provision of truck mixers, for a mean period of 50.6 minutes on each pour, there were no truck mixers present on-site and production was halted.

Table 1: Numbers and types of pour, sizes, duration, delays and resources supplied

Placing Method	***No of pours***	***Pour size (m^3)***	***Duration (hours)***	***Waiting for RMC (minutes)***	***Other delays (minutes)***	***Worker hours supplied (wh)***	***Truck mixer hours supplied (th)***	***Placing equipment hours supplied (eh)***
Pumped beam & slab	34	160.5 (208, 107)	7.20 (8.75, 5.65)	43.7 (61, 0)	67.0	84.5 (103.4, 50.1)	12.7 (15.9, 8.9)	8.1
Pumped column & wall	17	111.1 (129, 72)	5.86 (7.17, 4.83)	46.7 (68, 24)	55.6	56.0 (71.7, 43.5)	9.9 (11.8, 6.8)	5.9
All pumped	51	144.0 (183, 102)	6.76 (8.42, 5.08)	44.7 (65, 15)	63.2	75.0 (92.6, 44.8)	11.8 (15.1, 7.9)	7.4
Craned beam & slab	12	79.8 (98, 65)	6.73 (8.35, 6.67)	60.4 (122, 14)	46.2	59.7 (66.8, 51.6)	8.0 (9.9, 4.8)	6.7
Craned column & wall	31	92.5 (132, 62)	7.55 (8.92, 6.60)	47.4 (63, 33)	64.5	83.6 (124.7, 70.8)	9.1 (9.1, 8.6)	7.8
All craned	43	89.0 (121, 65)	7.32 (8.65, 6.75)	51.0 (69, 22)	59.4	76.9 (99.4, 54.7)	8.8 (10.1, 5.5)	7.5
All barrowed	43	105.3 (134, 52)	7.55 (8.60, 6.48)	57.0 (67, 33)	43.6	99.5 (115.5, 56.7)	9.7 (12.1, 6.2)	9.8
All tremied	17	163.4 (276, 88)	5.75 (7.33, 4.25)	50.9 (71, 20)	77.1	37.6 (43.1, 15.2)	9.9 (12.0, 8.3)	6.2
All pours	154	120.0 (152, 66)	7.02 (8.47, 5.43)	50.6 (67, 21)	58.2	78.2 (101.7, 44.1)	10.2 (13.4, 7.3)	8.0

Figures in parentheses are upper and lower quartiles (*i.e.*, one quarter of all results were greater than the higher value, and one quarter were less than the lower value).

Information was also collected on how the total time spent by truck mixers on-site was divided among queuing, being unloaded and washed out and leaving the site. Table 2 summarises these data. Mean time on-site was 32.8 minutes, of which 18.9 minutes was spent being unloaded. Mean interruptions in supply of 11.0%, 11.6% and 12.6% were measured for the pumped, craned, and barrowed pours respectively. About 12% of pour time, or 50.6 minutes on average, were spent waiting for concrete. Although truck mixers were present on-site for only 88% of pour time, the actual provision of truck-hours, a different measure of the level of RMC service, was generally much greater than the pour duration. The RMC companies actually provided 17.6 truck-hours on-site (*i.e.*, excluding travelling and at batching plant time) for every 10 hours of pumped pour duration. The corresponding figures for craned and barrowed pours are 12.0 and 12.9 truck-hours

Table 2: Observations of truck mixer usage of time on-site

Placing method	*No. of pours*	*Mean pour Size (m^3)*	*Mean pour time (hours)*	*Truck mixer* Not seen on-site *(% of pour time)*	*Seen On-site (% of pour time)*	*Mean time unloading (minutes)*	*Mean total time on-site (minutes)*	*% of Total Time on-Site* *Queuing (%)*	*Unloading (%)*	*Washing out (%)*
Pumped beam & slab	34	160.5	7.20	10.1	181	14.3	31.1	41.4	46.9	11.7
Pumped column & wall	17	111.1	5.86	13.3	167	15.2	31.2	36.7	50.2	13.1
All pumped	51	144.0	6.76	11.0	176	14.6	31.2	39.7	48.1	12.2
Craned beam & slab	12	79.8	6.73	15.0	120	20.7	34.5	22.6	62.0	15.1
Craned column & wall	31	92.5	7.55	10.5	120	21.3	33.7	27.9	63.0	9.0
All craned	43	89.0	7.32	11.6	120	21.1	33.9	26.4	62.7	10.7
All barrowed	43	105.3	7.55	12.6	129	25.4	36.9	20.2	67.1	12.7
All tremied	17	163.4	5.75	14.8	184	9.7	24.6	44.1	38.1	17.8
All pours	154	120.0	7.02	12.0	148	18.9	32.8	31.0	56.4	12.5

Performance Analysis - Productivity being Achieved

Table 3 shows that 17.4 m^3/hour (m^3/h) was the mean placing rate (productivity) achieved for the 154 pours. The 17 direct tip and tremied pours were the fastest, averaging 28.8 m^3/h followed by pumped pours at 21.4 m^3/h. Pours placed by crane and skip averaged 12.2 m^3/h - not much slower than those using the hoist and barrow method which averaged 13.5 m^3/h. The results also make clear that labour productivity is predictably high on direct tip and tremie pours, at 6.2 m^3/wh. It is useful to note that labour productivity when pumping, at 2.11 m^3/wh, is significantly greater than the figures for skipping and barrowing, 1.24 m^3/wh and 1.08 m^3/wh, respectively. For the whole sample, embracing all methods, labour productivity was 2.03 m^3/wh.

Table 3: Key performance parameters for all pours

Placing method	*No. of pours*	*Mean pour size (m^3)*	*Mean Measured Performance* *Overall (m^3/h)*	*Gang (m^3/wh)*	*Equipment (m^3/eh)*	*Truck mixer (m^3/th)*	*If No Delays* *Overall (m^3/h)*	*Gang (m^3/wh)*
Pumped beam & slab	34	160.5	22.3	2.14	20.9	12.9	31.7	3.07
Pumped column & wall	17	111.1	19.7	2.05	19.7	13.1	28.2	2.94
All pumped	51	144.0	21.4 (24.1, 16.1)	2.11 (2.3, 1.4)	20.5 (23.5, 15.8)	13.0 (15.4, 9.0)	30.4	3.03
Craned beam & slab	12	79.8	11.9	1.35	11.9	11.2	16.5	1.91
Craned column & wall	31	92.5	12.3	1.19	12.0	11.2	17.9	1.78
All craned	43	89.0	12.2 (14.7, 8.8)	1.24 (1.5, 1.0)	11.9 (14.7, 8.8)	11.2 (15.0, 7.5)	17.5	1.82
All barrowed	43	105.3	13.5 (20.1, 8.0)	1.08 (1.2, 0.9)	10.2 (12.1, 8.0)	10.2 (11.3, 8.4)	17.3	1.39
All tremied	17	163.4	28.8 (42.9, 12.3)	6.20 (9.2, 2.1)	28.1 (42.9, 12.1)	18.0 (23.1, 10.4)	55.0	13.2
All pours	154	120.0	17.4	2.03	16.1	12.3	25.9	3.35

Figures in parentheses are upper and lower quartiles (*i.e.*, one quarter of all results were greater than the higher value, and one quarter were less than the lower value).

Table 3 also expresses the truck mixer productivity in m^3/truck-hour (m^3/th) *on-site*. Except for the direct tips, when unloading takes only a few minutes and the productivity is 18.0 m^3/th, mean productivity is fairly steady: 13.0 m^3/th for pumped pours and 10.2 m^3/th for barrowed pours. For the whole sample, truck mixer site productivity averaged 12.3 m^3/th.

Columns 8 and 9 in Table 3 show the performances that theoretically would have been achieved if there had been no interruptions in the supply of concrete and no other delays due to placing equipment problems or moving or poor pour preparation, and so on. It is interesting to note the difference between what is actually observed and what perfect organisation would achieve. Instead of placing at 17.4 m^3/h with labour productivity of 2.03 m^3/wh, pours would achieve productivity of 25.9 m^3/h and 3.35 m^3/wh, increases of 50%.

Table 4 gives the productive time of labour and placing equipment for the four placing methods, including the mean figures and some of the upper and lower quartiles. Labour is typically busy between 82% and 85% of the time but much less so, at 56%, on tremied pours. This latter figure lowered the overall mean to 80.3%. Equipment productivity averaged 73.8% with variability quite high, evinced by the difference between the upper and lower quartiles.

Table 4: Production data: Mean percentage of pour time

Placing method	*Labour active (%)*	*Equipment Active (%)*	*Equipment fault or diverted (%)*	*No concrete on-site (%)*	*Other delays (%)*
All pumped	84.7	74.0	0.4	12.3	13.2
All craned	82.1	74.6	2.3	12.4	10.8
All barrowed	82.5	78.6	0.3	12.7	8.4
All tremied	56.4	58.8	0.0	16.4	24.8
All pours	80.3	73.8	0.9	12.9	12.5

Fig. 2 shows, for each pour the truck-hour provision on-site, as a percentage of pour duration, plotted against the interruption to concrete supply, also as a percentage of pour duration. This illustrates the difficulty experienced in matching supply to requirement. This is a particularly interesting and potentially useful diagram. In fact, if a "good" match of supply to requirement were arbitrarily chosen as a truck-hour provision of between 100% and 150% of pour time and an interruption in supply of not more than 10% of pour time, as indicated by the boxed area on Fig. 2, the majority of cases would lie outside the box. The poor match is unhelpful to contractors when wait times are long and to concrete suppliers when truck mixers are standing idle in queues on sites.

Fig. 2: Relationship between truck mixer provision on site and percentage pour time of RMC

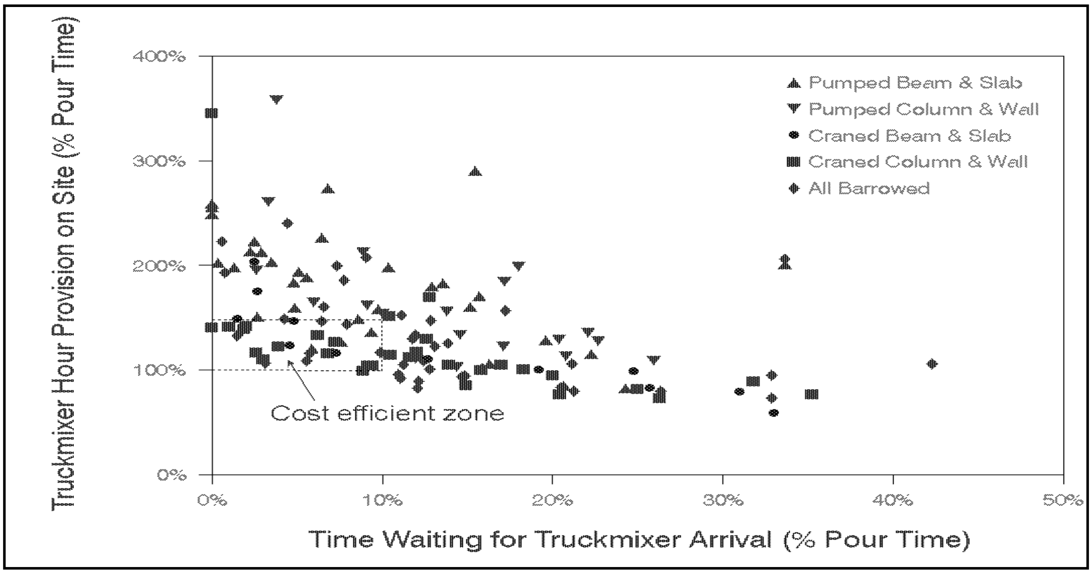

Fig. 2, describes the service sites are receiving and is a useful benchmark of RMC service in Hong Kong as it existed in the early 1990s on building pours. The productivity of concreting ought to be enhanced (a much higher percentage of pours would fit into the box) if the productivity of the site and the RMC supplier are seen as a combination. The site contractor is probably not over concerned with a high truck mixer provision, but the RMC supplier is interested in both of the service aspects portrayed. RMC companies try to avoid excessive gaps in the supply of concrete in order to maintain their reputation for reliability and will often back up two or three truck mixers on-site, and sometimes more. What constitutes an ‘excessive’ gap depends on several factors, including the importance of the pour (which usually equates to the size of pour), the placing method, and the degree of urgency communicated by the site. Taking these factors into account, as well as the distance involved, likely traffic conditions, and the other commitments that day, the RMC supplier assigns a certain number of truck mixers to a site. The outcome of this difficult allocation exercise is illustrated by Fig. 2. Although RMC suppliers do not do so, it would be relatively easy for them to assemble such data on a constantly updated basis. One effect might be the elimination of the extreme points - delays over 30% and truck-hour provision greater than 200% of pour time, for example.

Operational Uses of the Data Collected - Benchmarking

The studies provide placing performance data of various kinds on the concreting of buildings supplied from RMC plants. The data are useful as benchmarks for the Hong Kong building industry at a particular time and at its particular state of technological development. The various directly measured productivity indicators, such as placing rate *per* hour, placing rate *per* worker hour employed, and output *per* truck mixer *per* day (summarised in Table 5), are suggested as useful benchmarks, and companions to the Fig. 2 benchmarks. Such benchmarks can be monitored over time as indicators of changing construction industry productivity. They can also be used for comparisons with other large cities, as illustrated by Wang (1995) and Anson *et al.* (1996) with comparisons of data for cities in the UK and Germany with those for Beijing.

The data may also be directly useful to those actively involved in the daily business of concreting. Measures of the sort produced here can help to gradually improve the general level of performance by encouraging individuals to achieve at least mean performances on their own individual pours, thereby reducing the number of below-mean results. This is improvement of the industry by the industry.

Operational Uses of the Data Collected - Target Placing Rates

The data collected also enabled some estimation to be made of the effect of some variables other than size and placing method. Although larger pours do achieve higher mean placing rates because of economy of scale, it is conceivable that a very long pour might suffer as a result of labour fatigue in the final stages. Beam and slab pours that are relatively shallow ought to take longer than deeper ones of the same volume. Pours that are high above the ground might be expected to take longer than those that are near the ground. For Hong Kong buildings, a rule-of-thumb is that for every extra 10 m^3 of pour volume the placing rate is increased by 1.1 m^3/h (Anson *et al*, 1996). That larger pours are done at higher placing rates is a function of several factors. For example, more attention is paid to site preparation, concrete suppliers treat large pours as more significant, labour usage is more thoroughly planned, and although there are only a limited number of hours in the day, tasks must be completed. Smaller pours can be allowed to take longer.

Table 5: Profile of concreting industry characteristics in Hong Kong

Category	***Characteristic***	***Value***
Demand (38 plant samples)	Ready-mixed concrete output *per* plant *per* day	729 m^3
	Average pour size	33 m^3
	Mean distance to site from plant	9.6 km
	Journey time	25.9 minute
	Average number of sites served *per* day *per* plant	15
Resource Availability	Rated capacity *per* plant	1,205 m^3 /day
	Number of truck mixers *per* plant	23.6
	Staff *per* plant, including drivers	32.9
	Working days *per* year at plant	343
	Working hours *per* day at plant	10
	Numbers *per* site pour	11.1
	Typical number of placing plant units	1
Resource Utilisation	Utilisation of plants (percentage of rate capacity)	61.0%
	Utilisation of truck mixers	63.2%
	Round trip time of truck mixer	86.7 minute
	Ready-mixed concrete carried *per* truck mixer *per* day	32.5 m^3 6.6
	Number of deliveries *per* day *per* truck mixer	32.8 minute
	Average time of truck mixer on-site	73.8%
	Utilisation of placing equipment	80.3%
	Utilisation of placing crew	21.4 m^3/h; 2.11 wh
	Pumped pours (144 m^3)	12.2 m^3/h; 1.24 wh
	Craned pours (89 m^3)	13.5 m^3/h; 1.08 wh
	Barrowed pours (105 m^3)	28.8 m^3/h; 6.20 wh
	Tremied pours (163 m^3)	148.3%
	Truck-hours on-site (percentage of pour time)	12.0%
	Percentage of pour time spent waiting for concrete	

The effect of duration on production each hour is shown in Table 6. The mean volume placed is shown for each successive whole hour of operation for each of the three methods. Apart from the lunch time dip in craned and barrowed pours, hourly outputs hold fairly steady for the barrowed pours until the ninth hour, when they quite noticeably decline. Fatigue is the most likely explanation. The high production achieved in hour 10 for craned pours is explained by the ability of RMC to maintain a constant supply of concrete at that time of day since many sites will have finished concreting by then. The high pumped output in hour 5 is hard to explain. Possibly, pumped pours are benefiting from the absence of the lunch breaks that are common on craned and barrowed pours. Pumped pours keep going, with individuals rotating off for only short periods, and truck mixers may divert to these pours.

Table 6: Mean volumes (m^3) of concrete placed in successive hours

Hour Number										***Placing method***
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	
22.0	23.0	22.7	21.8	27.2	21.5	20.8	16.8	21.1	23.0	Pumped
13.0	10.9	10.9	9.4	11.4	12.4	12.8	10.3	10.6	16.3	Craned
14.1	15.3	15.2	9.4	12.5	14.0	15.5	16.6	11.2	10.3	Barrowed
17.3	17.7	17.4	14.7	17.9	16.0	16.0	15.6	14.2	14.0	All

The effect of height on pumped pours can be expected to be negligible. Since hoist hoppers move quickly and there is often a pair of hoppers at each drive station, the height effect on barrowed pours is not thought likely to be significant. A craned pour at height, however, is affected by the vertical travelling time of the crane hook and, other things being equal, takes noticeably longer.

Some pours are vertical, such as those for walls and columns. Other pours are horizontal and may be deep, such as foundation and basement pours, or shallow, such as superstructure beam and slab pours. The shape effect on pour duration is illustrated in Table 7 that provides data on the rates achieved for each of the three placing methods. For craned pours there is no apparent shape effect, and this seems reasonable. For barrowed pours, thin slabs are 4 m^3/h faster than thicker slabs and walls and columns. Thin slabs provide a larger work area than thicker pours of the same volume, allowing less interference.

Table 7: Effects of pour type on placing rate (m^3/h)

Placing method	*Column and wall*	*Beam and slab*			*Deep foundation*
		≤ 150 mm	*200 mm*	*400 mm*	
Pumped	19.7 (17)	14.6 (14)	22.2 (11)	25.5 (3)	34.7 (6)
Craned	12.0 (31)	10.7 (5)	11.4 (1)	-	12.0 (1)
Barrowed	8.4 (13)	12.0 (22)	7.8 (7)	-	-
Note: Number of pours in parentheses.					

Based on the data in the above tables, the rules-of-thumb given in Table 8 provide some quantitative feel for the influence of various factors on placing rates. This table can be used to predict the placing rate of a given pour.

Table 8: Influence of various factors on placing rate

Method of pour	*Type of pump*	*Pour volume*	*% of pour time waiting for RMC*	*Total pour time*	*Pour shape*
Pumped	Mobile: +2 m^3/h Fixed: -2 m^3/h	50 m^3: -5 m^3/h 250 m^3: +5 m^3/h	20%: -3 m^3/h 0%: +3 m^3/h	>8 h: -1 m^3/h	Deep, horizontal: +11 m^3/h Column and wall: 0 m^3/h ≤150 mm beam & slab: -5 m^3/h 200 mm beam and slab: -2 m^3/h 400 mm beam and slab: +2 m^3/h
Craned	Not applicable	40 m^3: -2 m^3/h 140 m^3: +2 m^3/h	20%: -1 m^3/h	Not applicable	Not applicable
Barrowed	Not applicable	50 m^3: -2 m^3/h 150 m^3: +2 m^3/h	20%: -1 m^3/h	>8 h: -1 m^3/h	≤150 mm thin slab: +2 m^3/h Other slabs, walls: -2 m^3/h

CONCLUSIONS

This paper highlights some basic concepts related to construction productivity, for example, its characters and the work-time model, then summarises where and how it can be improved through construction management especially performance measurement and benchmarking. The issues are further illustrated with a case study of RMC placing which provides factual information on productivity and performance figures that describe the state of the concreting industry in the early 1990s in Hong Kong. This information can be used as benchmarks against which improvements over time can be gauged and comparisons made with other places. The data distinguish the RMC placing productivity being achieved between different placing methods, and guidance has been given on the likely effects on placing rate of pour size, shape and other variables.

Professional bodies in Singapore should be encouraged to conduct similar R&D and to develop the benchmarks for various construction operations in the construction industry and make the benchmarks well-known and regularly updated to inform of corresponding management measures being taken to improve productivity.

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Functional Analysis Concept Design for Construction Projects

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Abstract

This paper presents and tests the efficacy and cost impacts of the Functional Analysis Concept Design (FACD) method. The method employed is a variant of Functional Analysis System Technique (FAST), and is a technique of "partnering" during the design phase. Various categories of change orders are taken as dependant variables in statistical testing. Tests show that the percentage of change orders is reduced for projects using FACD. The use of FACD therefore reduces costs and managerial tensions during project execution. The FACD technique is suited for use by developing countries.

Keywords: *Change order; FAST; FACD; partnering; value engineering.*

TECHNOLOGIES FOR DEVELOPING COUNTRIES

Developing countries need to adopt innovative, modern technologies so that past mistakes of developed countries may be avoided. In this regard, new techniques and technologies must be readily adopted. Doing so will ensure minimization of obsolescence, and will also yield greater benefits for the future.

A developing country needs to adopt technologies and management systems that are “suitable” to them. The main question is to see whether such technology will work for them and will help further their aims and missions. Technology selection is a plain problem of engineering decision making.

The same goes for management methods. If a management style is universally applicable, there may be no hesitation to adopt it. Cultural and social conditions must be considered, but there are some “constants” that do not change for developing countries. Laws of science are constants that are an obvious case in point; concrete mix designing methods is another. Also, constructability review and conflict management have to be exercised in any society or country; the same goes for improved communication, good designing, reduction of change orders, working within budget, reducing claims, and so on. The list of management technologies that are identical in construction project management between developed and developing countries is very large. This is because the philosophical and economic missions of projects are identical no matter where the project is performed.

THE PARTNERING CONCEPT

Owners, designers, and contractors need to be in agreement when it comes to determining the constructed facility’s functions. Understanding what is required is of the essence in avoiding change orders, and thereby minimizing claims. This is doubly important during the key design phase. Decisions made during design of items such as facility function, needs and requirements, and the solutions for fulfilling those needs and requirements have a bearing on the project as a whole for its entire duration.

If mutual understanding can be reached early during the design phase, it can be hypothesized that there will be fewer conflicts during project execution. This can thus impart a lasting sense of success to all parties. Probably nothing can be better than a sense of fulfillment in one's work for the project.

In that regard, this paper presents a way to achieve improved understanding of project definitions and purposes during the design stage, with an aim to reduce conflicts later (Singh and Stocks, 1997; Stocks and Singh, 1999).

FUNCTIONAL ANALYSIS SYSTEM TECHNIQUE

Functional Analysis Concept Design (FACD) takes up from Functional Analysis System Technique (FAST), which was first introduced in 1965 by the Society of American Value Engineers. FAST assists in obtaining cost reductions by analyzing basic functions of products and the way they are engineered for their purpose. FAST helps to define main and sub-problems, break a large problem down to small ones, and uses a balanced approach to recommend practical action.

However, intrinsic to FAST is the philosophy of providing value to the customer at lower cost. Value engineering is often pursued zealously on some projects. Incentives to contractors assist in value engineering savings. It is this fundamental aspect of "value to the customer" that prompted the US Navy to first study the extension of FAST to another realm, FACD, where "value to the customer" is provided through "clarity of functional design" and "fulfillment of purpose of the facility".

HYPOTHESIS AND RESEARCH METHODOLOGY

The hypothesis for this research, first performed at the US Navy Pacific Division Engineering Command at Pearl Harbor, Hawaii, is that the usage of FACD helps to lower eventual construction costs. This hypothesis was tested using statistical analysis which compared projects that used FACD and those that did not.

The research methodology was simply to collect change order information on projects that used the FACD method, and compare it with information on similar sized projects that were built using traditional methods. This helped to determine whether projects that use FACD are better than those that do not.

FUNCTIONAL ANALYSIS CONCEPT DESIGN

FACD has been developed by the US Navy at its Pearl Harbor office, with the purpose that detailed functional analysis during design stages would assist in providing the customer with a better facility, reduced project re-designs, and reduced construction costs.

The FACD process is a disciplined approach that involves ten days of continuous and regular meetings between the designer, the construction manager (US Navy) and the customer. The customer is typically another branch of the Navy.

The ten day rigor is mandatory, for it ensures continuity of thought and memory, perspective and function, and brings all relevant parties during the initial stages of the project together to thrash out and approve each other's needs and designs. This is essential to prevent customers from changing their minds later on the excuse that they were not *aware* of the ramifications or effects of the designs.

The process begins with the architectural-engineering (A/E) firm gathering information on the design to be performed, after which the firm prepares a *parametric cost estimate* of the facility. The 10-day meeting programme begins immediately afterward.

It is suitable to begin the 10-day meeting program on a Monday to avoid scheduling worries from contract to contract. By establishing a specification of starting on Monday, there is one less decision-making or coordination required. The parties to the contract *must* make themselves available starting on a Monday, else they can be disqualified from future jobs. Moreover, it is in the job description of the program manager of the construction management agency to ensure that the FACD meetings take place. Therefore, it is essential that the FACD needs and outline of work be included in contract conditions.

FACD Meeting Schedules

The 10-day schedule and needs and performance expected therein (Singh and Stocks, 1997; Stocks and Singh, 1999) are now outlined:

<u>Day 1; Monday</u>

The opening meeting is held with the A/E and customer; the customer describes their functions; scope of work and budget are discussed; A/E tours customer's existing facilities to further understand required functionality of the new facility.

<u>Day 2; Tuesday</u>

A/E develops FAST/function diagrams of customer's operations; value analysis job plan is developed; A/E develops design alternatives; rough floor plan and site plan are developed. An example of a FAST diagram is given in Figure 1.

<u>Day 3; Wednesday</u>

The customer, A/E and CM agency meet again to review customer's functions as understood by A/E; floor plan and site plan are reviewed; A/E and customer brainstorm design alternatives.

<u>Day 4; Thursday</u>

A/E continues the design at the meeting room.

<u>Day 5; Friday</u>

The customer, A/E and the CM agency meet again to review the design, design alternatives, and cost estimate; value engineering function analysis is used to prioritize cost reductions; cost reduction exercises undertaken; customer re-ensures that desired functions are being achieved.

<u>Days 6,7; Weekend</u>

A/E continues the design, coordinating the different aspects of the design and ensuring compliance with functions; A/E develops presentation graphics of the design and a draft of the Final Executive Summary (FES); design is now complete to the 10% stage.

<u>Day 8; Monday</u>

The draft FES is presented to the customer; a formal design brief is made to the customer; feedback on draft FES is requested from customer.

<u>Day 9; Tuesday</u>

Formal brief of the design is presented to customer's boss(es); this brief may include the unit commanding officer or base commanding officer; comments on draft are returned to A/E.

<u>Day 10; Wednesday</u>

Final FES is presented to the customer, in which all comments have been incorporated or addressed; all applicable parties sign the FES; the A/E is then given authorization to proceed to complete the design.

The usual result of the meetings is that the parties involved in the initial phases of the contract talk openly with each other, understand each others' priorities, and are able to address major issues affecting design & functionality. All of this contributes to a better, more purposeful and meaningful design, with fewer errors in either functional fulfillment or design drawings.

FAST Diagrams

A FAST diagram is a logical way of describing and analyzing project functions (Figure 1). Movement from left to right explains 'how' the work is being done, while movement from right to left explains 'why' the work is being done. In making the diagram, the functions of facilities can be analyzed and applied in the design by A/E. Of course, it is known that good architecture is related to fulfilling the customer's requirements within cost limits. The FAST diagram simply assists in breaking down a large problem.

The 'why' and 'how' are closely linked to each other from a standpoint of logic. For example, looking at Figure 1, construction of a prison reception center, if we ask "why" do we receive prisoners, the answer is because we want to examine them. Why do we want to examine them? Because we want to analyse them. Why do we want to analyse them? Because we want to process them. Why do we want to process them? Because we want to distribute them to different locations. Thus, we see that the analysis of the reasons for having different rooms and architecture, etc., is related to the functions being performed in the facility. These functions are related in a "cause" and "effect" that is easily represented by a flow diagram such as the FAST diagram.

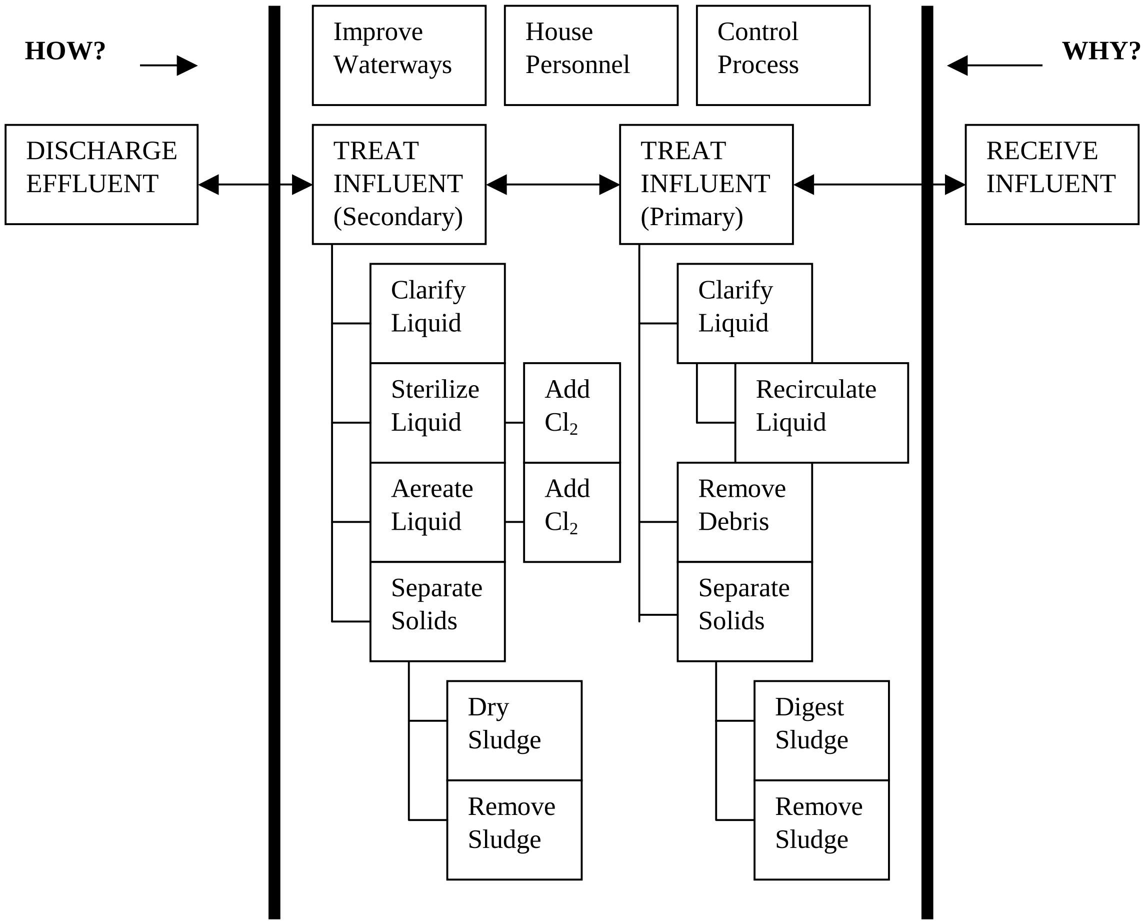

Figure 1: Example of FAST Diagram for a Waste Water Plant (Adapted from Dell'Isola (1982)

Next, going in the reverse direction -- from left to right -- we can answer "how" a particular work task is initiated. Thus, how does it transpire that prisoners are distributed? Because they have been processed. How does it transpire that prisoners are processed? Because they have been analyzed, and so on to the immediate right.

The FAST diagram is one of the major analytical tools used in FACD, though not the only tool. Surely, other creative exercises such as the fishbone diagram could also be used. The emphasis of the exercise, however, is on analyzing detailed functions of the facility in order to be better informed for the creation of a useful and purposeful facility.

Value Analysis Job Plan

Using the analysis made in the FAST diagram, a rough floor and site plan are developed, and items such as proposed utility connections, environmental permits, etc. are coordinated. Then, initial design ideas and alternatives are brainstormed within the A/E team to promote the analysis of value engineering alternatives that maintain functionality but lower the cost. This method, which results in functional evaluation alternatives, is based on a value analysis/engineering job plan that has five major phases, as below (Dell'Isola, 1982):

Phase I: Information	obtain all facts; provide a data base; select areas for detailed study; perform functional evaluation
Phase II: Speculation	generate alternatives to meet requirements; brainstorm; modify/refine
Phase III: Analysis	check for fulfilment of primary functions; evaluate and develop alternatives; assign dollar values to each idea; refine ideas
Phase IV: Development	check to see if designed system is workable and acceptable; present best alternative to decision-makers; work on specifics; prepare summary proposal
Phase V: Reports	define and quantify results; explain advantages and disadvantages; explain implementation procedures and problems; explain before and after; suggest follow-ups; remove roadblocks

Critical thinking for design and improvement, using of good human relations at all phases of the plan, and inquisitiveness are cornerstones for this process. The cost estimate of the facility is continually revised to ensure the project budget is met.

Features of FACD

FACD involves using critical thinking skills to question the purpose and arrangement of design sub-systems and to confirm constructability of design proposals. Attributes of the FACD process include the following:

- Validating functional requirements of the facility with the client early in the design process.
- Examining design alternatives through value engineering.
- Fostering teamwork among the designer, client and owner, and reducing costly re-designs.
- Providing a “partnering workshop” during beginning design stages.

FACD IN THE NEW MILLENNIUM

Among the great advantages of FACD is that it is a conflict resolution tool. Blake and Mouton (1975; Singh and Vlatas, 1991) characterized conflict management as the “fifth dimension” after science, law, religion, and hierarchy, to be the new advancement of civilization. FACD assists to undertake project design in a more civilized way, perhaps in the way it “should be,” with the maximum of understanding between project parties. In this respect, FACD is the immediate wave for the upcoming millennium.

DIFFERENCES BETWEEN FACD AND NON-FACD PROCESSES

So, it may be well asked, what are the differences between the FACD and non-FACD processes? The greatest differences between the conventional, non-FACD and FACD processes are the following:

1. The parties to the design contract meet only occasionally and irregularly in the non-FACD process compared to continuous meeting for ten days in the FACD process.
2. Functional analysis or FAST diagrams and value job analysis plans are not prepared in the non-FACD process.
3. Considerable brainstorming is conducted in the FACD-process and a more in-depth review of design considerations is undertaken.
4. Cost estimates are reviewed in greater detail in the FACD process.

Prolonged and necessary contact between parties is a basic necessity whenever *care* is required in the execution of work. FACD provides that necessary extra component of necessary contact and care.

CHANGE ORDERS AS A MEASUREMENT VARIABLE

While the FACD process has been described, we still desire to know whether the process is useful and beneficial in real time. The theory of management might be sound for FACD, but does it result in fewer problems and change orders? Does it reduce conflicts on the job? A good way of measuring these is to check the effects on change orders, since change orders are perceived to reflect flaws in the planning, design, or execution of a project. Typically, these change orders increase costs while delaying the completion of the project (Ehrenreich-Hansen, 1994). In addition, most contract claims are the result of disagreements over ambiguous or perceived changes from the original contract documents (Pepper, 1994). Thus, change orders are valid and logical dependent variables to check if FACD has worked.

CHANGE ORDER CATEGORIES

There are numerous causes of change orders. Nine codes used by the U. S. Navy to explain the reason for change orders are as follows (in alphabetical order):

CREQ	Customer/client requested change order
CRIT	Overall criteria change after construction has begun
DSGN	Design deficiency where the designer was not held liable
EROM	Design error or omission where the designer was held liable
LIQD	Liquidated damages assessed against the contractor
PLAN	Planned change; an additive bid item was executed
UNFO	Unforeseen condition encountered
UNIL	Unilateral change order where no agreement could be reached with contractor regarding price of the changed work
VALE	Contractor initiated value engineering change (contractor receives 55% of savings.)

DATA COLLECTION FOR COMPARISON BETWEEN FACD AND NON-FACD PROJECTS

To make a reasonable and statistically valid comparison between FACD and non-FACD projects, it is necessary to compare only projects that had similar attributes. In the analysis of their relative performance, we are able to ensure that any differences are accounted for solely by the FACD/non-FACD treatment and that there is no other management influence on the differences. The similar attributes were:

1. Projects did not utilise partnering and were firm-fixed price bids.
2. Projects did not utilise any other dispute resolution method such as DRBs.
3. Projects belong only to the US Navy Corps of Engineers at Pearl Harbor.
4. Projects of size less than $25 million only were considered.
5. All projects have been constructed in the period 1992-97, so they are contemporary.

EMPIRICAL COMPARISONS BETWEEN FACD AND NON-FACD DESIGNS

Critical results of time and cost performance are given in Table 1. In themselves, the numbers in Table 1 represent a substantial shift in time and cost performance, signaling that the use of FACD facilitates better time and cost performance.

Table 1: Basic Time and Cost Comparisons between FACD and non-FACD Projects

ITEM	FACD PROJECTS (n = 8)	NON-FACD PROJECTS (n=10)
Increase in cost of change orders from original contract award amount	2.19%	18.75%
Increase in project duration compared to original contract completion date	27.7%	49.1%

EMPIRICAL COMPARISONS IN CHANGE ORDER TRENDS

Whereas time and cost reductions are experienced, does FACD change the type of change orders that are affected? In other words, does FACD shuffle the trend of change order categories? Table 2 illustrates the major impacted change orders (Singh and Stocks, 1997; Stocks and Singh, 1999).

Table 2. Change in Award Amount (%) between FACD and non-FACD Projects

CHANGE ORDER CODE	NON-FACD	RANK	FACD	RANK
EROM	0.00	9	0.04	5
UNIL	0.23	6	0.00	7
DSGN	3.03	2	0.34	3
CREQ	0.74	4	0.76	2
UNFO	12.70	1	1.25	1
CRIT	2.45	3	0.02	6
VALE	-0.38	5	-0.23	4
PLAN	0.01	8	0.00	7
LIQD	-0.04	7	0.00	7

This shows that three types of change orders -- UNIL, PLAN, and LIQD -- are completely eliminated in FACD projects. Obviously, this simplifies project management since the number of change order variables being handled reduced.

UNFO remains the largest contributor to change orders. Design errors and omissions still take place (DSGN + EROM), but to a lesser degree. The only reason that customer originated requests (CREQ) increase is not because they are necessary, but because the customers find that value engineering and FACD have released large amounts of money for them for use elsewhere. The customers find they have an opportunity to spend this money for additional bells and whistles on their facility.

There is also a mentionable increase in the rank of contractor initiated change orders, VALE, from position 5 to 4. The contractor thus participates more in the overall price reduction effort, contributed largely by the encouragement he receives from improved contract documentation on the project.

STATISTICAL TESTING

Analysis of Variance

The hypothesis developed states that there is no significant difference in the sample means for the change order codes by use of the FACD design process compared to the non-FACD process. Table 3 identifies the test results and the confidence level of being able to reject the hypothesis. For the comparison, ten non-FACD projects were compared to eight FACD projects. The percent changes to award amount contributed by the change order code for all projects were the data compared.

The UNFO reason code (the code having the greatest influence) and the overall change order rate both have significance at more than ninety percent confidence, and therefore serve to reject the hypothesis at the ten percent level. This proves that the reduction in two of the *most important* change order variables -- the overall change order rate and UNFO -- is not due to chance and can therefore be attributed to the use of the FACD process, thereby proving that FACD is indeed beneficial and useful from a cost perspective.

Student t-Test

In this case, the t-test is used to determine the probability of various FACD project change order code means being less than non-FACD project change order code means. The results of this test overwhelmingly support the finding that FACD designed contracts change order code changes and overall change order rate will have means less than non-FACD contracts' reason code changes (Stocks and Singh, 1999). For instance, it was confirmed that there is greater than 99.5% chance that the FACD means of percent increase to award amount will be less than the non-FACD means for UNIL, DSGN, UNFO, CRIT, PLAN, and LIQD. For OVERALL CHANGE ORDER INCREASE and INCREASE IN CONTRACT COMPLETION DATE there is 100% chance that means will be significantly less (Table 3). The foregoing proves that FACD is an advantageous project management technique.

Table 3: ANOVA and t-TESTS

CHANGE ORDER CODE	CONFIDENCE LEVEL TO REJECT HYPOTHESIS IN ANOVA (%)	CONFIDENCE LEVEL THAT FACD MEAN < NON-FACD MEAN BY t-TEST (%)
EROM	72.4	15.9
UNIL	67.8	100.0
DSGN	50.4	99.5
CREQ	57.1	18.9
UNFO	94.3	100.0
CRIT	79.3	100.0
VALE	23.0	83.7
PLAN	60.3	100.0
LIQD	60.3	100.0
Overall Change Order Rate	94.6	100.0
Days Delayed	63.0	100.0

CONCLUSIONS

Though it may take some time for the FACD project management technique to become prevalent in construction management, there is no doubt that it saves money. This is borne out by the empirical and statistical tests undertaken. It was clearly seen that the overall change order rate for FACD projects was reduced from 18.75 for non-FACD projects to 2.19 percent. To ensure that this large reduction was not due to chance, both ANOVA and t statistic tests were performed, both of which overwhelmingly support the notion that the FACD process has significantly reduced the overall construction contract change order rate and completion delays.

There are no costs to introduce FACD, but there are cost savings. FACD is able to prevent costly re-designs. Customer satisfaction is greatly enhanced; this is evident by the fact that they have spare money to add bells and whistles for their facility. It is thus recommended to seriously consider the use of FACD in all important construction projects. FACD promises to be an important management technique in the next millennium.

Thus, FACD is a process that is recommended for every significant construction project, where cost overruns are a concern, where customer requirements are stringent, where value is desired for money, or where conflicts are desired to be mitigated. The applications here for developing countries are apparent and clearly indicated, since there is a lot that can be done in developing countries to adopt suitable technologies.

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Changing Construction Procurement for the Millennium

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Abstract

As the millennium approaches it prompts researchers and practitioners to consider what type and structure of construction industry is most appropriate to meet the challenges posed by market driven economies. Client demands are responding more rapidly to changing organisational and market imperatives. Creative and innovative solutions are expected from client-based advisers and consultants, from within and outside the construction industry. Previous research conducted by the authors in several client organisations at the project initiation (pre-design) stage, indicate that typically, a building is not necessarily the only, or best solution. It is contended that these trends have implications for the nature and workload of the construction industry in developed and developing countries alike. The authors review the past, consider present trends and suggest the effect such directions may have on the construction industry in developed and developing economies.

Keywords: *Construction industry; characteristics; project initiation.*

INTRODUCTION

Before we make projections about the kind of industry we may have in the new millennium, it is useful to review how today's construction has evolved. With this in mind, the framework for this paper is a 100-year time span. As the authors are most familiar with the Australian and UK industries, their trends and characteristics will be described. The chosen time frame for this paper's analysis is *1949* for the past, *1999* for the present and *2049* for the future. These dates have been carefully chosen because none of the authors are likely to be around to test whether their predictions in this paper turn out to be correct! This paper focuses on the building industry part of the construction industry. It does not consider the civil engineering/infrastructure component of the construction industry. Needless to say, this is an equally important sector that cannot be ignored in any comprehensive analysis of the construction industry. The authors' analysis of the building industry for each era is based on six distinctive features (that are certainly not exhaustive) which overlap in practice. However, they are considered to be useful categories to highlight and to trace the industry's changing characteristics over time:

- client involvement;
- procurement methods;
- project organisation;
- construction firms;
- construction methods; and
- education.

THE NOSTALGIC PAST – 1949

Stability and a lack of structural change characterized the construction industry during this era. Building firms enjoyed post-war expansion due to rebuilding, capital investment catch-up and increasing levels of immigration, which provided economic buoyancy. Materials supplies were a problem as a result of the Korean War.

The culture of the professions, companies and the industry was generally paternal, hierarchical and conservative. Demands for change and greater efficiency began to emerge, particularly in the UK as a result of numerous published Government reports (HMSO, 1944, 1950). Clients were led by their design team and were not encouraged to become involved to a significant degree in the decision-making processes of design and construction. The Government (State, Federal/Central, and Local) and Statutory Authorities were the industries' major clients with projects in health, public housing, welfare, utilities and education. Public expenditure often represented more than half the demand for construction.

The design team largely decided the product of the design and construction process and most clients generally accepted what they were given. The type of procurement methods were decided by the architect, possibly in consultation with the quantity surveyor, and most often, traditional methods were preferred (Gray *et al.*, 1994). For example, lump sum forms such as specification/drawings, bills of quantities/drawings and schedules of rates were often preferred. Such methods also tended to reinforce the division of the professions in design and the trades in construction. Alternative forms, such as design and build were rarely used and were considered a novelty rather than a mainstream choice.

In project organisation, the architect and engineer dominated. The architect clearly led the design team acting on behalf of the client. The professions of architecture, engineering (structural, mechanical, and electrical) and quantity surveying had become entrenched and based on narrow, distinct specialisations. The hierarchical structure with the architect at the apex of the pyramid typically dominated government and private sector projects. The educational system replicated the separation and distinct education and training of the professions and the trades.

In site activities, most of the finished work used labor-intensive site-based construction techniques based on materials delivered to site. These materials, often in loose form, are assembled and prepared for installation into the works by the traditional trades. With the exception of city centre projects, construction methods have evolved slowly and were largely based on forms of construction that had been used for decades. Unions gained strength in the manufacturing sector, and this was duplicated in the various building trades. The scene was set for the protection of designated trade activities, leading to labor disputes caused by demarcation of trades. Project duration times and costs became endemic features of the industry. (For a comparison of the past and present construction industries refer to Table 1).

THE VOLATILE PRESENT – 1999

The present day construction industry is characterized by the need to cope with change. Greater demands from clients for a better quality of building product delivered on time and within budget are now part of the construction service ethos. The time, cost and quality triumvirate now dominates the industry. However, this stage has not been reached without some pain and the industry still has a long way to go before many clients are satisfied with its performance. Reports on the construction industry have been critical, regular and too often, ignored (e.g., HMSO, 1962; 1964, 1965; National Economic Development Council, 1964, 1975,1978, 1983, 1985, 1987; Latham, 1994; Egan, 1998). These reports have all stressed the need for change, greater efficiency and a stronger client focus in the construction industry.

Table 1 Comparison of past and present construction industries

Features of Industry	*1949 (PAST)*	*1999 (PRESENT)*
1.Client Involvement	• Not encouraged • Lead by design team • Government a significant client	• Closer involvement with client, the key driver of change • Clients with financial and organisational advisers focussed on cost, time and quality • Project initiation and briefing receiving more attention • Government less significant client
2. Procurement Methods	• Lump sum traditional • (Specification/Drawings; Bills of Quantities; Schedule of rates) • Separation of design and construction	• Traditional procurement methods losing ground • More design-build, novation, management contracts • Alternative integrated arrangements expanding
3. Project Organization	• Architect and engineer dominate • Architect leader of design team • Narrow professionalism • Designers determine client's problem	• Project managers leading the design team and delivering client needs in cost, time and quality • Specialist consultant roles expanding • Design seen as a service • Growth of value management, and facilities management.
4. Construction Firms	• Paternal, hierarchical, accepting of design team authority, not pro-active for change • Poor financial management skills with high levels of bankruptcy	• Companies leaner and more competitive • A more professional attitude toward marketing • Financial base improved to satisfy client demand • Improved cash flow and claims management
5. Construction Methods	• Site based and traditional • Traditional craft trades dominate • Low levels of technology and industrialization • Unions gaining strength • No builder registration	• More off site activities, methods and components • Enterprise bargaining at national and local levels • Buildability, time and cost, prime factors for consideration • Increased use of management techniques
6. Education	• Separation of disciplines and trades	• Multi-skilling in trades • Emergence of joint education programmes for designers and construction managers

The industry is still plagued with problems, despite the emergence of alternative forms of procurement, value management, partnering and the like. The industry must address its problems if its aim is to become an efficient, effective provider of capital works to the economy. The problems that confront today's industry include:

- separation of design development from the realities of construction practice. This inherent weakness contributes to a lack of practical design solutions and to separate groups whose aims rarely seem to merge;
- inefficient organisation of sub-contractors. The large number of small building and sub-contracting firms makes it difficult to achieve a comprehensive and unified approach to improving performance and efficiency within the industry;
- patterns of conflict seem to characterise relations in the industry. Contracts are based on adversarial relationships, not co-operation and the sharing of joint objectives. As a consequence, the client's needs are often lost in inter-organizational rivalry, which seems to contribute little to the projects' outcome. Too often, there appears to be little cohesion between project and construction team members;

- contractors have a poor image based upon illegal and collusive tendering practices, bribery, and corrupt work practices, which are far too prevalent for the general public to hold the industry in high esteem (Gyles, 1992);
- inefficient and outdated practices tend to reduce the potential for improvements in productivity.
- a poor quality finished product. Quality assurance programs may be established, but are not properly implemented. In fact, they may be implemented without the full commitment of employees;
- delays caused by factors which are within the control of the design and construction teams and should not occur;
- poor risk management assessment and management strategies;
- low profit margins with unrealistically low bid tendering. Competition is often on cost alone rather than quality that can be delivered. Similarly, commercial behavior is dominated by the need to maintain cash flow, which puts financial pressure on suppliers, subcontractors and the client;
- poor marketing and client relations. Lack of attention to public concerns of noise, nuisance, danger and generally poor public relations; and
- pre-qualification of tenderers is expanding, but issues of *contestability* need to be safeguarded (Construction Industry Development Agency, 1993b).

The construction industry has been forced to change because the economic, social, financial and political/legislative environments (of which it is an important part) have demanded it. Fundamental reorientation has forced, and is still forcing change. Government-sponsored change through the establishment of construction industry agencies is apparent in Australia, Singapore and the UK. A primary reason for these changes has been the incessant drive for more efficiency and greater competition, nationally and internationally. No industry can insulate itself from change by pleading they are different. Clients, private and public, are now the key catalysts for transformation of the industry.

In this turbulent construction environment, clients have forced major structural and procedural changes on the industry through the increased use of alternative procurement methods (such as design and construct, and novation), integrated project management teams, partnering, benchmarking, re-engineering, and many other developments. In fact, it is surprising that it has taken so long for the supremacy of client needs to be fully recognized by many of the industry’s professionals. The subdivision of services, developed as a result of history rather than as a response to client needs, seems to be changing rapidly. Clients naturally have no interest in the traditional division of the construction disciplines within a conventional procurement method where it is obviously not satisfying their needs (Love *et al*., 1998).

These client pressures have led to a major reorientation of design and construction services within our industry that will have a permanent and lasting impact on the way we service clients. Whilst design, project management, cost control, quality control, planning, competitive tendering and contractor selection are enduring activities in construction, the means of delivering them are many and varied and subject to rapid and continuing change. The modern construction adviser must be aware of these trends and be prepared to adapt in this volatile and demanding environment. Rapid change and greater demands for accountability and high quality building supported by rigorously applied professional and construction services will be the standard operating construction climate for the foreseeable future (Smith, 1998).

THE CHALLENGING FUTURE: THE PRESENT (1999) TO 2049 AND BEYOND

In Australia, the National Public Works Conference (1990), Construction Industry Development Agency (1993a, 1995) and in the UK, Latham (1994) and Egan (1998) have urged everyone in the construction industry to bring in their performance with higher levels of productivity and efficiency. In fact, the manufacturing industry has provided the model for many of the changes and innovations. Improvements have already been made in the following areas:

- multi-skilling of the trades, so that demarcation disputes between unions and trades are reduced;
- integrated approaches to design and construction services for clients;
- improved education of construction managers and practitioners including, for example, integrated courses and problem-based learning;
- pre-qualification criteria for consultants, contractors and sub-contractors adopted on many projects by federal and state governments and by a large number of private sector clients;
- minimum standards for registration and business operations;
- adoption of benchmarking for productivity and Australian Standards in Quality Management and documentation;
- strategic alliances, strategic and project partnering have been adopted by public and private sector clients establishing longer term relationships between client and contractor to the benefit of both parties;
- improved marketing of construction services, especially by the large contractors;
- improved penetration of overseas markets, principally those in the Asian region and Europe; and
- concurrent engineering, lean construction, supply chain management and re-engineering of processes now firmly established in the manufacturing sector have permeated the construction industry and are now becoming part of its approach to process improvement.

The situation is certainly improving, but there is a long way to go and more effort is required. Also in recent years trends towards *best practice, benchmarking, quality assurance* and *re-engineering* have influenced the construction industry through the manufacturing sector. However, a great hindrance to progress on many of these fronts is the disparate nature of the industry caused by the large number of small firms. This is a characteristic not likely to change greatly in the future. The registration of all building firms is now firmly established in Victoria, Australia (Building Control Commission) and is likely to become standard in the future. This represents now and the immediate future, but what are likely to be the major changes over the next few decades?

Change will occur on many fronts. The use of information technology in the management of the design and construction process will continue unabated. Success is more likely in smaller parts of the system, rather than the grand vision of a fully functioning comprehensive information management system for design and construction. The lack of progress here should not be a cause for alarm because in the next millenium, as through all previous ages, the social systems will always lag behind the technological systems we create. Or as Bennett (1986) puts it, we will tend to overestimate social change and underestimate technological advancement.

The primacy of client needs will continue and not abate. Servicing client needs will pervade the design and construction service. Since space does not permit a comprehensive analysis of the features noted earlier, the authors wish to concentrate on two areas in the pre-construction stages because we believe these areas will change the most in the decades following the turn of the millenium. These are:

- project initiation; and
- design management/design and build.

Project Initiation

The authors have conducted research and practice studies using *Strategic Needs Analysis* into the pre-design or project initiation stage of a project, working closely with the client on developing strategies for solving perceived problems (Smith *et al*., 1998; Smith and Jackson, 1998). The technique attempts to understand the client's reasons for requiring new facilities. It asks fundamental questions regarding the present way an organization carries out its activities. The technique does not accept that a built solution is the standard answer and reviews the strategic case for solving the problem identified by the client. A range of solutions or options may be developed, some of which may involve a built solution. The process of working through the project initiation stages is shown schematically in Figure 1. In fact, the process emphasizes that clients need sound guidance with this crucial first step in the process.

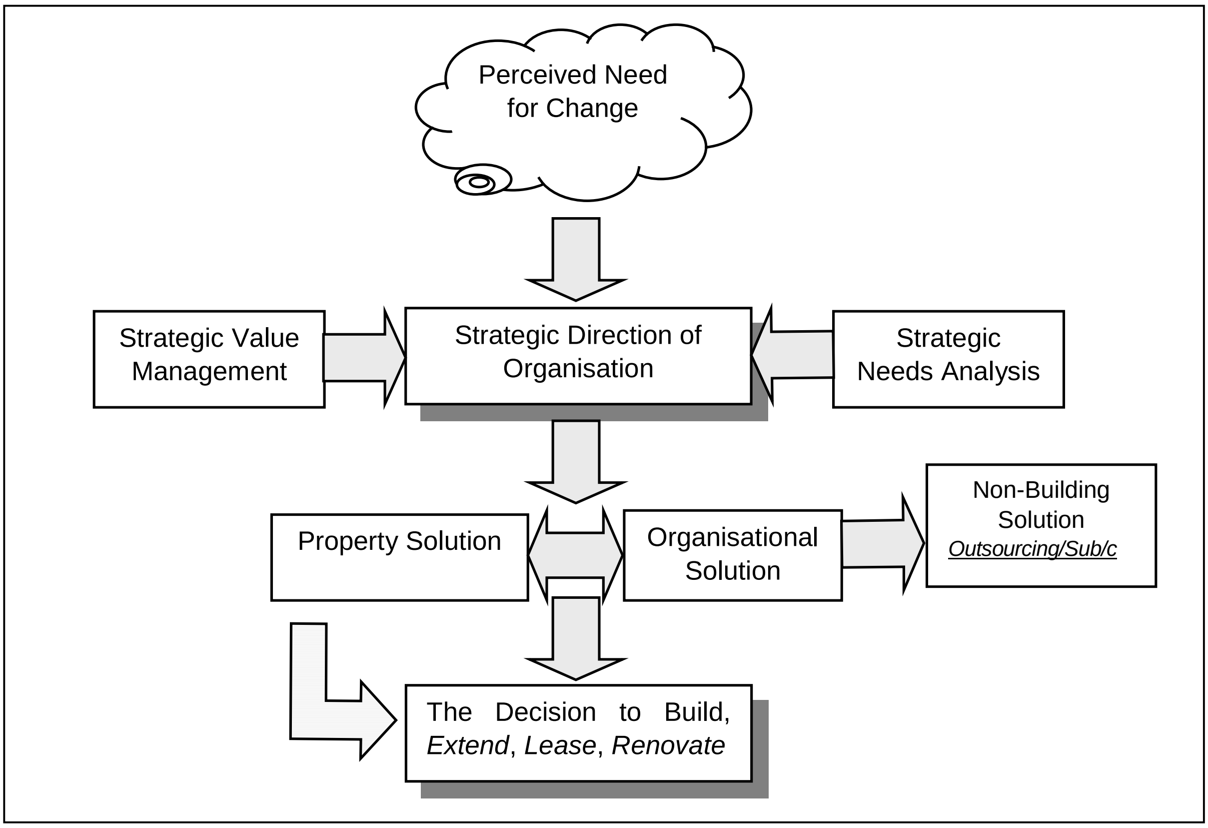

Figure 1: Pre-briefing (Project Initiation) Stages

The implications for the construction industry are that increasingly solutions at this strategic level may not involve the client in constructing a building. As a result, the demand for new building, particularly, may decrease and we may have less underused facilities in the community. Solutions involving reorganization may involve *refurbishment*, *renovation*, *extension* and possibly *new build*. Alternative process location solutions from *outsourcing*, *sub-contracting* or deletion of the process may lead to downsizing and loss of facilities rather than expansion. An important dynamic in considering opportunities as well as a solution is the effect of telecommunications and information technology. Many processes and procedures are changing beyond recognition, becoming redundant or whose use is being questioned. Whilst we cannot predict with certainty which processes will change, we do know that the effect of technology will be incessant and pervasive. Clients and their strategists have to be sufficiently aware to maintain the flexibility and adaptability of the organization to respond to market forces and innovation. Buildings must also be designed to be flexible and adaptable to meet these changes.

The construction industry and specifically the design team can play a valuable role in the project initiation stage. Most clients will require advisers who know about built solutions. It is essential that the design of these facilities reflect the real immediate and future needs of clients. The *project advisers*, as Latham (1994) called them, must understand the client's business case intimately. However, it is essential that these advisers have no further involvement beyond this initial stage, so they will not be influenced in the chosen strategic option. These advisers may arise out of the design professions, but a trend towards using trained facilitators from business and financial backgrounds is emerging. The possible lack of specialised knowledge of buildings and facilities in these advisers does not appear to influence clients in their appointment. Thus, the design teams of the future may probably be competing with business management and financial services consultants for this initial work and many design teams may in the future find themselves part of these national and international companies.

Integrated Procurement Forms and Design Management

Poor design management is a primary factor that contributes to poor quality (Love *et al.,* 1999) and time cost overruns in projects (Chan and Kumaraswamy, 1997). Such poor quality and time and costs overruns is often attributed to poor contract documentation and communication practices between design team members and the contractors. This invariably results in claims (Love *et al*., 1998b; Yogeswaran *et al*., 1997). To improve the effectiveness of the design and construction process and break down the traditional barriers that exist between designers and constructors, integrated forms of procurement based on the principles of concurrent engineering (CE) have been advocated (Love and Gunasekaran, 1997). According to Love *et al*. (1998c), CE-based novation could be the most effective form of procurement method in the near future as it promotes cooperation and collaboration between project participants from the outset of a project. Moreover, with the assistance of the client's and project advisor's involvement during design development the project team can jointly develop the project's goals and objectives. This can be developed further through the initiation of partnering between the contractor and the design consultants during the production process on being novated to the contractor. At the moment advances in information technology (IT) can be used to support virtual project organisations. However, the problem that construction faces is not technological by any means but organisational and cultural. Thus, it is envisaged that with a CE procurement strategy and effective design management the problems that construction currently encounters (in 1999) may be significantly reduced.

Design management is already emerging as a specialist field. The function of creative design appears to be separating from the management of the design process, simply because the production of contract documentation is a critical function contributing to the achievement of project cost, time and quality criteria. Clients are selecting the design-build procurement method and variations of this *one-stop* all-in service will expand and include more financial packages than currently on offer (in 1999). Design team services, like their construction counterparts, will be in the form of specialist sub-contract services under the management umbrella of the design-build contractor.

CONCLUSION

The authors are aware that the prediction business is an expanding profession as the complexity of modern life overwhelms most of us. We turn to an *expert* who simplifies this complexity and tells us what to do. More often than not the expert is as wrong or as lucky as the gambler on a horse race. Similarly, we are more likely to be totally wrong in our predictions in this paper, but it a useful exercise in thinking about the future and shaping it rather than allowing it to overwhelm or control us.

Noteworthy is the apocryphal story from about the turn of this century, when the transport adviser to the London City Council warned the city managers that if nothing was done to curb the numbers of horse drawn carriages on London streets then the citizens would be neck deep in horse manure in the immediate future! Thus, the prediction business has to be treated with a little bit of healthy scepticism.

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Contrasting Perceptions: A study of entry barriers to participation in public works contracting by micro enterprises in India and Pakistan

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Abstract

There is growing interest in encouraging private sector involvement in the construction and maintenance of public works in developing countries, and a preference to involve micro-enterprises in this work so as to achieve economic benefits and enhanced local employment for the poor. However, the administrative and procedural requirements of the public sector act as barriers for many small-scale contractors and hence discourage their participation in the procurement process. Whilst most clients and most contractors agree with this proposition in principle, their perception of the nature of the barriers and the practicality of their removal are likely to differ.

This paper describes the results of practical research carried out in conjunction with the Karachi Metropolitan Corporation and the Pakistan Public Works Department, and a range of Indian officials from public works departments, coupled with a questionnaire survey and direct interviews with proprietors of micro-enterprises. The study reveals the contrasting perceptions of contractors and clients' representatives, and concludes that clients are sometimes excessively concerned with eliminating risks that are not particularly serious in the context of a highly competitive environment with relatively large programmes executed through small contracts by large numbers of very small enterprises.

Keywords: *construction industry development, small-scale contractors.*

INTRODUCTION

Effective and efficient infrastructure procurement is essential if construction industry performance is to be improved, and there is usually scope to involve micro-enterprises (very small businesses operating on the verge of the formal and informal sectors, usually sole proprietors) in this work so as to achieve economic benefits and enhanced local employment for the urban poor (Edmonds and Miles 1984, Sohail 1997). Furthermore, small enterprises have been widely assumed to offer significant development potential (Young 1993). In most developing countries the public sector is the predominant client for urban infrastructure work; hence it is essential to understand its procedures and requirements and examine how it encourages or obstructs the participation of small-scale contractors both directly and indirectly as formal or informal sub-contractors to larger firms. Whilst most public-sector clients accept in principle that micro-contractors should be enabled to compete fairly for work, they may be complacent regarding the working of the established system and it appeared likely that micro-contractors might have a different perception.

This paper draws on a survey of 25 contractors who undertake work for the Karachi Metropolitan Corporation (KMC), which is the municipal authority for the largest city of Pakistan with a population of 10 million, and compares and contrasts their views with the views of construction clients. The municipal system in Karachi has undergone many changes due to the politically unstable situation in the last five years. The administrative system has two tiers. A metropolitan corporation was set up in 1988 along with the four zonal committees in four districts; Central, East, West and South. The Mayor is elected by the councillors from each local area, and is the chief executive of the corporation. The local councils have the powers to levy taxes. The salient compulsory functions of the corporation include provision and maintenance of urban infrastructure including water and sanitation, drainage, street lighting and solid waste management.

A parallel study examined practices in the Pakistan Public Works Department (PWD), which is a public sector organisation involved in procuring works on behalf of the central government. It regularly produces documentation including recommended procedures, a schedule of rates and standard specifications. Its procedures have influenced almost all the pubic sector organisations, including quasi-government organisations. Another interesting aspect is that the PWD procedures are similar to the works procedures used in India due to the common inherited legal framework.

Based on the study of departmental practices in PWD the key issues were identified and some of those were further explored in the survey, which related mainly to the contracts used in routine procurement. The advice provided in the standard texts for survey research (Fink and Kosecoff 1985) was followed. Purposive sampling was used to get the basic information related to the procurement process and the perception of the stakeholders involved. The questionnaire was intended to:

1. Cross-check the awareness of the respondents regarding the procedural issues with the information gathered by the initial review of documents.
2. Obtain base line factual information.
3. Explore the perception of the respondents with respect to the contractual procedures in routine procurement and community-participated procurement.

Client responses included four KMC officials, five KMC consultants, one official from the Sindh Katchi Abadi Authority (a provincial level authority responsible for the development of squatter and informal settlements and negotiating with municipalities and other urban authorities) and 18 Indian officials from public works departments. Although the contractor respondents were all from Pakistan and the client respondents were from both India and Pakistan, the views of Indian and Pakistani client representatives were largely similar and the experience of the authors suggests that the views of Indian and Pakistani micro-contractors would also be similar.

Both correspondence and face-to-face meetings were used to obtain the views of officials and consultants, but the 25 micro-contractors were all interviewed. Two assistants were employed to trace and interview the contractors. It was quite difficult to reach these respondents as many have no permanent office, and most have little time to spare due to the exigencies of their businesses with a need to attend personally to such tasks as purchasing, hiring of labour, and organizing their sites. Basically the contact point was the office from where they obtain work. The surveys were completed by the beginning of 1995. In total 53 questionnaires were completed by the respondents (25 by contractors and 28 by clients/consultants).

PERCEPTION OF MICRO-CONTRACTORS

Table 1 provides a summary of the key findings of the survey of the organisations and people involved as micro-contractors in the procurement of infrastructure at the tertiary level of infrastructure procurement. The study also indicates the benchmarks or the requirements to become a micro-contractor in a local urban government department. The survey also provides an overview of people acting as micro-contractors in the procurement of infrastructure in an urban local authority. It is notable that these micro-contractors are not very well equipped, but are well experienced. They have also demonstrated their capacities to meet the procedural requirements, and have good connections in the market to fill in the gaps as far as the logistics are concerned. They possess basic business survival skills including how to get registered, get enlisted in the department, open a bank account and deal with the public sector. They are, in short, small entrepreneurs. They could act as a model for any newcomers in the contracting business including the community groups.

PERCEPTION OF OFFICIALS AND CONSULTANTS

In the procurement process, the key stakeholders include the officials of the client organisation, their consultants and the small scale enterprises who bid for work (although it is rare in public sector departments in the study countries to hire an independent consultant for micro-contracts). The outcome of the questionnaire survey of the client and consultants representatives is summarised in Table 2. The respondents were selected from typical urban local organisations. Some very basic questions were asked from the officials to see if they are aware of the procedural issues and to corroborate the finding from the document reviews and interviews. Non-parametric tests were run to see the goodness of fit. The non-parametric tests were considered to be relevant as they do not require certain assumptions required by parametric tests (Siegel 1956). The tests are particularly useful when dealing with relatively small samples. The significance level was set at 0.05.

REGISTRATION - THE CLIENT'S VIEW

The public sector requires its contractors to be of demonstrable legal status. In general, some sort of registration as a company or as a registered co-operative society is required. The firm can enter into a contract with the public sector as a registered organisation, company or society to undertake commercial or non-profit based activities. The registration is generally done by the registrar at district level. The registration has its own requirements and a set procedure. This registration is different from the registration with a department as a contractor. Later the contractor may be registered with the concerned department to undertake a certain class of work. In some relatively large projects there is an additional requirement that the contractor has to be pre-qualified. When pre-qualification is used the restriction of being registered with the department is generally waived.

Sureties are used to provide an additional safety net for the client. An evaluation of the capacities of the contractor is generally done to ascertain that the contractor is capable of undertaking the work. In some cases this review takes place simultaneously with the price offer, but generally it is done before the offers are invited. In some cases only documentary evidence is required but in other cases interviews are also held to ensure that the contractor can give a responsive and reasonable offer to carry out the work. Documentation could take the form of the audited balance sheets for three years as evidence of financial stability. The criteria clearly favour the established commercial contractor. The underlying question which needs to be answered satisfactorily before the contract is awarded is 'can the contractor perform successfully?

The message that the contractor evaluation is important to predict contractor failure is quite clear. The methods used are prequalification and surety bonds or both. The time spent in evaluation is seen as worthwhile in terms of the benefits of reducing the risk of problem contracts. However, when tackling the three questions of how to do it, what factors are to be considered, and which among the long list of the factors are truly significant, the feeling is that the process is still an art rather than an exact science. Sophisticated techniques have been used but the basic assumptions have not been challenged.
Routine procurement of infrastructure requires certain conditions to be met by the potential contractors. The following section explores the perception of the contractors who have gone through the enlistment process. The micro-contractors were asked to identify the factors which they think were instrumental in getting them enlisted in the to public sector organisation. Some of the factors were quite sensitive and the contractors were assured of their anonymity. A set of factors was provided with an option to add any factor if they so wished.

Table 1: The Procurement Process: Perception of micro-contractors.

Statements	***Agreed by (%)***	***Comments***
The contractors have one or two levels of organisation. The numbers of permanent staff, including managerial personnel, are 0-3.	84	In small firms, the chain of command does not go beyond two levels, with few (if any) permanent staff. This supports the findings that sub-contracting is more common than formally permitted.
The contractors have no geographical preferences to work.	96	Contractors are willing to bid wherever the work comes up in the city. There are many divisions in a city and contractors have no preference for a particular division. The contractors are quite small but have capacities to go beyond one division.
Contractors do not own plant and machinery but own tools and simple equipment.	84	This is quite interesting as on paper it is one of the factors or criteria of enlisting the contractor in a department, but in practice it is clearly not enforced. This response also suggests that some of the requirements could be relaxed since much of the work is not of a nature which requires mechanization.
Facilities for hiring tools and plant are available.	100	It adds to the flexibility of the organisations, since it lowers capital investments and overheads. The rental charges could be charged to the project directly.
There is no facility for institutional loans.	100	Formal credit is not available to micro-contractors even if they are registered. They must rely on informal finance or private resources.
They have bank accounts.	100	This is a necessary condition. A bank account would be required from a community group if they want to become a micro-contractor of the local public sector.
They are registered and enlisted with a governmental organisation.	100	Also a necessary condition.
The majority contractors have 4-6 years experience	60	The micro-contractors have experience of many years of work. This again is something that would be expected from any newcomer in the procurement process.
The annual turnover of the micro-contractor does not exceed RS 1.0 million. The most frequent range of turnover is RS 0.5 to 1.0 million [Exchange rate approximately US$1= RS 50].	84 52	If a micro-contractor could get contracts of RS 1.0 million, assuming the profit margin of 20% the monthly income comes out to be around RS 16666. This is a quite acceptable income for a micro-contractor, and micro-contracting is seen as a good source of income.
No verbal contracts were used - all the contracts were written.	100	In the informal sector and in many community groups written contracts are not used. This again is something that would be required from the community groups.
The contractors also act as a sub-contractor.	64	The role of micro-contracting is not restricted to micro-contracts. This also highlights the frequent use of sub-contracts and indirect entry of relatively smaller contractors into the process of large contracting.
Getting private-sector work is easier than public-sector work.	96	This indicates that in the public sector there may be complex procedural requirements.
The majority of contractors have the capacity to undertake the works not exceeding RS 500000 at one time.	60	This indicates the financial and managerial capacities of the micro-contractors to handle the contracts.
The majority of contractors perceive work costing more than Rs.25,000 as of minor nature.	80	This highlights the relative nature of the meaning of the term ‘minor work.'

Table 2: The Procurement Process: Perception of officials and consultants

Statement	***greed by (%)***	***Comments***
More than 60% of the infrastructure development budget is contracted out.	74	Contracting is perceived to be the main method of procurement. This correlates with the literature and document review.
Managing one contract is easier than dividing it into smaller packages.	74	Preference for dealing with a single party has the implication of using large main contractors.
Small scale contracting is beneficial to the local community.	81	Communities have a better chance to benefit from small scale contracts (only one respondent had experience of working with a community contractor).
Most (75-100%) of the work is repetitive in nature.	87	The work is standard, hence risks are lower since small contractors will be competitive in simple routine tasks.
A significant share of the work (up to 50%) is sub-contracted by the selected contractor.	78	This occurs even where sub-contracting is not formally permitted. Sub-contracting is common even in small-scale contracting. The officials know and accept it. The implication is that this mechanism must have some appeal to all the parties concerned. Another implication is that the 'real' contractor is the sub-contractor who does not have a direct contractual link with the public sector and is effectively denied access to the procurement process. It also indicates an avenue which could be explored by community groups.
The work cannot be awarded without competition.	81	The perception of the majority of respondents is that competitive bidding is the only acceptable method for awarding contracts.
A bid bond is essential even small scale contracts.	82	The perception is that financial surety is vital, even where risk is minimal (as is often the case with micro contracts).
A security deposit is essential even for small-scale contracts	89	Even where the bills are paid in arrears the security deposit is considered to be critical.
All micro contracts are in the range of 0-2 million rupees.	100	Fairly small contracts. The concept of micro contracts covers the bulk of contracts used in the procurement of urban infrastructure.
At least 50% of the local contractors are involved in government works.	78	The perception is that the public sector is a major client in construction.
Proportions of contracts are completed on time are: 0-30% 70-90%	 26 39	There is no clear message about the time performance. The implication is that as many as 70% of the contracts may have time overruns. This indicates a very inferior time performance as compared to the cost performance.

Source: Questionnaire Survey

Table 3: Who is allowed to bid for public sector work? - The client's view

Response	***Commentary***
1. The Engineering Department operates a system whereby only those contractors who are enlisted can submit tenders	
2. The contractors are enlisted within a particular class, which specifies the financial limit of the works for which they are deemed competent to bid.	
3. The requirements of enlistment are to demonstrate capacity in terms of experience, financial credentials, tools and equipment owned and personnel employed.	• The requirements are demonstrated by submitting relevant documents.
4. The contractors are enlisted for a particular duration and are required to pay an enlistment fee.	
5. In general if a contractor is already working in one department it is relatively easy to work in another department. Conversely, if a contractor does not perform well in one department then he can be banned from other departments.	• Litigation against the department is one of the reasons for 'blacklisting' a contractor.
6. In large scale works, potential bidders are selected for the one project only; this process of prequalification is similar to that of enlistment.	

Source: Interviews and documents

Table 4: What administrative and financial demands are made on a contractor? - The client's view

Response	***Commentary***
1. Earnest money (2%-3% of the tender value) must be deposited. 2. A performance bond for small works may be required. A typical bond is 10% of the contract value and is released after the end of the defects liability period. 3. Insurance is not usually required for very small works. 4. On acceptance of the tender, the contractor has to deposit typically 10% of the tendered amount as security money with the department. This is inclusive of the earnest money already deposited. In some cases the money is deducted from the running bills. All money is released at the end of the defect liability period. 5. Liquidated damages can be imposed if there is a serious time overrun.	• For a micro-contractor this could be an additional financial burden. • There is no recourse to easy and fast compensation in case of an accident. • No study has been carried out on the frequencies of accidents or claims for small works. • These demands have high associated costs which may reach over 25%; this can create serious problems in arranging finance. • The ultimate cost of this is borne by the client; it is reflected in the tender prices. • Generally used as a bargaining tool. Actual incidences of imposition are rare.

Source: Interviews and documents

REGISTRATION - THE CONTRACTOR'S VIEW

The clients and consultants see the game of contracting as akin to the game of cricket, with established rules and procedures, independent umpires and a broad commitment to 'sportsmanship' - not to mention a level playing field. The contractors saw things rather differently, and the game seems to them more akin to poker, and sometimes poker played with marked cards! From their point of view, becoming enlisted in a public sector department is at best a complex process. It is seen as neither so simple nor so unbiased as some of the official documents report it to be. The factors considered important in getting access to the public sector works are shown in Table 5, and the responses were categorized in the four alternative categories of 'very often', 'often', 'occasionally' or 'never' important (the percentage figures refer to the individual or grouped responses in column 2).

Table 5: Who is allowed to bid for public sector work? - The contractor's view

Factors	***Response***	***%***	***Comments***
Reading notices of tenders or prequalifications.	Very Often	100	It triangulates with the documentary evidence that there is a set procedure for the enlistment
Technical competency of the contractors.	Very Often/ Often	88	Generally seen as being of importance
Managerial competency of the contractors	Very Often/ Often	52	Fewer respondents perceived it to be important as compared to the technical competence.
Legal status of the contractor.	Very Often/ Often	80	Important.
Political background.	Occasionally/ Never	92	Only a few respondents perceived it to be important.
'Relations' with the officials.	Very often/ occasionally.	100	It was not reported by anyone as 'never'. It is generally seen as an important factor.
Experience of the contractor.	Occasionally/ Never	96	Interestingly, the contractors do not perceive experience to be important. The message is that having experience is not a guarantee to getting enlistment in the public sector. This view was completely denied by the officials.
Competency of the contractor's staff.	Often/ Occasionally	56	Again it is not seen as a critical factor.
Bribery.	Very Often/ Often	100	*Bribery is the factor perceived to be important by all*. This tells a lot about the working environment of the public sector. It is not just the factors which are written in the documents which govern the enlistment; others which are unwritten are seen (rightly or wrongly) as more important. This is the environment in which the community group needs to survive. Understanding what is not written is also important in understanding aspects of the procurement process.

Source: Questionnaire Survey

It is noteworthy that factors which are not mentioned by the client's representatives, and which (not surprisingly) do not feature in any of the documents, are perceived by key stakeholders to be so influential, for example bribery, politics and relationships with officials. Reading the notice board for tender, technical competency and experience are all important. It could be envisaged that any organisation wishing to enter into a legal contract with the public sector in the study organisation under the existing situation is expected to have the characteristics (and perhaps the attitudes) of these micro-contractors. How can community involvement be promoted in such a situation? Further research would be required through a pilot study of the processes where the community did participate in the procurement.

BIDDING AND CHOOSING

In practice, the criterion for selection of the contractor is normally the lowest bid. The lowest bid can be rejected but in practice this is seldom done. The argument put forward in support is that if the contractor has fulfilled the basic criteria that indicate capacity to give a reasonable and responsive bid, the only concern left is that of a mistake being made. The argument against the award to the lowest bid is that, if the bid is too low as compared to an estimate made by the professionals, then there is no way that the contractor could deliver the work to the quality specified.

On the other hand the competing contractors may know their market better than the professionals (including the level of quality and general performance which is normally accepted in practice). Different opinions exist. One solution could be to set a threshold below which any bid should be automatically rejected. Some think that this should be the Engineer’s estimate, some think that the average of the bids should be used and some have gone into detailed analysis after reference to a data base of similar bids. Although there are factors besides the cost that ought to be considered, current practice in South Asian local government is still the acceptance of the lowest bid given by the selected bidders.

In principle it can be argued that the market is the most objective means of determining the prices and hence the value of the work. But this implies a state of free competition. The form of competition that is routinely used is invitation of sealed bids. The sealed bid system is generally preferred since it is considered to be transparent and audit friendly. Professionals make estimates which are used as a basis for comparison, but the final contract value is determined by the offers received. In a form of modified competition the public sector may develop a schedule of rates which becomes the basis for all engineering estimates. Table 6 describes the typical basis of cost estimation.

Table 6: Cost Estimates and Market Rates

Response	***Commentary***
1. Government engineers prepare detailed cost estimates for technical sanction.	• This provides a standard basis for tendering
2. These estimates have to be based on the latest edition of a schedule of rates provided by the Public Works Department. 3. Provision is made for the schedule to be updated periodically; the problem is that this is a tedious and time-consuming process and in practice many years may elapse between updates.	• High construction cost inflation means that the estimates rapidly become unrealistic. • In one extreme case, the schedule of rates was over 15 years old, with tender prices coming in at many times the estimated value.
4. The cost estimates which are given technical sanction do not reflect the actual cost of procuring the works unless the schedule is up to date.	• These estimates serve no purpose in terms of managing the work for the contractor
5. The market rate for doing the work is therefore nearly always greater than the engineers’ cost estimate. 6. Prices tendered for work have to reflect market rates.	• If the actual cost of a contract increases beyond a certain limit then the approval process has to be repeated.

Source: Interviews and documents.

CONCLUSIONS

Conclusions from the research are set out under three broad headings.

Micro-contractors as business enterprises

- Micro-contractors competing for public-sector infrastructure work generally know how to satisfy the procedural requirements.
- Most of them are sole proprietors.
- They do not own the plant and equipment as required by the procedures but have access to it.
- They have bank accounts but no facility for institutional loans.
- They have experience in the kind of work they undertake.

- They sometimes act as sub-contractors as well as bidding in their own right.

The process of procurement

- Public-sector clients are heavily protected against the non-performance of the contractors through screening methods and sureties.
- A prospective contractor has to pass many screening stages.
- Only organisations with demonstrable legal status could enter into a legal contract with the public sector.
- Criteria for evaluating the capacity of the contractor are established.
- There is little empirical evidence supporting the assumption that detailed screening of contractors is necessary to protect the client from risks of non-performance.
- The legal and procedural requirements are designed for the commercial private sector, and effectively exclude community groups from the procurement process.
- There are set procurement procedures which are used in the public sector.
- Competitive tendering from registered contractors is routinely used.
- The estimation of cost by clients is frequently not based on the current market rates.

Barriers faced by micro-contractors

- Even for very small contracts the procedural requirements are stringent.
- Time taken for fulfilling the procedural requirements is often more than that for actually doing the work.
- Involvement of many signatories is seen by clients as a way of increasing accountability, but is a significant burden for micro-contractors.
- Delay in payments adversely affects the performance of micro-contractors who are usually short of working capital.
- No advance is provided to the small contractors.
- Only contractors with significant capital can survive in public-sector contracting.

UNDERSTANDING AND TRUST

So what can be done to improve the situation? The group of micro-contractors studied in this exercise appear sufficiently technically capable and sufficiently competent (or at least street-wise) to undertake the range of basic urban infrastructure work for which they compete. What seems to be lacking is understanding and trust, with clients perhaps over-concerned with eliminating risks that are not particularly serious in the context of a highly competitive environment with relatively large programmes executed by large numbers of very small enterprises.

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Construction Materials Selection and Sustainability

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Abstract

Among the notable technological developments of the 20th century has been the development of tens of thousands of new materials for use in construction and engineering. The construction industry has also grown to the point where it is a very large consumer of energy and materials. Concern for the environment and the impact of anthropogenic activity on the Earth's ecological systems has now become acute.

We are faced with the problems of material selection, and the environmental consequences of their use. Environmentalists have proposed various methods for assessing the impact of materials and energy use, these include ecological footprinting, ecological rucksacks, embodied energy and carbon dioxide values, and so on. Engineers have put forward rational selection methods for the choice of materials. These techniques will be reviewed and explored in an attempt to provide an environmentally-aware, materials selection methodology for use in construction.

Keywords: *Sustainability, materials, energy, selection, construction.*

INTRODUCTION

Sustainability has become a term of very frequent currency at the end of the 20th century. Despite its frequent use, it is rarely defined. It is used to give a green "gloss" to statements in situations which are not sustainable, and its use is probably inappropriate in many situations where it is employed. Strictly, the term sustainable means that something is capable of being sustained not for an hour, or a day, or a week, month or year, but indefinitely. The implication is that if some process which uses materials and energy, is described as sustainable, then the materials and energy which are consumed are capable of being replaced by natural or other processes as fast as they are consumed. In many cases materials and energy appear to be consumed at a faster rate than they are being replaced. However, to make a judgement, we would need to know what the respective supply and consumption rates are, in other words, we need some quantitative or numerical index to help us.

What are the indices available to us? Environmentalists have proposed various ways of measuring environmental impact, including the "ecological footprint" (Wackernagel and Rees, 1996) and the "ecological rucksack" (Schmidt-Bleek, 1994) and these are briefly reviewed.

However, there is another important factor. The 20th century has witnessed an explosion in the number of materials that we have at our command. Whereas the Victorians had a couple of dozen materials which had to serve all applications, we now possess between 40,000 and 80,000 different materials (Ashby, 1992). The Victorians' materials had to serve in many applications for which they were less than ideal, so it is fortunate that, in the main, their materials were rather abuse-tolerant. One hundred years later, the problem is to make the optimum choice from the huge number available to us. Engineers have devised rational selection methods for materials selection as part of an overall design methodology (Dieter, 1991, Ashby, 1992).

The central themes of this paper are twofold: (i) is it possible to apply rational selection methods to construction materials; and (ii) can these methods be extended to include environmental criteria as well as the straightforward mechanical and physical material property data?

CONSTRUCTION MATERIALS

The construction industry is very important, as it uses larger quantities of materials than any other industry. The UK construction industry is worth around £40 billion, and it consumes approximately 400 million tonnes of materials per annum. The Boeing Corporation has an annual turnover in the region of $30 billion, and it consumes perhaps 250,000 tonnes of aluminium alloys and other expensive materials. Rolls-Royce, the aero-engine manufacturers, turn over £4.5 billion per annum (Jones, 1999) selling between 1000 and 2000 engines of various sizes up to their most powerful model, the Trent (Coney, 1999). These engines all contain significant weights of exotic materials (such as nimonics and titanium alloys) designed to operate at what are, in engineering terms, very high temperatures. So the £4.5 billion turnover is generated on a throughput of less than 5,000 tonnes of material. If the construction industry is considered globally, it is by far the largest consumer of materials on planet Earth. The figures quoted above indicate that the materials consumed by construction are low value, non-strategic materials.

The fact that construction materials are low-value should not surprise us; neither should it blind us to the importance of these materials. In view of the quantities used, they have to be cheap, otherwise buildings would be very much more expensive, and not universally affordable, as they effectively are. However, the sheer scale of consumption means that their use has a major impact on the environment, and economists, engineers and environmentalists have all devoted much thought to ways of measuring this impact. A number of criteria or indices of impact have been devised, with the objective of furnishing numerical data, which can help decision making. Qualitative assessments are useful up to a point, but if real progress is to be made it is necessary to quantify the impacts of materials consumption.

It should also be recognised that we do not yet fully understand the workings of the life systems on planet Earth. It is becoming apparent that it takes the combined effects of all the ecosystems to maintain the conditions for life. The incomplete nature of our understanding of the Earth's biosphere should not deter us from attempting to minimise the impact of anthropogenic activities.

ENVIRONMENTAL CRITERIA

Since construction uses such large quantities of materials, it has a major impact on the environment. The last twenty or thirty years have seen the emergence of the modern environmental movement, and there has been a gradual acceptance of the environmental agenda. In the UK, there is now a Government Department responsible for the environment (Department of the Environment, Transport and the Regions) and legislation designed to cut down environmental damage is emerging. In order to assess and evaluate such impact, a number of criteria or indices have been devised by economists, engineers and environmentalists, and the more important of these are now reviewed.

Embodied Energy

This is quite simply the amount of energy consumed in manufacturing a unit quantity of a material, and it is usually expressed in kJ/kg. Its value is determined by the efficiency of the manufacturing plant. Values range from 275 GJ/tonne for aluminium (a high value) to 0.1 GJ/tonne for gravel aggregates (a low value).

Embodied Carbon Dioxide

Embodied CO_2 is similar to embodied energy. It is the weight of CO_2 emitted during manufacture of unit weight of the material, and is usually expressed as kg of CO_2 per kg. Again, the value will depend upon the efficiency of the manufacturing plant.

Ecological Rucksack

The ecological rucksack concept was devised as a way of assessing material efficiency by Schmidt-Bleek (1994). He recognised that many tonnes of raw material could be extracted and processed to make just one kilogram of material. For example, the environmental rucksack for the precious metal platinum is 250,000:1. This means that 250,000kg of material have to be extracted and processed to make 1kg of platinum. On the other hand, natural stone has a much lower rucksack at 1.05:1. We can quarry stone, extracting it in near finished sizes, the 0.05 representing the small amount removed in dressing the stone to finished size. It is apparent that this index will provide a very good way of illustrating and evaluating environmental impact, but could it be used with the rational selection method proposed by Ashby (see below)?

To provide an answer to this, it is necessary to analyse exactly what the rucksack is measuring, or, put another way, what are the factors that determine the size of the rucksack. The rucksack can obviously be determined by the size of the overburden when the resource is mined or extracted. The concentration of the species being extracted within the Earth's crust will also be significant. The chemistry or thermodynamics of the extraction process will play a part. All of these factors are functions of the physical and chemical properties of the material, ie. they are real material properties. The ecological rucksack can change with time, as does the embodied energy value. Whereas the embodied energy value tends to fall as process technology improves and becomes more efficient, so the ecological rucksack can increase with time as the readily available deposits of ores are worked out, and leaner or less accessible ores are exploited. Copper is an example of a material whose ecological rucksack has increased over time. In the 19^{th} century it was possible to find native copper (i.e., nuggets of pure copper). Then the oxide ores were exploited and worked out, and now very lean, sulphide ores are being worked where the copper content is typically only 5% or less. So the ecological rucksack has gone from around 1:1 to more than 100:1.

Therefore, the ecological rucksack can be treated as a material property and incorporated into the Ashby selection methodology, as well as being a good way of illustrating environmental impact.

Ecological Footprint

The footprint concept assesses the impact of a process by the size of its footprint, i.e., the area of the Earth's surface which is tied up in maintaining the process. The concept is due to Wackernagel and Rees (1996), and is proving to be quite powerful. It depends on conversion factors for the areal impact of consumption of all consumer products, and a share of the infrastructure, which uses land. It can be expressed mathematically:

$$\text{Area required} = \sum_{i=1}^{N} (\text{Area intensity})_i \ (\text{Consumption})_i$$

Four types of land have been identified:

i. Consumed land (unavailable) - this is the land covered by the built environment,
ii. Energy land - land impacted by energy use,
iii. Managed productive land - cropland, pastures, managed forests, gardens, and so on, and
iv. Land of limited availability – productive natural ecosystems e.g. rainforests.

The method cannot be used as a design tool, but it is a very powerful method of illustrating and assessing the approach to limits and the impact of human activity.

Environmental Profiles

The environmental profile concept is typified by the work carries out at BRE (Edwards, 1997). It aims to provide an easy-to-use format for designers and architects to use, by considering a number of parameters, such as: smog, europhication, ozone depletion, acidification, land take, and global warming. These parameters cover the material's potential for various kinds of pollution. Having decided on the parameters by which the material will be evaluated, the next decision is the choice of where in the material's life cycle the profile is to be applied. The design of a building goes through a number of stages:

- the concept for the complete building;
- individual elements such as floors, walls, roofs, and so on;
- individual products such as fittings and finishes to go inside the building; and
- the profiles can be applied at each stage.

Environmental Preference Method

The environmental preference method originated in the Netherlands in 1991, being developed by Woon/Energie, within the Dutch 'Steering Committee on Experiments in Housing' programme on sustainable living (Anink *et al.,* 1996). It was recognised that there was a need for easily accessible information on the likely environmental impact of various building materials and components, and so the method is embodied in a reference manual.

This method is very 'user-friendly'. The architect, engineer or contractor is able to quickly refer to the manual for the preferred solution to his/her requirement. The manual covers the various elements of a building, from floors, walls, roof, glazing, and so on, through to such items as fittings, kitchen units, etc. The various classes of product available are surveyed and ranked according to their environmental impact (for both new build and for refurbishment work). Such factors as cost and aesthetics are not considered. The method also takes account of the facts that present knowledge is incomplete, and that the ideal environmental solution may often not be attainable.

RATIONAL SELECTION METHOD

There are various approaches to the problem of selecting materials from the huge numbers now available. Designers can have recourse to materials property charts and data books. Alternatively, they can talk to their colleagues, hoping that by widening the knowledge circle, they will not omit a significant group of materials. Another strategy is simply to specify the same or a similar material to those used in previous, similar designs. All these are valid approaches, but they may result in the specification of a less than ideal material, and overall, a less than optimal solution to the problem.

The basis of the rational selection methods devised to date is a recognition that the performance of a component, artefact or structure is limited by the properties of the materials from which it is made. It will be rare for the performance of the item to depend solely on one material property; in nearly all cases, it is a combination of properties, which is important. To give an example, in lightweight design, strength to weight ratio σ_f / ρ, and stiffness to weight ratio E/ρ will be important. Ashby (1992) has put forward the idea of plotting material properties against each other to produce material property maps. On these maps, each class of material occupies a field in material property space, and sub-fields map the space occupied by individual materials.

These materials property charts are very information-rich, they carry a large amount of information in a compact but accessible form. Interestingly, they reveal correlations between material properties, which can help in checking and estimating data, and they can also be used in performance optimisation, in a manner such as that set out below.

Material Property Charts

If we consider the complete range of materials, it immediately becomes apparent that for each property of an engineering material there is a characteristic range of values, and this range can be very large. For example, consider stiffness (Young's Modulus E). Materials range from jelly (very low stiffness) up to diamond (very high stiffness). The properties can span five decades (orders of magnitude), and they must therefore be plotted logarithmically, when set out on material property charts. An example of such a chart is shown in Fig. 1. In this case, one property, the Elastic Modulus, E, is plotted against another, the density ρ on logarithmic scales. It can be seen that the range of the axes span the lightest, flimsiest foams through to the heaviest, stiffest metals. Ashby found that when so plotted, the data points for a given class of material cluster together in one region of material property space on the chart.

These diagrams are very useful; they can be used to make material selections. To do this it is necessary to delineate an initial search area (Ashby, 1992).

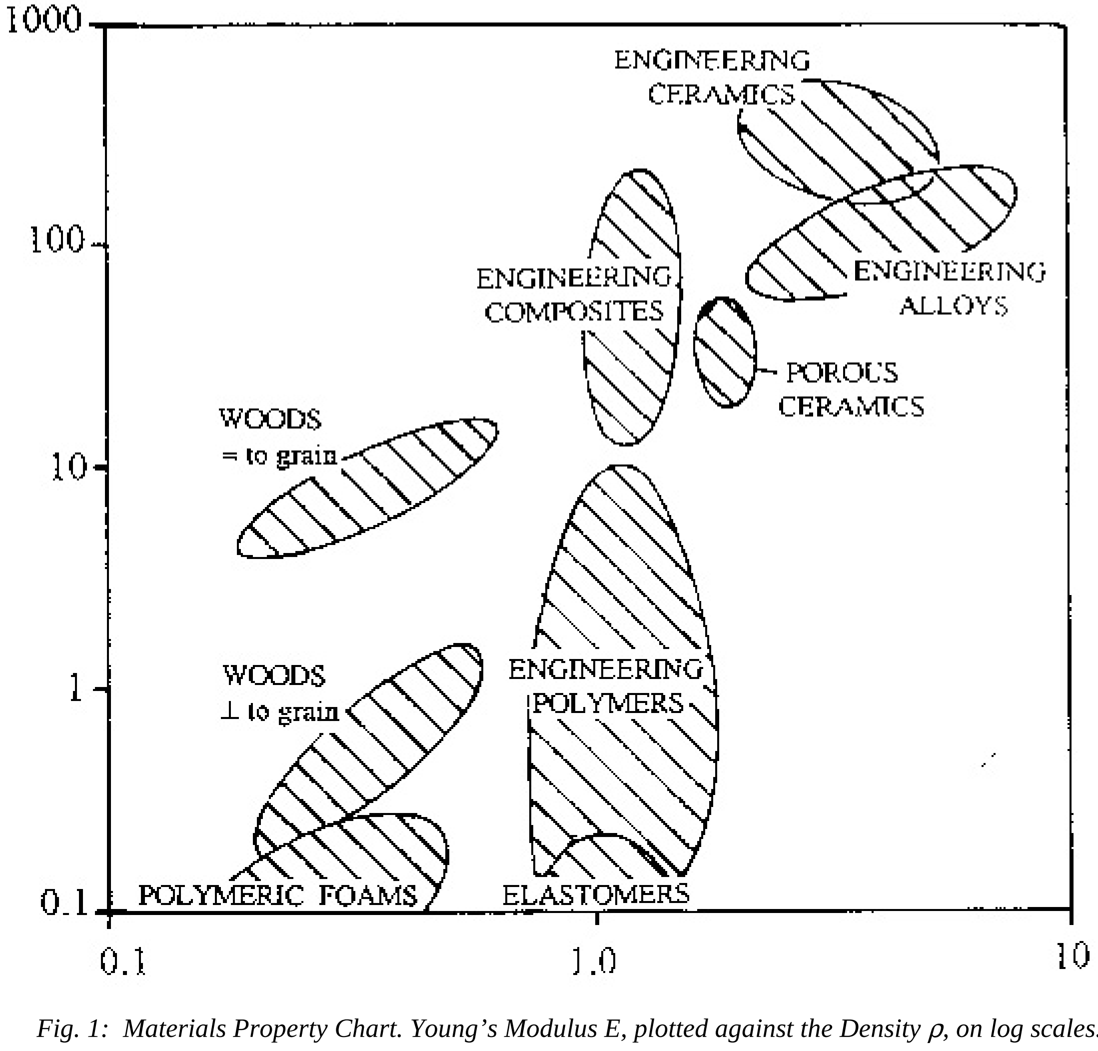

Fig. 1: Materials Property Chart. Young's Modulus E, plotted against the Density ρ, on log scales. (After Ashby, 1992)

DENSITY, ρ (Mg/m³)

DISCUSSION

The rational method of selection developed by Ashby works with the various physical, mechanical and cost information available for all materials. In principle, any specific material property can be used, and so the list of properties can be extended to include environmental parameters such as embodied energy and CO_2, and the ecological rucksack. The author has constructed Ashby diagrams for plots of Young's Modulus (E) v. Ecological Rucksack (Fig. 2) and of Relative Cost (C_R) v. Ecological Rucksack (Fig. 3).

The results of this exercise are encouraging. Figure 2 shows values of stiffness plotted against the ecological rucksack. The search area for optimum solutions can be delineated, within a minimum value of stiffness, say E = 0.1 GPa), and an upper value of ecological rucksack (1,000:1). It can be seen that all the materials plotted on the diagram (which are many of the materials traditionally used in construction) fall within this area. Interestingly, the traditional materials, wood and stone show the lowest values of ecological rucksack. No data for new materials such as polymers, engineering ceramics or advanced alloys have been plotted, as no data was immediately to hand. The idea at this stage is just to illustrate the concept feasibility.

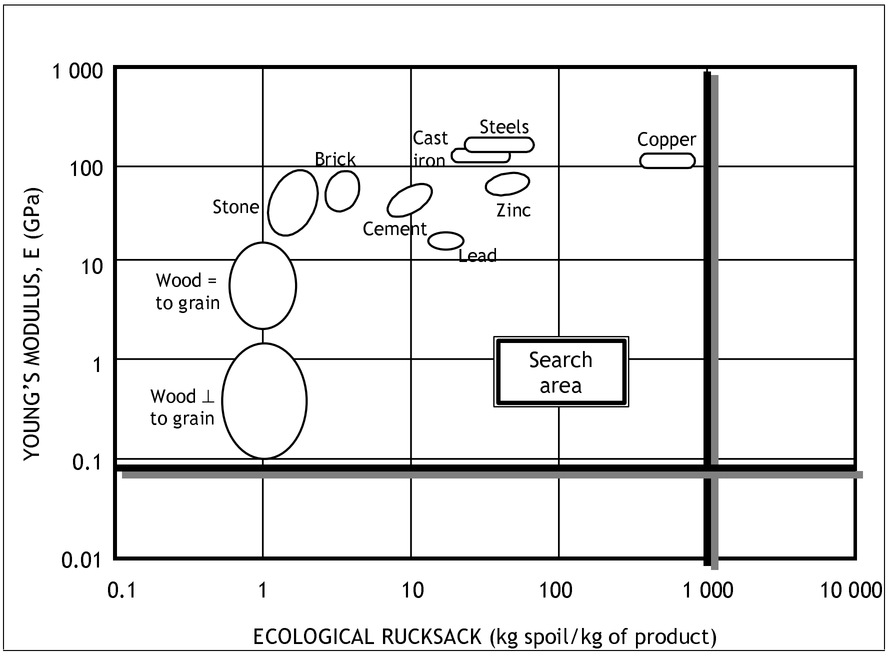

Fig. 2: Materials Property Chart. Young's Modulus, E plotted against the Ecological Rucksack.

Looking at the plot of relative cost versus ecological rucksack (Fig. 3), the optimum search area could be below a relative cost of say, 100 and below a rucksack value of 1,000:1. Again, it is apparent that the traditional construction materials fall within this area. As before, no data for the newer materials such as engineering ceramics, polymeric materials or advanced metal alloys have been plotted, as the objective is merely to illustrate the potential of this approach to materials selection.

The two examples shown in Figures 2 and 3 are sufficient to demonstrate that the rational selection method proposed by Ashby is capable of working satisfactorily using environmental impact properties as well as the usual mechanical, physical and cost properties. The diagrams work well; the optimum search areas can be delineated and are seen to show materials known to be optimal. The inclusion of data for hundreds of new materials could be expected to furnish similarly reliable selections.

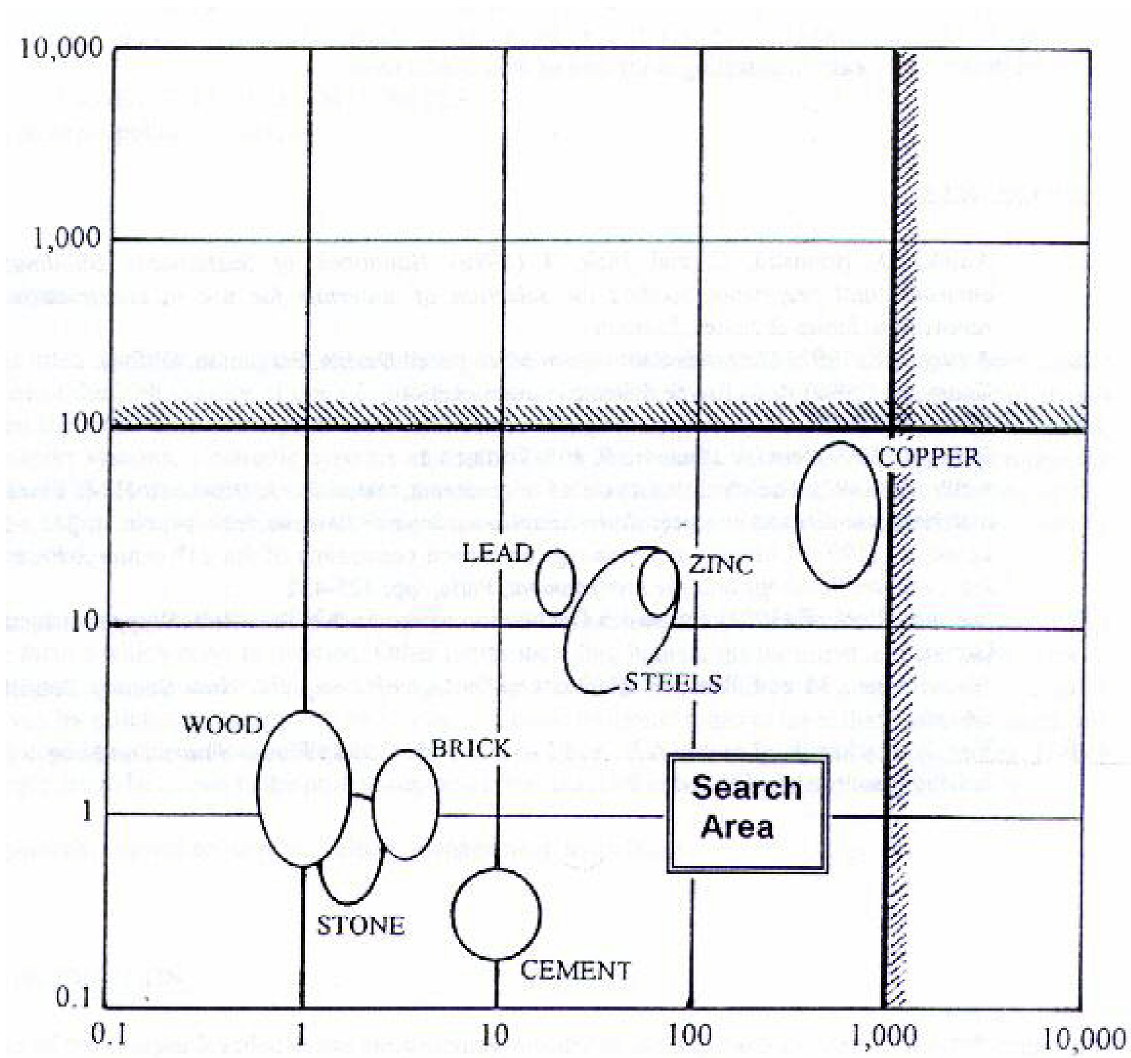

Fig. 3: Materials Property Chart. Relative Cost C_R ,Plotted against the Ecological Rucksack.
ECOLOGCICAL RUCKSACK (kg spoil/kg of product

Before concluding this discussion, it is worth making the point that the achievement of a sustainable state of affairs will involve the industry in looking at what happens to its materials when they come to the end of their useful lives, as well as their initial selection. Just as construction is the major consumer of raw materials, so it is also a major producer of waste – demolition waste. One approach is to increase the amount of materials that are recycled. However, to do this better, information on the grades and compositions of the materials present in buildings will be required, and buildings will need to be designed for systematic dismantling at the end of their useful lives. This will enable the setting up of a properly segregated waste stream to provide the materials for recycling, at minimum cost.

CONCLUSIONS

A number of conclusions can be drawn, including:

1. A rational selection method such the one put forward by Ashby is capable of incorporating environmental parameters such as embodied energy and CO_2 or the environmental rucksack concepts, thereby making possible rational selections based on environmental considerations.

2. This method is not as simple to use as the environmental preference method or the environmental profiles method. However, this rational method could be used to generate data for the environmental profiles and preference methods.

3. The construction industry needs to take steps to better integrate itself into the materials cycle. The quantity of demolition waste needs to be reduced, and more of it should be recycled. To this end, the building designers need to keep full records of materials of construction, and buildings need to be designed for easy dismantling at the end of their useful lives.

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Innovation in Construction

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Abstract

It is often said that the construction industry is not very innovative. While this may have been true of some of the 20th century, if one takes a historical perspective, it can be shown that this has not always been the case. This century has seen spectacular developments in many fields including, materials, transport systems, electronic systems and information technology. It is illuminating to examine the cultures of other industries and to compare them to construction. It will be shown that differing factors have helped to shape the construction process. Some of the forces that drive innovation will also be examined.

The paper examines aspects of the respective cultures of construction and other industries, as well as the factors which drive innovation. Other issues including human, management and the importance of dialogue, are discussed. The industry potentially stands on the threshold of a new era of innovation driven by efficiency, energy and environmental considerations. It has to meet these new demands, and this could provide a worthwhile challenge to a new generation of young people of high ability. If such people are to be drawn to the profession, then construction will have to project itself differently.

Keywords: *innovation, drivers, culture, management, knowledge*.

INTRODUCTION

One of the charges levelled at the construction industry as we approach the end of the 20th century, is that it has had a poor record on innovation, when compared with manufacturing industries such as aerospace or electronics, for example. Is this charge justified, and if so, what is the justification? If the charge is at least to some extent true, are there any lessons to be learned by the construction industry? This paper examines aspects of the industry's record and presents some thoughts on this, based on the authors' experience in being involved in innovative developments in another field of activity.

It is necessary to specify what is meant by innovation. Innovation really means change, and the change can be one of two types; firstly, change in the product or service being provided, or secondly, change in the process by which the product or service is created. So innovation can apply to the invention of new products, and it can also apply to new ways of marketing existing products, for example.

HISTORICAL DIMENSION

The 20th century has witnessed impressive developments in the fields of transport and communications technology, and whole new industries have been brought into being. Intimately associated with these developments have been developments in materials and energy technology. Indeed, these new industries have fed off and stimulated each other; and we must recognise that, in many cases, none of them would have developed alone. If we consider the construction industry, much of what takes place on a housing construction site in the UK today would be recognisable to a Victorian builder, if he were able to travel through time to see it. While there have obviously been developments in the past hundred years, on the face of it, construction does not present the same dynamic picture of progress displayed by other industries.

However, if we take a longer, historical perspective, a different picture emerges. Consider the medieval cathedral builders of northern Europe. Who has not admired these hugely impressive buildings, and marvelled at the combination of ingenuity, industry and workmanship, that they represent. They frequently dwarf the surrounding buildings, and soar to heights that, even today, are much greater than those of most buildings. They were bigger and much more ambitious structures than had been constructed before, and they were built in an age when mankind had to rely to a great extent upon natural materials such as stone and timber in the main. They were built at a time when fired clay products were available and the metals and glassmaking industries were tiny.

The Byzantine builders had solved the problem of creating large internal spaces by the use of the arch. Their most famous building is the Hagia Sophia in Constantinople that was put up between 532 and 537AD. This building is crowned by a large dome which, statically, it was not initially successful. The dome suffered a partial collapse 30 years after it was completed, and it was rebuilt to a modified design (Musgrove, 1987). The Byzantine builders realised that the horizontal forces needed to be carried by buttressing, and this provided a key concept for the medieval cathedral builders.

So what was specifically innovative about the cathedrals of Northern Europe? The innovation lay in the combination of height and slenderness that they sought to achieve. The cross-section of Hagia Sophia shows a structure that is more squat than those of the later medieval cathedrals. There had been no significant improvements in construction materials technology in the 500 years or so which elapsed between the building of Hagia Sophia and the European cathedrals

So what were the main structural materials? Natural stone was used for cathedral buildings, in particular, granite, limestone and sandstone. These materials would be cut into ashlar, the surfaces of which would be less than perfect. These surfaces would be grouted with lime mortar. This mortar would tend to carbonate with the passage of time, and in any case, would possess little tensile or compressive strength (Mark, 1982). Limestone, being a sedimentary rock, is of very variable quality, and so its strength in compression will vary from 19.3 MPa (2,800 p.s.i.) up to 193 MPa (28,000 p.s.i.). The yield strength of mild steel is around 300 MPa in comparison. The strength in tension for all natural stones is an order of magnitude less than this. Even so these tensile strengths, low as they are, are an order of magnitude greater than that of the lime mortars used to join the ashlar. The picture that emerges therefore, is of a world with a tiny fraction of the materials we posses today, and furthermore, a world where the materials were of very variable quality, and where significant tensile stress could not be accommodated. Yet the medieval builders constructed buildings which still impress us today, seven or eight centuries later.

The fact is that these medieval builders were being highly innovative. They were operating at the frontiers of knowledge, with only an empirical knowledge or understanding of how their materials worked, and no means of analysing the performance of their structures. Despite these (in our eyes) severe limitations, the builders were driven by local pride and ambition to construct progressively larger, higher and wider cathedrals. In doing so, they were expanding the limits of knowledge. They knew that their design was for a larger structure than that built in a neighbouring city, but they did not know whether their structure would ultimately be stable when it was completed. It should come as no surprise, therefore, to find that some of these structures collapsed.

One of the well-known collapses occurred at Beauvais cathedral in Northern France (Stewart, 1961). Here, the builders were very ambitious; the nave was to be 15.2m wide, and no less than 48m high, 5m higher than that of the cathedral in the neighbouring city of Amiens. Moreover, the builders were determined to achieve this with as light and slender a structure as they could. Construction began in 1247, and the choir was completed. Height and slenderness were achieved, but were pushed beyond the limits of stability, for in

1284 a part of the great choir vault collapsed. The structure was rebuilt, and modifications were made to improve stability, the work being completed in 1324.

The work on Beauvais was recorded in detail, and many have speculated about the exact reasons for the collapse. Indeed, there is an extensive literature on this dating back well into the 19^{th} century (Viollet-le-Duc, 1854-68). However, only in the latter half of the present century have we been in possession of the analytical and experimental tools to provide a detailed picture of the stresses at all points in any given structure. The medieval masons had no detailed theory of the strength of materials such as we possess today, but they would have an empirical knowledge of material behaviour under static loads. A large, tall structure such as Beauvais would have encountered significant wind loading in addition to the dead weight of the structure. Mark (1982) reports the results of a recent detailed analysis and experimental work using photoelasticity techniques to model the stresses in the structure. According to his analysis, the stresses in the choir piers due to dead-weight and wind loading would have been just 2.76 MPa (400 p.s.i.), and the stresses in the clerestory walls just 2.07 MPa (300 p.s.i.), well below the strength values given above. His analysis also showed that there would have been tensile stresses in the pier buttresses due to deadloading. Wind loading would have added to these tensile stresses, to the extent that the tension due to dead and wind loads would have reached 1.8 MPa (260 p.s.i.). The imposition of tensile loads onto these materials, given their almost complete lack of tensile strength suggests that this was the likely cause of the collapse.

None of this should detract in any way from the builders' achievement at Beauvais. The development of a comprehensive theory of the strength of materials has been the work of the last 150 years or so (Timoshenko, 1950). The work of Mark (1982) and others merely emphasises the fact that the building of the medieval cathedrals was an achievement at the forefront of human endeavour, and therefore a highly innovative exercise.

We need to examine some of the other major cultures that were contemporaneous with the era of cathedral building. The Yuan (Mongol) dynasty ruled in China, and comparatively little building survives from that era. Such buildings as were constructed would have been largely of timber, and nowhere near the height of the European cathedrals. In Japan, this period coincided with the Kamakura Shogunate, and again, the buildings would have been wooden framed and not so high. Very little survives from that period in Japan's history. In Central America, the Toltec, Aztec, Mayan and Inca civilisations had reached an advanced state of development. Their architecture was impressive, and a good deal of it has survived. These peoples built massive, pyramid-like structures, with none of the slenderness and height of the cathedrals. In central Asia, the Mongols conquered a vast Empire stretching from China to Eastern Europe, they left no architecture, and inflicted much damage to the architecture of the peoples they conquered. So we see that the efforts of the cathedral builders were truly innovative. Paradoxically, the collapse at Beauvais confirms just how ambitious and innovative their work was. The masons learned enough to make the construction of other surviving and impressive buildings in the cities of central Europe, well within the bounds of knowledge.

MEDIEVAL INNOVATION – THE DRIVERS

We can therefore appreciate that the construction of the medieval cathedrals was an exercise in innovation, in which the limits of human knowledge were extended. Eventually, the limits of what could be achieved using materials possessing only compressive strength was reached, and these limits were recognised by the builders. Thus, the construction of cathedrals reached a level of maturity, and this phenomenon of technological maturity will be referred to later.

What drove this innovation? Some would say of the builders that they were putting up wonderful structures to the glory of God. This was an era when Northern Europe was almost entirely Christian, and this motivation undoubtedly drove the builders in their efforts. Human nature is a wonderful amalgam of altruism and self-interest, and part of the motivation in each case was the desire to outdo their rivals in building ever taller, wider and more beautiful church buildings. For those involved, the building of a cathedral was their life's work and they invested their best efforts in it. The building would also be an expression of civic pride to the local citizens. Therefore, the drivers for innovation were very powerful ones. The task was highly visible – literally high profile – and the fear of ignoble failure would also be a spur to success. Finally, construction obviously attracted high-calibre people reflecting the important place that it held in peoples' estimation.

INNOVATION IN THE 20TH CENTURY

Construction Industry

While construction has not been as innovative as other industries, it has brought about some innovations during the 20th century, and a few examples will be briefly referred to here. In the first two or three decades, it responded to rapidly escalating land values in the inner cities of the United States by producing buildings that made the best use of very expensive land – it developed skyscrapers. These were very innovative projects, making use of the major developments in materials, in particular, structural steel. Steel become cheaply available in large amounts towards the close of the 19th century, and it was the best material for the frames of these huge buildings. Steel combined high strength, high stiffness and the ability to be pre-cut, drilled, and rapidly erected on site.

This century has seen remarkable strides in bridge-building technology too. Again, the availability of steels (a material with high tensile strength) has made possible the building of firstly, large suspension bridges, and then more recently, the cable stay bridge, which is even more materials efficient.

Another area of development and innovation has been in fastener technology used in construction.
Many types of fastener have been introduced which speed up the construction process by reducing the number of operations required and reduce the number of operatives needed, and this process continues. There have been many more examples of innovation, such as novel piling and foundation systems, and new composite materials for the rapid erection of industrial buildings. These innovations have all been created by the industries that serve construction, they are all for specialist niche products, and they all come from industries that have invested heavily in the factors that favour innovation, and which, at the same time, keep the entry barriers to these industries high.

Other Industries

Whole new industries have been born since 1900 that did not exist before. The aerospace, automobile and computer/IT industries are three well-known examples. In each of these industries, numerous firms started out, some have grown and expanded, others have failed or been taken over. The markets that we see now are the results of a rationalisation process in each case. However, each of these industries has, of necessity, developed a culture of innovation in order to survive. They have each made a marketing virtue of innovation, in ways that are not open to the construction industry.

They have also invested heavily in capital-intensive plant and equipment, they employ high-calibre staff, and they have expertise, gained over a long-term, in various advanced manufacturing techniques. Indeed, they have been instrumental in developing some of the techniques, collaborating with other companies and universities as necessary. So they now have high barriers to entry.

Technological maturity

It is appropriate to discuss technological maturity at this point. All technologies go through a period of rapid growth and development, where new opportunities are discerned and grasped. Eventually the rapid pace of development slows as the technology achieves its potential. Once a technology achieves this level of maturity, the perception is that most of the exciting, innovative developments are over, and the future holds a steady series of improvements of a more mundane variety. This view, while not wholly accurate, contains some truth. One consequence of this perception is that fewer really able people are drawn to the discipline or profession. Of course, able people enter all professions, but the areas where exciting new developments seem to be taking place will always tend to attract more.

We have seen that construction was one of the first industries to reach a high level of maturity, and this occurred several centuries ago. There were no major technological achievements to make in order to provide the range of buildings which society required. Construction differs in certain respects from other industries. Comparing construction with the automobile and aircraft industries, these differences become apparent. In Britain and the United States, car and aircraft manufacturing companies were founded in the first two decades of this century. The great depression of 1929 resulted in many going out of business, so that by the outbreak of World War II, there were just 20 or so aircraft manufacturers in both Britain and the USA. The same was true of their respective car industries. In the 50 years since the War, a process of rationalisation has occurred in these industries in Britain and the USA, so that there is now only one large manufacturer of passenger aircraft in the UK (British Aerospace, part of Airbus) and in the USA (Boeing). The car industry presents a similar picture, and the same rationalisation process is discernible on the global scale.

One of the most significant developments in the automobile industry was that of the annual model change. General Motors first recognised that this was a powerful marketing device. You could sell a person a car this year, and the same person would change it for the latest model next year. As well as being a marketing tool, this fact has also been a powerful driver of innovation. The manufacturer sees an advantage in constantly improving its product. There are similar, powerful drivers for innovation in the aircraft industry. Military aircraft design generates a constant need to improve performance, speed, range, ordnance carrying capacity, and so on. Each development then brings the fear that the potential enemy will duplicate the improvement, and so the improvement in its turn must be countered – an innovation spiral. Civil aircraft face similar demands from the airlines for improved performance; such demands for improvement are much less insistent in construction.

Construction in the UK has to conform to planning and building regulations, and in the house-building sector, to the requirements of the building societies. To the building society, a house is their security for the loan. They may shy away from lending money on something they think they may not be able to sell. These factors inhibit innovation to some degree, and favour traditional building methods and styles of houses. If construction has not appeared to be so dynamic and innovative, there are valid reasons why this has been so.

Economists have developed sophisticated theories about markets; they have modelled the markets for buyers and sellers, or manufacturers and consumers. The number of players in a market will depend upon the barriers to entry, where the barriers can be financial or technological. If we consider the car and aircraft markets, there are considerable barriers to entry, both financial and technological. Modern cars and aircraft are technologically advanced, and any would-be manufacturer would need huge investments in plant and equipment to enter. The launch of a new car, which these days is done on an international scale, requires the investment of hundreds of millions of pounds. On the other hand, a small construction company can be set up for a very small investment. In the UK, this ensures that the small construction company sector is always crowded, and that competition is very fierce.

INNOVATION: WHAT ARE THE FACTORS INVOLVED?

We have considered a few examples of innovation separated by many centuries. In each case we have identified some of the factors which drove the respective innovations. These drivers were and are important, and stand apart from any considerations of organisational culture, management issues, etc. However, there were other factors involved, and some of these will now be examined. They include cultural, human, management factors, and an attempt will be made to identify some of the key ingredients that bring about that original spark which leads to the creation of something new.

Cultural Factors

There is little doubt that in the 20th century, some industries and some companies and organisations have been more innovative than others. As we approach the new millennium, people talk increasingly about the pace of change, and they are more conscious of the need for companies to innovate in order to survive. Some organisations have, consciously or unconsciously, created a culture in which innovation can take place and thrive.

Egbu *et al.* (1998) have examined the management of innovation in construction by surveying a number of companies which are, by general consensus, innovative. They have highlighted certain characteristics all shown by innovative organisations. These are:

- a culture where people are open-minded, willing to accept change, flexible, and free from dogma;
- flexibility in the lines of communication, structures that allow top-down, bottom-up and lateral;
- communication within the organisation; and
- a risk-tolerant climate where it is accepted that lessons can be learned through mistakes.

Other characteristics or conditions favourable to innovation included:

- a 'knowledge-friendly culture' where people are not inhibited about sharing knowledge and do not fear that sharing knowledge cost them 'power and influence' or even their jobs;
- a climate where people genuinely feel valued and where people feel some sort of 'ownership' or involvement with the innovation; and
- a climate where people feel some job security.

This last point requires some amplification. The lead author spent some years of his career involved in research in a leading UK university department of mechanical engineering. This department was very research active, and a good deal of innovative work was always in progress. Much of this work was carried out by people on limited-term research contracts, i.e. they did not have tenure. Nevertheless, they knew that their posts were secure for the duration of the contract. These were highly intelligent, well-motivated people, who in many cases valued job interest above job security. Although employed on a limited-term basis, in all other respects they enjoyed the same employment conditions as their tenured colleagues.

Human Factors

Given the right atmosphere or culture, innovation will not readily take place without the right people. Who are the right people? They are the intelligent, highly motivated people, who are drawn to tackle challenging tasks. They like to work in small or medium sized groups, where they can make an impact. They enjoy interaction with their colleagues, and a certain amount of freedom to organise their work. Indeed, given a problem to work on, they can be self-organising to a fair degree. Some will be natural organisers, and others not. But they will recognise each other's strengths and weaknesses, and organise themselves so that the work will be accomplished.

Such people are drawn to new ideas, and to new technologies, and tend to avoid situations where novelty is absent or rarely encountered. Construction is not perceived as being at the leading edge of technology, and so many naturally innovative people have not been drawn to it. This is unfortunate, and it needs to change.

Management Factors

Management can play a part, though it is often a passive part. There is a lesson to be drawn from the fate of Colossus, the world's first electronic computer. This machine was seen by management, i.e. the UK government of the day, as part the UK's intelligence gathering capacity, and therefore highly secret. Very few people indeed, aside from those who worked at Bletchley Park, knew of its existence. If it had been presented to the world as a general purpose computing machine, it would have been hailed as a wonderful new development by the people who could begin to imagine its potential. Hardly anyone would have asked exactly how it came to be invented, and of those that did, none would have jumped to the conclusion that it was a cryptographers tool. The problem was that those who had created it could only view it as a cryptographers tool, and as a state secret. Some of these computers were therefore broken up and disposed of when Bletchley Park was closed down (Smith, 1998), and all those who knew of its existence were sworn to secrecy. What can we conclude from this? Simply that management needs the vision to see beyond the immediate product to the potential applications and markets.

THE SPARK FOR INNOVATION - THE IMPORTANCE OF DIALOGUE

In the lead author's experience, the stimulus for innovation is most often provided by dialogue with a colleague. Another person comes with a problem he wishes to solve. The person who is capable of generating the innovation needs the stimulus provided by the person with the problem. Until the second person arrives on the scene, the innovator may not see the problem as something to be solved. He may be aware of the problem, but it does not become "his" problem until the second person makes the approach. He will often not be aware of the problem, although he may be in possession of the combination of skills and experience required for its solution.

The solution to the problem may not occur to the innovator during the initial dialogue, but the stimulus has been provided, and the innovator will know that here is a worthwhile problem on which to work. He will often have an instinctive feeling that he is capable of generating a solution. The germ of the solution will often come to him during the following few days, perhaps at a moment when he is not consciously thinking about it. This has been very well expressed by the American physicist, John Wheeler (1985), in his centenary tribute to the great Danish physicist Niels Bohr:

> I never saw Niels Bohr make progress with an idea or concept except in dialogue or dictation or sudden revelation out of the depths of the subconscious.

Wheeler refers to dictation, and it is recognised that the act of articulating the essence of a problem to a colleague will often lead to a revelation of the idea or concept required for its solution.

Knowledge Management

The term "knowledge management" has gained currency in recent days. There is a large literature on the ways in which knowledge is gained, transmitted, exploited, developed, and so on, typified by the book by Tidd *et al.* (1997). It is fascinating, and potentially very useful, to analyse the ways in which various discoveries and developments have come about. When the range of innovations in various fields is reviewed, a number of things become apparent. Many innovations arise because of an element of luck. The person generating the idea is stimulated by a chance meeting with another person who has a problem. In other cases, the innovation occurs after the originator has spent a long time, perhaps many years studying a phenomenon.

Another factor which recurs is the way that innovation frequently consists of taking an idea from one situation and applying it to another, different situation. The person making the innovation has the insight to realise that an idea used initially in one way is of more general applicability. Just as a good design is one that is capable of considerable development, so a good idea is one capable of wide application.

Sometimes innovations cannot be predicted, and if so, they certainly cannot be managed. Managers need to recognise this, while at the same time striving to create the conditions that encourage and nurture innovation. One of the most important factors in innovation is provision of the stimulus, i.e. the crucial interaction between the man with the problem and the man with the solution, or with the combination of ability, experience and insight to come up with the solution. Occasionally, all that needs to happen is for the innovator to be made aware of the problem (the innovation driver).

The Innovation or Ideas Supply Chain

In construction, as in other industries, people are familiar with the concept of the supply chain. This is the set of firms and organisations that supply materials and other goods and services required by the industry. Marketing people in industries such as car manufacturing regard feedback from their dealer networks as an ideas supply chain. Customers' remarks about their products, feedback in general, both positive and negative, provide them with useful information in developing their products, and in keeping them attuned to market requirements. They are cultivating and encouraging such feedback; the ideas flowing from it provide a stimulus for innovation. We can regard this as an innovation or ideas supply chain. Such a flow of ideas and remarks, both positive and negative, is a powerful stimulus where consumer goods are being manufactured and sold, and this factor has largely been absent from the culture of the construction industry.

The aerospace industry cultivates long-term relationships with its suppliers. The aero-engine companies get regular input from the airlines about their future plans (Coney, 1999). The industry therefore obtains regular stimuli which help it to develop its products in a continuous and timely way. There has been much less of this long-term contact in construction. However, this is not entirely the fault of the industry. Many clients commission only one building during their lifetime. The whole area of repeat business, and therefore, long-term relationships, frequently does not arise.

INNOVATION IN CONSTRUCTION TODAY

We have seen that the construction industry has not been continuously innovative during this century. However, we have also seen that there are valid cultural reasons for this. The Egan Report (1996) has recommended that construction can learn from the manufacturing sector, and create a more innovative culture.

Innovation requires some powerful driver(s), together with the right people and the right culture in which it can take place. As we approach the New Millennium, it is very apparent that the construction industry faces some major challenges, including that of improving its environmental performance. The industry must be innovative to tackle these problems, which are the drivers for innovation. If the environmental challenge is not met voluntarily, European legislation is likely to force the issue, early in the new millennium (Smith, 1999). Construction differs in important ways from manufacturing industry, so its requirements for improvement need careful analysis. At the same time, the different types of innovation brought into the manufacturing sector must also be categorised to see exactly where lessons may be exchanged.

Here indeed is a challenge worthy of people of high calibre. Construction must project itself as an industry providing challenge, providing a career for high-calibre entrants.

CONCLUSIONS

There are a number of conclusions to be drawn:

- Historically, construction has been highly innovative. It is now a mature industry catering for a market that differs in important respects from those served by the newer industries.
- The newer industries have had to develop an innovative culture in order to survive (the annual model change concept) in a highly competitive market.
- Construction has been regulated in ways that have tended to promote conservatism rather than innovation.
- There is a need for more research into the types of innovation process, so that the appropriate lessons can be learned by the construction industry.
- Construction faces the challenge of minimising the environmental impact of its consumption of materials and energy. It will need to become more innovative to meet this challenge.

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Let us consider one of the most familiar 20th century developments, the electronic computer. What circumstances led to their development? Mechanical calculating machines had been developed much earlier, and these devices required the operator to set up each calculation in turn. Electro-mechanical devices were faster, but could only tackle repetitive calculations of the same type. Developments in the theory of numbers before the Second World War, notably by Turing (1937), suggested the possibility of creating a universal computing machine, which could be "programmed" to perform any calculation required. However, it took the unique pressures of war to bring about this development. The development of the first general-purpose electronic computer took place at the Post Office Research Station at Dollis Hill, in England, in conditions of the utmost secrecy (Hinsley and Stripp, 1993). Its construction was stimulated by the cryptograhers at Bletchley Park, where the computer was eventually installed and operated. The need to decrypt enemy intelligence where the code was changed on a daily basis, brought about the need for a truly high-speed computer. Only an electronic machine could try all the millions of possible code combinations within a time period short enough to be render the intelligence useful. After VE day, the machine was broken up, and very few people were aware that it had ever existed.

In the US, another powerful general-purpose computer was developed as a result of a collaboration between Herman Goldstine and John von Neumann. Herman Goldstine and his group at the University of Pennsylvania School of Engineering developed a crude electronic computing machine, which they called ENIAC. By chance Goldstine met John von Neumann on a station platform, and their conversation turned to Goldstine's work. John von Neumann quickly saw the potential of ENIAC for the nuclear weapons programme, in which he was involved. He redesigned it to incorporate a stored operating programme (Goldstine, 1972). This machine was built after Colossus, and at the start of the Cold War. The Americans had no idea that a general-purpose electronic computer had already been secretly created, and then destroyed, in the UK. The American machine set to work to perform many of the complex calculations required in the thermonuclear weapons programme. Again, such a machine could save months of computing work, and it enabled the US weapons programmes to be accelerated.

What were the drivers for these developments? They were the most powerful imaginable, nothing less than national survival in the case of Britain's Colossus computer. The Battle of the Atlantic was being lost, and without intelligence about the U-boat activity, the battle and the war may well have been lost. In the case of ENIAC in the United States, the detonation of Russia's first nuclear bomb in 1949, seemed to pose a major threat to their national security. The United States had disarmed after World War II to a large degree, secure in the knowledge that it alone possessed the secret of how to produce nuclear weapons. the events of August and September 1949 came as a great shock to the US military establishment. The Americans had confidently expected their nuclear monopoly to last for at least 20 years, if not longer.

Looking at the computing scene today, it is apparent that this is the age of the personal computer. Over the past two decades, the pace of development has been rapid and spectacular. A new PC has a service life of 3 or 4 years at most, by which time it is fast becoming out of date. This in itself is a driver for innovation. It is analogous to the annual model change in the automotive industry. A market is created where people want the latest model. We must remember, when judging the construction industry, that there is nothing analogous to this. People buy a house, and they live in it for 10, 20 or 30 years. They do not look for "next year's model". This planned obsolescence is a factor in many of the industries with which construction is unfavourably compared.

So we see that frequently, innovation is powerfully driven. Where drivers are absent, or fewer, the pace of innovation slows. However, the drivers, while being a necessary pre-requisite for innovation are not sufficient by themselves.

Learning by Doing in Singapore Construction

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Abstract

This study examines the significance of learning-by-doing (LBD) in Singapore’s construction using the production function approach. Learning was found not to be significant, possibly as a result of the industry’s high dependence on imported construction technology, industrial fragmentation as well as transient, and largely unskilled, foreign workers. Learning is socially rather than technologically driven and occurs at individual, project, corporate and industry levels. Since learning by doing is an important determinant of productivity, measures should be implemented at all levels to encourage it. In particular, the fragmentation of the industry is a serious impediment to learning since small firms generally do not have adequate resources to learn effectively.

Keywords: *Learning-by-doing, productivity.*

INTRODUCTION

The purpose of this paper is to determine whether learning-by-doing (LBD) is significant in Singapore's construction industry. The study is motivated by two main reasons. First, it is interesting to investigate whether learning does occur in Singapore construction given its fragmented nature, high dependence on imported construction technology and transient foreign workers, factors that allegedly lead to low levels of learning. The high dependence on imported technology may cultivate a posture of technological passivity (Frank, 1969; Rosenberg, 1976) while the extensive use of transient foreign workers, especially in the 1990s, may disrupt efforts to encourage long-term learning by doing. Since construction productivity is generally lower than other sectors of the economy (World Bank, 1984), a lower rate of LBD may be expected.

Second, since firms and industries with higher learning rates can gain competitive advantage, building on such capabilities through the right policies may provide contractors with the competitive edge to compete in world markets for construction exports. In general, small construction firms do not have adequate resources or the capacity to learn effectively. Building construction is a complicated task, and valuable experience cannot be built up if small firms are vulnerable to the vicissitudes of construction cycles.

This paper is only a preliminary report of the findings of a LBD study, initiated in 1998, which is now in the final stages. The results reported here should be treated as tentative. Much more needs to be done to understand learning at all levels within the construction industry.

THEORETICAL BACKGROUND

LBD may be defined as the realization of productivity gains (or cost reductions) by an individual firm from production experience. The experience that a firm acquires is often represented by the cumulative output or investment. Production experience that leads to labour, capital or organisational (or general) improvements are called ‘labour’, ‘capital’ or ‘organisational’ learning respectively. LBD is therefore distinct from static scale economies that occur at the plant level.

Early investigations of learning focused on the behaviour of individuals. The general understanding from such psychological studies was that individuals become more efficient in performing a task, though at a decreasing rate, as experience with the task increased (see Argote, Beckman and Epple, 1990).

At the firm level, Wright (1936) first reported the learning curve phenomenon in his study of airframe manufacturing. It was found that the direct labour cost (or number of direct labour units) of producing an airframe declined with the accumulated number of airframes produced. Subsequent studies, both in the aircraft as well as other industries, confirmed Wright’s findings (Searle and Goody, 1945; Hirsch, 1956; Preston and Keachie, 1964; Hirschmann, 1964; Rapping, 1965; Webbink, 1977; Zimmerman, 1982; Joskow and Rozanski, 1985). There is considerable variation in the rate at which firms learn (Yelle, 1979; Dutton and Thomas, 1984; Hayes and Clark, 1986; Argote and Epple, 1990).

Learning has also been observed at the industry level, such as chemical processing, manufacturing, utilities, automobiles and electronics (Sheshinski, 1967; Lieberman, 1982; Sukuma, 1995; Al-Mutawa, 1996). This is not surprising since an industry’s output may be viewed as an aggregate of the output of individual firms. If widespread learning occurs at the firm level, it should be reflected in aggregate performance. Hirschmann (1964) suggested that increases in aggregate productivity observed in the petroleum refining industry reflects the joint effect of many inter-related factors such as technological advance, increased capital investment, better methods of management, increased health and education of workers, and improved communications. This entails more than individuals becoming better at their jobs, or factors such as improved co-ordination of the production process at the firm level.

There have been a number of LBD empirical studies pertaining to construction, particularly power plants construction (Searle and Goody, 1945; Hirschmann, 1964; Joskow and Rozanski, 1979; Zimmermann, 1982; Joskow and Rose, 1985; Al-Mutawa, 1995). Learning by operators, suppliers, design and construction engineers, construction firm, researchers, architects, managers was found in these studies.

THE MODEL

Often, the cost or production function approach is used to estimate learning. This study uses the production function approach. The production function may be written as

$$Q_t = A_t f(K_t, L_t),$$

where Q refers to output, K is capital input, L is labour input and $A_t = h(X_t, t)$, the technological progress function. This function has two arguments; X represents an endogenous LBD component and t (time) represents the exogenous technological progress component. X refers to the industry’s stock of knowledge (experience) and it is, in short, the learning variable.

For simplicity, the Cobb-Douglas production function is used. Assuming constant returns to scale to overcome multicollinearity, the model may be written as

$$\ln(Q/L) = \ln(A) + (1-\alpha)\ln(K/L)$$

where α denotes labour’s share of the output. The technological progress function is of the form

$$A(t) = A_0 X e^{gt}$$

where A_0 is a constant and g refers to the Hicks-neutral rate of exogenous technical progress. Finally, if the learning variable X is specified as a power function of cumulative output (Levy, 1965; Bairam, 1989; Bahk and Gort, 1993; Jones and Barr, 1996), the final estimating equation (omitting time subscripts for brevity) is

$$\ln(Q/L) = A_0 + gt + \omega\ln(\Sigma Q) + (1-\alpha)\ln(K/L) + u \quad (1)$$

where ω is the learning coefficient and u is the error term. The expression ΣQ represents cumulative output up to t-1.

DATA

The output Q is the annual value-added construction output at 1990 prices. It was obtained from the *Monthly Digest of Statistics*, Singapore and the *Yearbook of Statistics*, Singapore. The output values were compiled in accordance with guidelines of the United Nation. Cumulative output began from the year 1960. This corresponds to the year in which Singapore embarked on a massive public housing programme.

Labour hours were derived using the formula $L_t = E_t \times H_t \times 48$ where E_t and H_t refer to the number of persons employed (as at the end of a June in that year – i.e., the average for the year) and the average number of weekly hours worked respectively. These were obtained from the *Yearbook of Labour Statistics*, as well as the *Ministry of Labour Annual Reports*. The number of working weeks in a year is assumed to be 48. This was derived after subtracting employees average leave time (2 weeks) and the number of non-working days arising from public holidays (2 weeks). Adjustment for labour quality to reflect differences in educational qualifications and skills among workers was not done since such data were only partly available.

Capital data were taken from the *Census of the Construction Industry, 1996*, as well as the *Corporate Sector Performance and Structure, 1992 and 1997* (Department of Statistics, 1998). The latter source gives yearly capital stock data (value of net fixed assets (NFA) at historic cost) for the construction industry from 1980 to 1995. Data for the years 1970 to 1979 were obtained directly from the Department of Statistics**.** NFA was extracted from financial accounts of 3,916 firms filed with the Registry of Companies and Businesses or provided directly to the Department of Statistics (DOS) via survey. Sole proprietorships and partnerships were excluded. As of end 1995, there were 5,036 construction companies of which 4,765 are local.

Some adjustment was necessary to take into account the asset inflation in Singapore in the early 1980s and 1990s. Given the relatively high land prices in Singapore, it was assumed that 25% of net fixed assets was attributed to land and buildings. Data from the Census indicated that the ratio of real property to other fixed assets was 46%; this percentage was deemed too high since 1996 was the peak of the Singapore property cycle. The Property Price Index (all types of properties) was used to deflate the real property portion of net fixed assets. For the rest of the fixed assets (mainly motor vehicles, machinery and equipment), the selected deflator was the Domestic Supply Price Index for Machinery and Transport Equipment. Both deflators are standardised to 1990 base periods. They were taken from the *Monthly Digest of Statistics*. Current year deflators are used only for NFA deemed to have accrued for that year (this is taken as the difference between NFA in two corresponding years). The only exception was the year 1970, where NFA was deflated by the 1970 deflator. No adjustment was made for rates of capacity utilisation due to the unavailability of data. Neither was adjustment made for capital not owned but leased.

The Singapore construction industry is as defined in the *Singapore Standard Industrial Classification* (SSIC). Data for the periods 1986 to 1987, 1988 to 1990, and 1991 to 1997 were based on SSICs' 1978, 1986 and 1990 respectively. These various classifications differ only slightly. The SSIC was used by all the sources providing the data for the study. For construction, data were given under the broadest classification grouping (one-digit code).

RESULTS

Since the variables may be non-stationary, unit root tests were first carried out using standard augmented Dickey-Fuller (1979) and Phillips-Perron tests (Phillips (1987) and Phillips and Perron (1988)). Results are given in Tables 1a and 1b. The lag length is three, based on formulae suggested by Said and Dickey (1984). The testing strategy by Perron (1988) was used in the specification of deterministic regressors. The test for multiple roots follows that suggested by Dickey and Pantula (1987).

The variables ln(Q/L), ln(ΣQ) and ln(K/L) were of order I(1), I(2) and I(1) respectively and were therefore not cointegrated. Hence Equation (1) was estimated using variables in their differences. The results are shown in Table 2, together with standard ordinary least squares diagnostics. These diagnostics showed that the estimated equation is a reasonable one. The learning variable, ω, was not significant.

Table 1a: Unit Root Tests

Variables in Second Difference, I(2)

Variables	ADF									Phillips Perron								
	τ_τ	$\tau_{\beta\tau}$	ϕ_3	Std	τ_μ	$\tau_{\alpha\mu}$	ϕ_1	Std	τ	τ_τ	$\tau_{\beta\tau}$	ϕ_3	Std	τ_μ	$\tau_{\alpha\mu}$	ϕ_1	Std	τ
Lag = 3																		
ΔΔLNQ/L	-5.91**	-	-	-	-	-	-	-	-	-9.74^{+}	-	-	-	-	-	-	-	-
ΔΔLNV	-2.49	-	3.12	-	-2.25	-	3.12	-	-2.06**	-2.88	-	3.12	-	-2.76*	-	-	-	-
ΔΔLNK/L	-5.74**	-	-	-	-	-	-	-	-	-17.24^{+}	-	-	-	-	-	-	-	-

Variables in First Difference, I(1)

Variables	ADF									Phillips Perron								
	τ_τ	$\tau_{\beta\tau}$	ϕ_3	Std	τ_μ	$\tau_{\alpha\mu}$	ϕ_1	Std	τ	τ_τ	$\tau_{\beta\tau}$	ϕ_3	Std	τ_μ	$\tau_{\alpha\mu}$	ϕ_1	Std	τ
Lag = 3																		
ΔLNQ/L	-2.80	-	3.92	-	-2.53	-	3.95	-	-2.58**	-5.22^{+}	-	-	-	-	-	-	-	-
ΔLNV	-2.17	-	2.44	-	-1.24	-	2.55	-	-0.99	-1.91	-	2.44	-	-2.17	-	2.55	-	-1.93*
ΔLNK/L	-1.85	-	2.20	-	-2.13	-	2.17	-	-1.91*	-6.19^{+}	-	-	-	-	-	-	-	-

Variables in Levels, I(0)

Vari-ables	ADF									Phillips Perron								
	τ_τ	$\tau_{\beta\tau}$	ϕ_3	Std	τ_μ	$\tau_{\alpha\mu}$	ϕ_1	Std	τ	τ_τ	$\tau_{\beta\tau}$	ϕ_3	Std	τ_μ	$\tau_{\alpha\mu}$	ϕ_1	Std	τ
Lag = 3																		
LNQ/L	-0.94	-	1.03	-	-1.39	-	0.79	-	0.47	-1.7	-	1.03	-	-2.09	-	0.79	-	0.06
LNV	-1.07	-	2.51	-	-2.22	-	3.84	-	2.07	-2.59	-	2.51	-	-3.11	-	3.84	-	7.0
LNK/L	-2.47	-	3.07	-	-1.91	-	3.32	-	0.98	-2.94	-	3.07	-	-2.53	-	3.32	-	1.23

Table 1b: ADF & Phillip-Perrons Unit Root Tests Summary

VARIABLES	**ADF**	**Phillips-Perron**
	Lag=3	**Lag=3**
I(0) Variables		
LNQ/L		
LNV		
LNK/L		
I(1) Variables		
ΔLNQ/L	√	√
ΔLNV		
ΔLNK/L	√	√
I(2) Variables		
ΔΔLNQ/L	√	√
ΔΔLNV	√	√
ΔΔLNK/L	√	√

√ - Indicates Stationarity

Table 2: Estimation Results

Model 1:	Dependent Variable			Variables									Technique
	ln(Q/L)	Δln(Q/L)	ΔΔln (Q/L)	A_0	t	lnV	ΔlnV	ΔΔln V	ln(K/L)	Δln (K/L)	ΔΔln (K/L)	
1.	√	-	-	33.62 (8.83)	0.11 (3.05)	-1.36 (-3.54)	-	-	0.599 (6.63)	-	-	OLS R^2=0.86 F-Stat=23.45
2.	-	√	-	-0.02 (-0.82)	-	-	-	2.31 (1.17)	-	0.56 (4.91)	-	OLS R^2=058 F-Stat=13.75
3.	-	√	-	0.16 (2.38)	-	-	-1.93 (-3.19)	-	-	0.61 (6.42)	-	OLS R^2=0.67 F-Stat=23.24
4.	-	-	√	**0.02 (0.31)**	-	-	-	**-1.49 (-0.87)**	-	-	**0.58 (6.65)**	**OLS R^2=0.83 F-Stat=29.54; DW=2.03**

Note: Figures in brackets refer to t-statistic

POLICY IMPLICATIONS AND CONCLUSION

This study examined the significance of LBD in Singapore construction using the production function approach. LBD was not found to be significant. Model specification errors, estimation errors, and the wrong choice of LBD proxy could have influenced the study. There are, however, strong reasons to suggest why learning was not significant. The first concerns the transient and largely unskilled foreign workers in the industry. High labour turnover disrupts learning significantly (Mody, 1989; Argote and Epple, 1990; Nile, 1995). The industry has depended heavily on foreign workers, especially in the 1990s. Many foreign workers usually remain here for a short period of time, taking with them labour-embodied knowledge when they leave Singapore. It will take some time for replacement workers to learn all over again. The ability to learn also depends on workers' skills and educational qualifications (Levy, 1965; Stiglitz, 1987; Jovanovic and Nyarko, 1995; Nile, 1995).

Second, it may be due to the industry's high dependence on imported construction technology. The high dependence on imported technology may cultivate a posture of technological passivity (Frank, 1969; Rosenberg, 1970). Imported technology that is introduced too rapidly may also impede learning since it leaves little time to learn about a new technology before another is introduced (Young, 1992). However, this issue is contentious; for instance, the rate of introduction of new construction technology may not be as rapid as in the case of the manufacturing industry.

Third, the fragmentation of the industry is an impediment to learning since small firms generally do not have adequate resources to learn effectively. Learning resources such as data management systems have been identified as important for learning (Jaikumar,1986; Mody and Wheeler, 1987; Mody, 1989; Nile, 1995). Small firms also have less past experiences to learn from because of the smaller volume of operations handled by them. This is compounded by the ad hoc nature of their work, which frequently leads to organisational forgetting (Argote and Epple, 1990; Argote, Beckman and Epple, 1990).

Clearly, there is a need to re-examine the high dependence on unskilled foreign workers and retain the skilled ones so as to exploit learning experience. Learning to effectively use foreign construction technology is also an area that has not been emphasized and needs further attention. Finally, consolidation of the industry appears necessary to facilitate learning.

Ultimately, measures should be implemented at all levels – individual, project, corporate as well as industry - to encourage learning. A change of mindset elevating the importance of learning as a productivity tool is a good start.

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The Elasticity of Capital-Labour Substitution in Singapore, Hong Kong and Japanese Construction

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Abstract

An important issue is improving construction productivity is the flexibility in which capital and labour may be substituted. Using the production function approach and time series data, the hypothesis of a unitary elasticity of factor substitution could not be rejected for the Japanese and Singapore construction industries. In contrast, the estimate for the Hong Kong construction industry was much lower and inelastic. Various tentative hypotheses were explored to explain the difference.

Keywords: Elasticity of substitution, construction productivity.

INTRODUCTION

The purpose of this paper is to estimate the elasticity of capital-labour substitution for the Singapore, Hong Kong and Japanese construction industries. The study is motivated by two factors. First, construction productivity is a key policy issue given the allegedly low productivity in construction in both the developed and developing countries (Stokes, 1981; World Bank, 1984). Second, there are few estimates of the elasticity of capital-labour substitution in construction. The only available studies are by Cassimatis (1969) for the US and Tan (1996) for Singapore. In both cases, the hypothesis of a unitary elasticity of factor substitution could not be rejected. In a related work, Risager (1993) reported a high degree of substitution between skilled and unskilled labour in Denmark.

This study extends Tan's (1996) work to include the Hong Kong and Japanese construction industries. These countries are chosen because of their economic dynamism and different institutional structures. The laissez faire approach in Hong Kong may be contrasted with the more interventionist strategies adopted by the Singapore and Japanese governments.

THEORY

The neoclassical production function relates a firm's output Q as a function of capital (K) and labour (L) inputs so that $Q = f(K, L)$. It is assumed that the marginal products are positive ($\partial Q/\partial L>0$; $\partial Q/\partial K>0$) but diminishing ($\partial^2 Q/\partial L^2<0$; $\partial^2 Q/\partial K^2<0$). If K and L are continuously differentiable, the infinite combinations of inputs required to produce a given output Q trace out an isoquant convex to the origin. The slope of an isoquant gives the rate in which one factor may be substituted for another without altering the level of output. The absolute value of this slope is the marginal rate of substitution (MRS), that is,

$$MRS = dK/dL$$

Since the MRS depends on the units of measurement, a more appropriate measure of the curvature of the isoquant is the elasticity of substitution

$$\sigma = \frac{d(K/L)/(K/L)}{d(MRS)/MRS}. \qquad (1)$$

If firms maximise profits under competitive input and output markets, the marginal productivity conditions are (see Henderson and Quandt, 1986)

$$\partial Q/\partial K = r/p; \text{ and} \qquad (2)$$

$$\partial Q/\partial L = w/p \qquad (3)$$

where p is unit output price, r is the rental rate of capital and w is the wage rate. To apply Equation (3), the production function needs to be specified. A common specification is the constant elasticity of substitution (CES) production function (Arrow et al., 1961)

$$Q = \tau[\delta K^{-\theta} + (1-\delta)L^{-\theta}]^{-\varphi/\theta} \qquad (4)$$

where τ is the efficiency parameter, δ is the distribution parameter, θ is the substitution parameter [$\sigma = (1+\theta)^{-1}$] and φ is the returns to scale parameter (assumed to be unity). Thus, from Equations (3) and (4), we have

$$(1-\delta)(Q/L)^{1+\theta}/\tau^{\theta} = w/p. \qquad (5)$$

The efficiency parameter τ is often assumed to be of the form

$$\tau = \tau_0 e^{gt} \qquad (6)$$

where τ_0 is a constant, t denotes time, e is the base of natural logarithm and g is the rate of technical progress. Substituting Equation (6) into (5) gives the estimating equation

$$\ln(Q/L) = \text{constant} + \sigma\ln(w/p) + (1-\sigma)gt \qquad (7)$$

By adding a disturbance term, the estimated coefficient of ln(w/p) gives the required elasticity of substitution.

DATA

(a) Singapore construction industry

The annual data for the Singapore construction industry (see Table 1) are taken from the *Year Book of Statistics* (DOS, various issues). The dependent variable Q is the annual construction output at constant 1968 market prices. The labour input, L, is approximated by the product of the number persons employed in the industry per year and the average weekly hours worked. The data underwent many different classifications. The Census estimate for 1990 was adjusted downwards by taking the average of the 1989 and 1991 figures. For the other years, no adjustment was made since the reclassification does not appear to substantially inflate the employment figures.

The time variable t is set to 1 for 1982 and so on until 11 for the last year (1992). The wage rate, w, is based on the nominal weekly earnings in the construction industry. It is then deflated by the consumer price index. In certain years, only average monthly earnings are reported and these are converted to weekly figures by dividing by 4.36.

(b) Japanese construction industry

For the Japanese construction industry, the data are taken from the *Monthly Statistics of Japan* (Statistics Bureau, various years). The dependent variable Q is the total construction works completed annually in the private and public sectors. It includes buildings, residential, mining, manufacturing, commercial and civil engineering works. It is deflated using the construction deflator for 1961-84; thereafter, the wholesale price index for construction materials (1990=100) was used as a proxy.

The labour input, L, is obtained by first multiplying the number of persons employed in the construction industry annually by the average weekly hours worked and then by 46 (taking into consideration holidays and annual leave) to convert it to annual input in man-hours.

The independent variable t is set to 1 for the first year (1961) and so on until 38 for 1998. The wage rate, w, is constructed from the nominal average monthly earnings per regular employee in the construction industry. It is then converted to annual earnings and deflated by the consumer price index p.

(c) Hong Kong construction industry

The annual construction output (Q) from 1982 (t = 1) to 1995 (t = 14) is obtained from the *Hong Kong Annual Digest of Statistics* (Census and Statistics Department, various years). Q is the nominal gross value of construction work performed by main contractors (including general and special trade contractors). It is deflated using the implicit GDP price deflator to obtain the real output.

The number of persons employed in the construction industry is obtained from the *Labour Market Information for Hong Kong, China* (APEC HRD LMI Database, 1998). Since the weekly man-hours worked in the construction sector is not available, the weekly working man-hours in non-agriculture activities in the *International Marketing Data and Statistics* (1998) is used as a proxy. The number of weeks in a year in which a construction worker is employed is assumed to be 46 weeks. This number is obtained by deducting three weeks of public holidays, two weeks of annual paid leave and one week of sick leave from the annual 52 weeks.

The wage rate, w, is obtained from the *ILO Labour Statistics Database* (ILO, various years). The published data are based on the nominal daily wage rates for the government project workers. These daily wage rates are multiplied by 5½ days to derive the nominal weekly wage rates. These are then deflated by the consumer price index taken from the *Hong Kong Annual Digest of Statistics.*

RESULTS AND DISCUSSION

The results of the estimation are given in Table 1. The standard diagnostic checks indicate that the regression is reasonably reliable. For the Japanese case, the Durbin-Watson statistic was too low and the model was re-estimated using nonlinear least squares with an AR(1) error term. The main conclusion is that the hypothesis of a unitary elasticity of substitution cannot be rejected for Singapore and Japan. For Hong Kong, the elasticity of substitution is much lower. Several preliminary hypotheses may be put forward to explain the difference.

Table 1: Estimation results.

	Singapore	***Japan***	***Hong Kong***
□	1.80 (±0.52)	0.98 (±0.27)	0.49(±0.18)
g	0.131	-0.961	0.045
Durbin-Watson statistic	1.67	1.97	1.65
R^2	0.69	0.94	0.92

(a) Availability and diffusion of technology

It is unlikely that required technology is not available. Although research and development expenditure in Hong Kong (and Singapore) is lower than that of Japan (see Hasegawa, 1988; Webster, 1994), foreign contractors who dominate both the Hong Kong and Singapore construction markets may still import the technology. Little is known about the rates of diffusion of construction technology in the three countries.

(b) Access to bank credit

Most construction firms in the three countries are relatively small (Ganesan, 1982; Hasegawa, 1988). Access to credit is generally difficult for small construction firms since banks tend to view them as risky enterprises. In Hong Kong, banks have also been predisposed towards providing short-term trade credit and working capital. Longer term loans for R&D and capital investment have been relatively scarce, even for large firms (Berger and Lester, 1997).

Nonetheless, access to bank credit does not appear to be a major constraint. Other forms of non-bank credit are available in all three countries. For instance, small Japanese contractors may obtain credit through the construction equipment mortgage system, from main contractors or specialised institutions. In Singapore and Hong Kong, various financial assistance schemes are also available to small contractors (Ganesan, 1982).

(c) Labour resistance

Labour resistance may impede the introduction of new plant and equipment. Firms may not respond to relative factor price changes in the manner predicted by standard price theory. Instead, institutional channels operating in the form of work rules may restrain the employer from fully adjusting the capital-labour ratio in response to higher wages (Freeman and Medoff, 1981). Empirical studies are ambiguous on the proposition that the elasticity of substitution should be lower where unionisation was stronger (Maki and Meredith, 1987; Clark, 1984).

The non-competitive role of Japanese unions in labour-management relationships may make it to easier for firms to adoption of new products and technology. It has been suggested that, because the Japanese labour expects management to act in their employees' best interest, workers are more receptive towards mechanisation (Takezawa and Whitehill, 1983). In Singapore, the similar tripartite arrangement between the government, management and workers may operate in the same manner. Since 1968, Singapore had enjoyed virtually uninterrupted industrial peace with the introduction of the Employment Act and the Industrial Relations Act.

Nonetheless, labour resistance does not explain the difference in the elasticity of factor substitution since powerful industry-wide unions are also absent in Hong Kong (Rowlinson and Walker, 1995). Further, the three main characteristics of the Japanese style of management, namely, life-long employment, house unions and seniority wage scale system are undergoing change amid the recession of the 1990s. Life-long employment for regular employees in big corporations is no longer guaranteed. Office and factory automation have undermined the skills and experience of the regular male factory worker and contributed to the declining power of house unions. Finally, the seniority wage scale system has also declined in importance as the labour market becomes even more fragmented by status (regular or part-time employees), age, education levels and gender (Itoh, 1990).

(d) Instability in construction demand

Firms may not substitute capital for labour if future workloads are uncertain. In all three countries, the massive public housing and infrastructure programmes provide some stability in workloads. Further, in Japan, the main contractor virtually guarantees profit for the subcontractor to ensure his loyalty and the government decides on the percentage of public works that should be carried out by small and medium enterprises (Ganesan, 1982).

Despite these efforts to stabilise construction output, volatile fluctuations are not absent in all three countries. Even in Japan, the main contractor is unable to offer all its loyal subcontractors work in a prolonged recession. Public sector house-building is also limited by differing views on the role of public housing construction in stabilising demand. If it is used in a counter-cyclical manner to even out general business fluctuations, then construction output itself must be counter-cyclical (Colean and Newcomb, 1952).

In sum, demand instability does not appear to be a major factor influencing the flexibility of factor substitution. All three countries experienced considerable fluctuations in construction output.

(e) Labour supply

The availability of labour affects capital-labour substitution in a dynamic way. If labour shortages are viewed as temporary, firms with unstable workloads are less unwilling to mechanise when relative factor prices change. Consequently, a dual construction labour market comprising of a core of regular employees and a secondary belt of temporary (and less skilled) workers exists (Averitt, 1968).

All three countries are plagued by the shortage of skilled construction labour. The reasons include the fast pace of economic development that outstripped the growth of labour supply, rapidly ageing populations (Sako and Sato, 1997), and the perception that construction work is dirty, risky and unrewarding, leaving the industry with residual labour.

The responses to labour shortage are quite different. In Japan, the number of foreign construction workers is negligible (Hippoh, 1983) and firms are more pressed to substitute capital for scarce labour. In contrast, Hong Kong and Singapore rely on foreign workers, both legal and illegal (Ganesan, Hall and Chiang, 1996; Ofori, 1997). Apart from its effects on the elasticity of factor substitution, enforcement is also a major problem when dealing with illegal foreign workers.

(f) Site constraints

Firms may be reluctant to substitute capital for labour in response to changing factor prices if site and traffic constraints prevent full utilisation of construction equipment. Prefabrication may not be used if the components are difficult to transport. The situation seems to be most severe in Hong Kong where the population density is highest. Many parts of Hong Kong are hilly and mountainous. Possibly unknown to the casual observer, most buildings in Japan are not built to maximum densities (Noguchi, 1994). Apart from topography, land ownership is also fragmented in all three countries.

(g) Lack of appropriate skills

Machinery cannot be properly introduced if workers lack the skills to operate them. In terms of generic skills, the average level of education is highest in Japan, followed by Hong Kong and Singapore (UNDP, 1998). The education levels in the two cities are broadly similar. There may be a threshold effect whereby education levels affect productivity significantly beyond the elementary level of schooling (Lau et al., 1993).

Retraining of the existing pool of labour may have an impact on the elasticity of substitution. Such training is not emphasised in the construction sectors in Singapore and Hong Kong.

(h) Competition

The extent of competition may also affect the elasticity of substitution. The construction industries in all three countries are competitive; in Hong Kong and Singapore, competition is intensified by the penetration of foreign contractors into the domestic market. Although the entry of foreign contractors into the Japanese market is relatively recent (since the late 1980s), the structure of the Japanese construction industry is also competitive (Ganesan, 1982).

CONCLUSION

A crucial aspect in improving construction productivity lies in the ability to substitute capital for labour. The elasticity of capital-labour substitution was found to be relatively more elastic for Japan and Singapore than for the Hong Kong construction industry.

Several tentative hypotheses were explored to explain the difference. The availability of construction technology, access to bank credit, labour resistance, instability in demand and competition do not appear to have major effects. Labour supply, site constraints and the lack of appropriate skills appear to be more important.

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Technology Mapping: a contribution to the Management of Resource Development for Construction

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Abstract

Technology Mapping studies address the technology status and the technological capabilities in production sectors. The concept of technological capabilities only emerged during the last few decades. It comprises the stock of national resources that can be committed to the production systems. The technology status in a sector and the technological capabilities were mentioned to be the major elements that seem to separate the winners from the losers in nations and between them. Technological capability building is seen as a gateway towards an improved production performance through an optimal exploitation of a sector's potential resources.

It is stressed that Technology Mapping studies should be carried out to bring in the, so far missing, technological dimension in the conventional economic analyses of the production performance in sectors. The results of the technology Mapping studies should benefit the resource management and policy planning in an industry like the construction industry.

In this paper, the results of the application of a methodology for Technology Mapping Studies are presented. These studies were carried out in the residential building construction sector for the lower income households in Tanzania and Costa Rica.

Keywords: Technology Mapping, methodology, Technological capabilities, Resource development, Construction Management, Socio-economic development, Tanzania, Costa Rica.

TECHNOLOGY MAPPING: USEFUL FOR MANAGEMENT PURPOSES?

Emergence of new theoretical views on technology

Worldwide, an increased international competitiveness to survive can be noticed, at least in terms of economic survival. At the same time, there is a worldwide dependence on the same scarce and limited resources, that are being exhausted if no preventive actions are taken. The majority of the natural resources and a considerable amount of human resources are provided to the international market by the developing countries. These countries have the most problems of economic growth and sustainable societal development. The above points highlighted the need for further thinking about the paths to be taken to reach sustainable societal development goals in countries by making use of their available resources.

The process of societal development requires economic growth. At the same time, an effective and efficient deployment of resources in production processes is needed. This indicates a *challenge for resource management* to achieve the desired societal development goals. It also indicates the need for technology development to optimize the allocation and scale of the use of resources and process technologies in production processes, which results in a more effective output at lower costs and higher quality. Technological capabilities enable firms and nations to maintain and upgrade their production performance in order to follow the rapid pace of socio-economic development. Technological capabilities comprise the stock of national resources that can be committed to the production systems in a country.

The status of technologies and the technological capabilities were recognized as the major factors that determine the competitiveness of a nation (Bell, et al., 1984; Fransman, 1984). Porter (1990) states that a nation's pace of development depends on the capacity of the totality of its industries to make use of the available resources, utilize technologies and to innovate.

Due to a lack of technological capabilities, a country may fail to use scarce resources efficiently, resulting in rather high costs to enterprises and to the national economy. This becomes evident in the inefficiency of utilization of the existing facilities, declining productivity over time, a high and continuing degree of dependence on imported inputs and technologies, a lack of local technological infrastructure and therefore limited integration in industry. The result is an increasing technological dependency position and a missed opportunity to create a *technological self-reliance situation* (Fransman, 1984; Lall, 1982, 1985, 1987, 1990, 1992; Stewart, 1978; Rosenberg, 1986). *Technological self-reliance* is defined as the *autonomous capacity* to make and implement decisions and thus to exercise choice and control over areas of partial technological dependence or over a nation's relations with other nations (Stewart 1978).

These theoretical views were only introduced during the last two decades. By the late seventies, the neo-classical economists began to lose a great deal of their influence on technology-related development studies. Various scholars mentioned that the neo-classical economics could not precisely explain the role of technologies in production and in the processes of technology development. (Fransman, 1984; Lall, 1982, 1985, 1987, 1990, 1992; Stewart, 1978; Rosenberg, 1986; Nelson and Winter, 1982). The new ideas were based on the common experience regarding the patterns of industrialization in Europe, the U.S., Japan and Korea. Their successful development seemed to have thrived after human resources development and the competence to use these to optimize the allocation and scale of the use of resources and process technologies in production processes.

A less favourable socio-economic situation can be seen in countries with nearly no endogenous science and technology base (Stewart, 1978; Sagasti, 1979). International competitiveness in technology-based industries that relies on technological capabilities seemed to a new metric of national economic performance.

Defining the new concepts

The concept of *technological capabilities* has been defined in a number of ways. Like technology, it is a complex concept which encompasses both the utilization of technology and the development of technologies, either through indigenous efforts or through international technology transfers (Lall, 1982, 1985, 1987, 1990, 1992; Amsden 1989, Dahlman et al 1987, Westphal et al., 1985, Romijn 1996). There has been no discussion on the idea that technological capabilities are reflected in the efficiency and effectiveness to carry out the processes of: (1) Production by efficiently and effectively utilizing technologies; (2) searching for available and alternative technologies; (3) selection and acquisition of most appropriate technologies; (4) adaptation of technologies to suit specific production circumstances; (5) improvement of technologies (incremental developments); (6) execution of basic research and R&D for technology development either in-house, in the enterprises, or through R&D institutes.

Despite this, the definitions for the concept show a wide variety. In our studies the concept of t**echnological capabilities** is defined as **the complex totality of national resources** that can be committed to the production system in the country. This complex of national resources includes: (1) the stock of available technologies for production; (2) the stock of human resources; (3) the stock of available and exploited natural resources; (4) the technology infrastructure of institutionalized R&D, education & documentation facilities, technology and intermediate products producing and supplying enterprises and organizations that supply the financial resources to the production system to support their production processes.

This stock of national resources should supply the country with the means, skills, know-how and knowledge, to select, master and adapt the technologies that are needed and most appropriate to the social system of the country. But this stock should also enable the country to develop and generate its own new technologies (self-reliant technology generation).

Technological Capability Building and Technology Management

By taking the importance of technological capabilities as a starting point, a most obvious route to increased competitiveness and socio-economic development should then be *Technological Capability Building*. This implies that technology management should be focused on a number of efforts to increase the quantity and quality of the stock of national resources. Adequate *technology management and policy making* is recommended for technology capability building (UNESCAP 1989).

Technology Mapping

Adequate *technology management* requires insight into the explicit status of technological capabilities and technologies in production sectors. *Mapping of the status of the technological capabilities and the technologies in production processes* is thus considered an important prerequisite for management purposes.

The technological capabilities and the status of the technologies in the construction projects are considered to be reflected in the technological production performance of an industry. The mapping of the technology status takes place at enterprise and production process level. The effectiveness and efficiency of the technology utilization in the production processes are mapped. The effectiveness is measured in terms of the quality and the quantity of the production output. The efficiency is measured in terms of the quality and quantity of the process technologies and inputs of material resources in the production processes. Also the particularities of the firm level setting of the production processes are taken into account.

The mapping of the technological capabilities takes place at sector level. Four sub-studies have to be carried out for the mapping: (1) of the technology stock by means of a survey among the enterprises in the sector, (2) of the human resources stock by making use of the available statistics, (3) of the natural resources stock also by making use of the available statistics, (4) of the technology infrastructure preferably by means of a survey among the actors in the actor network of the sector or by making use of secondary sources like literature and expert opinions.

The complexity of the concept that includes the multi-dimensional aspects involved in the activities of utilisation and development of technology requires a multi-disciplinary approach in the Technology Mapping studies.

THE SECTOR OF RESIDENTIAL BUILDING CONSTRUCTION

Based on the theoretical considerations discussed above, Technology Mapping studies were carried out in the sector of residential building construction for lower income households in Tanzania and Costa Rica. The objective was to provide insights into the present and potential stock of national resources that is responsible for the performance of the sector.

Like many other countries, Tanzania and Costa Rica have to deal with *a human settlements problem*, which has a great magnitude. The enormous population growth and the unfavorable economic position of a high percentage of the population in the countries are the major factors that result in a *housing need*. The determining factors of the housing problem have increasingly become the diminishing volume of resources that are necessary for the construction of adequate shelter for all sections of society in these countries.

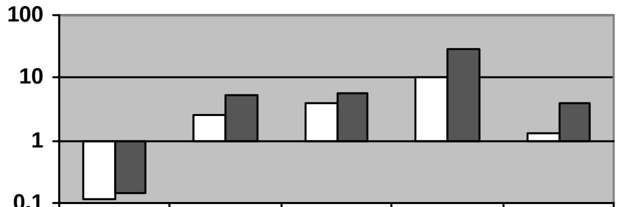
The *construction industry* has the challenging task to contribute to the alleviation of the housing problems of the lower income households. Housing supply largely depends on the production output of the construction industry. This implies a supply of more adequate (higher quality) houses, a better affordability of the houses for the households and an increased profit margin for the involved contractor. Moreover if a contractor is able to realize the construction process on site more efficiently this may contribute to strengthening his position on the construction market. The improvement of the technology status that results in a better technological production performance in the construction projects requires technology management.

Construction projects are not carried out in a vacuum and consequently in every respect the technological production performance on project sites depends on external factors in the project environment. These include at sector level the status of the stock of national resources: the *technological capabilities*. At national level the characteristics of the socio-economic and geographic-physical setting influence the production performance on the project sites

The Technology Mapping Studies resulted in data-sets on the present and the desired status of technologies and potential of resources in the construction projects. The desired utilisation of resources is assumed to lead to a *best practice technological production performance*. This production performance should meet the terms of reference for houses for the lower income households. The acquired set of information should facilitate the determination of the possible interventions by technology management and technology policies that lead to an improvement in the utilization of resources and an optimization of the technological production performance in the dwelling construction segment of the industry.

THE TECHNOLOGICAL PRODUCTION PERFORMANCE (TPP) AND THE STATUS OF THE TECHNOLOGIES IN THE PROJECTS (STP) IN THE TANZANIAN AND COSTA RICAN DWELLING CONSTRUCTION INDUSTRY

A comparison of the Technological Production Performance (TPP) at the project level -like was done in these technology mapping studies- gives insights into the internal project factors that result in a certain level of TPP. The project setting. is taken into account as an explanatory variable. The TPP in the dwelling construction sector is determined by the effectiveness and efficiency of the status of technology utilization in the construction projects (STP) : .TPP = *f* (Teffect x Tefficy)



	Teffect	Proceste	M input	Tefficy	TPP
□ Tanzania	0,12	2,61	4,06	10,6	1,27
■ Costa Rica	0,14	5,2	5,5	28,6	4

Fig 1 TPP and STP in Tanzania and Costa Rica

The TPP in the dwelling construction sector for the lower income households in Tanzania was 1.27 while the TPP in Costa Rica was 4. (0<TPP<10).

This difference in performance can be explained by the lower t*echnology effectiveness* in Tanzania that was 0.12, while that in Costa was 0.14. (0<Teffect<1). The technology effectiveness (Teffect) represents the rate to which the quality requirements (adequacy and affordability) of the houses and the quantity of the actually needed houses were met. It is remarkable that in Costa Rica only 16-18% of the required quantity is produced while in Tanzania approximately 20% of the demand are produced on annual basis. But this last (estimated) figure is questionable and is assumed to be too high. Exact data were difficult to acquire since most houses are constructed in the informal sector and are thus not registred. Nevertheless it does not change the low average effectiveness rate for Tanzania. (See figure 1, the scores are delineated in a logarithmic scale) The *affordability* of the houses scores higher in Tanzania than in Costa Rica. The houses are not affordable for the lowest income households in Costa Rica without support from the National housing financing system (SFNV). On the other hand the output of the dwelling construction processes in Tanzania is of such a quality that maintenance, repair and substitution of building components are needed nearly all the time needed, which may imply a true waste of investment. In Costa Rica the quality of the houses does not require additional investments beyond the normal maintenance expenses for a period of 25 years.

The TPP results are achieved with *a technology efficiency* (Tefficy) in Costa Rica of 28.6, while in Tanzania the technology efficiency (Tefficy) was only 10.6. (0< Tefficy < 100)

The technology efficiency is determined by the type, quality and availability of the material inputs (Minput) and the type, quality and availability of the process technologies (Processtec) that are utilized. Tefficy = *f* (M input x Processtec)

In Costa Rica, the scores for the type, quality and availability of the *materials input* (M input) in the construction projects are higher (5.5) than those in Tanzania (4.06). (0< M input < 10). A large part of the houses in Costa Rica are built with prefabricated construction systems. The requirements for process technologies on the construction site are less for these systems than for the traditional or conventional construction systems.

Also the status of the *process technologies* (Processtec) scores higher in Costa Rica (5.2) than in Tanzania (2.61). (0 < Processtec < 10)

In both countries, only simple tools and equipment are used and the labor force shows a lack of sufficient skills and knowledge. In Tanzania, contrary to Costa Rica, the level of project organization is relatively low and the availability and application of information and documentation on site is negligible. In Tanzania the majority of houses are built with the soil-cement blocks masonry system, which requires quite some knowledge and skills of the labor force on site. At the same time the largest constraint in Tanzania is the lack of knowledge, skills and experience of the labor force. The situation is even worse since the construction of houses takes place with a minimum level of information and documentation and a limited availability of tools of a rather simple nature. This confirms that the stimulation of the application of prefabricated construction systems on the construction sites contributes to higher technological efficiency.

A description of *the project setting* in qualitative terms indicates the promoting and constraining factors in the *direct project environment*. From the results of the technology mapping studies it can be concluded that the complex of variables that constitute the project setting in Costa Rica (5,5) are more favorable than in Tanzania (2,75). The project setting score is calculated by taking mean of the scores of the project setting characteristics. (0 < projectset < 10).

The *climatological and geographic* circumstances form a relative constraining factor for the TPP of the dwelling construction projects in Costa Rica. more for than in Tanzania. Both countries are located in a similar climatological area with high relative humidity levels. In Costa Rica one has to deal with earthquakes and hurricanes that require more precautions in the construction of the houses. These increase the costs of the houses. The *landform* in both countries is characterized by its differences in height. of the project site. This implies in many cases a need for heavy equipment for site preparations and leveling, which is not always available and affordable, consequently forming a constraint to the project performance. The *soil conditions* in both countries do not require specific attention for the dwelling construction projects. The houses are rather small, and simple strip foundations will do in most cases.

The *legislative environment* forms a constraining factor in the project setting in Tanzania. The house owners often have occupied non-registered land on non-legal basis. This harms their access to all kinds of facilities. Also the *size of the projects* in Tanzania has a negative impact on the TPP. In Costa Rica the houses are in most cases legally built in mass construction projects. This enhances a shorter production time, more standardization, less labor input and lower costs thanks to economies of scale.

The *financial situation* forms a true burden for optimal production performance, in particular, in Tanzania where the population has to rely on own sources of finance for their houses. Thanks to the national financing system for housing in Costa Rica the situation is less constraining for the lower income households provided that the national budget admits to continue and -even more desirable - to expand the expenditures on social dwelling construction.

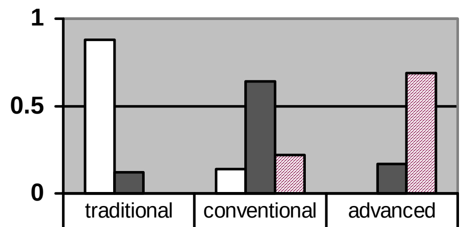
A major difference in the project setting between Tanzania and Costa Rica concerns *project management.* In Costa Rica this is in the hands of experienced and skilled project managers. In Tanzania the house owners act in the majority of cases as project manager themselves. They are responsible for the choice of the product and process technologies, for the selection and acquisition of materials, for hiring the labor force unfortunately often with too limited knowledge and skills to do it properly.

The conclusion was that legalised building in mass construction projects with proper project management provided with sufficient infrastructural facilities and financial means contributes to an improved TPP. For these last aspects the construction units depend on external factors and actors.

THE STATUS OF TECHNOLOGICAL CAPABILITIES (STC) IN THE TANZANIAN AND COSTA RICAN DWELLING CONSTRUCTION INDUSTRY

The technology mapping results in the status of the Technological Capabilities in the sector (the major external factor that has an impact on the TPP at project level are the following.

The technology stock



	traditional	conventional	advanced
Tanzania	0.88	0.14	0
Costa Rica indiv. Proj	0.12	0.64	0.17
Costa Rica mass proj	0	0.22	0.69

Fig 2 Construction systems in Tanzania and Costa Rica

The technology stock represents the availability and nature of product technologies (construction systems) and process technologies (equipment, labour force, information and documentation and organizational framework) among the contractors that can be committed to the execution of their construction projects.

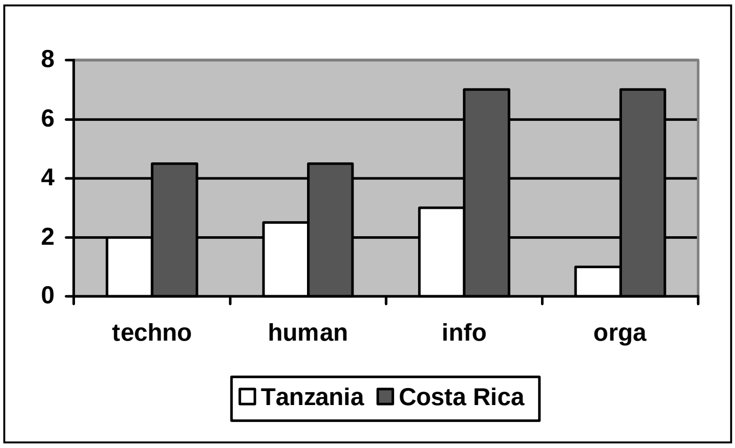


Fig 3 Process technologies in Tanzania and Costa Rica

The range of technologies available and utilized in housing construction in lower income countries like Tanzania can be ranked in the lower class of technological advancement. The major construction systems for the houses for the lower income households are still the traditional systems (88%). The foundations, walls, floors and roofing structure are in 92% of the cases still built traditionally. Only the traditional roof finishing has been substituted for 29% by clay and concrete tiles (12%) and by metal roofing sheets (17%). The application of new construction systems implies that the actual production of the houses partly moved from the construction site to the factory. This happened in Costa Rica as in many industrialized countries, but it is not yet noticeable in Tanzania. In Costa Rica, a middle income country, the technologies utilized in housing construction for lower income households can be ranked in the more advanced class. (See figure 2). In Costa Rica only some 14% of the houses is still built on the traditional way by applying the timber and zocalo systems. The majority of individually built houses are built with the conventional concrete blocks masonry system, the rest with the advanced prefab systems. The reverse is the case for the mass dwelling construction projects a higher percentage is built with the advanced prefab systems than with concrete blocks.

This is also reflected in the advancement of the process technologies used on the construction sites (equipment and tools, the level of skills and education of the labor force, the nature of information and documentation and the organizational framework). Moreover, the characteristics of the process technologies in Tanzania compared to Costa Rica show that in Costa Rica more progress has been made with regard to the level of advancement of the process technology components.

The stock of human resources

The human resources stock represents the availability and the nature of manpower stock that is potentially available and employable in the sector. Compared to Costa Rica Tanzania has the advantage of a *population size* (ca 30 million) that is ten times larger. In Tanzania (40%) and in Costa Rica (33%) belong to the *age group* that is younger than 15 years. The relatively large population size in Tanzania forms a favorable market and the number of young people forms an enormous potential of labor force for all productive activities. However these resources are not fully exploited. The problems in Tanzania concern the low life expectancy and the lack of skills and knowledge among the population. This situation is better in Costa Rica.

The difference in *level of knowledge and skills* in Tanzania and Costa Rica is reflected in the illiteracy rate and the enrollment figures in different levels of the education system. Also the ratio between the total third level teaching staff in Tanzania, Costa Rica and the Netherlands (T:CR:N= 1:10:30) indicates the existing differences in education opportunities in the countries. A relatively high percentage (91%) of the total labor force is not formally trained in Tanzania and a number is trained on-the-job. A problem is formed by the lack of training opportunities- for the labor force on the construction sites in both countries. The employment in the construction sector as percentage of the total employment in Tanzania is less than 1% (excluding the informal sector), in Costa Rica 8%, and in the Netherlands 9%. One can also notice a higher labor productivity in the Costa Rica is reached compared to Tanzania and but a lower labor productivity than in the Netherlands.

Regarding the *occupational status* of the labor force in both countries can be noticed that a relatively high percentage of the labor force is employed as craftsmen. Tanzania has to face a shortage of skilled and well-educated project managers. The Costa Rican construction industry has the disposal of relatively enough managers and engineers but a lack of skilled labor on the project sites. The percentage of scientists and engineers of total population is in Tanzania very small (0,0026%). In Costa Rica this is 0,006% of the total population and in the Netherlands the percentage is 2,5% (UNESCO 1995).

Natural resources stock

The natural resources stock represents the availability and nature of raw materials stock that is potentially available in the sector. The level of utilization of these resources reflects the capabilities to make use of these.

The *land area* in Tanzania is some 17 times more than the land area of Costa Rica and 26 times more than the Netherlands. The internal *renewable water resources* per capita are in Costa Rica more than 11 times available compared to Tanzania. Land development in Tanzania has scarcely taken place. *Deforestation* still takes place at a high pace in Costa Rica (nearly 7% per annum). In Tanzania this percentage is only 0.3 %. *Energy consumption* per capita has increased in Costa Rica (3.1%) and Tanzania (2.3%). This seemingly has contributed to a higher productivity in the countries, given the percentage of energy consumption in kg oil equivalent per US$ 100 GDP that has decreased in Costa Rica (2.6%) and Tanzania (1.3).

The availability of the *mineral resources* in Tanzania is higher than in Costa Rica. However the exploitation of these is poor in Tanzania. Unfortunately no further exact data can be given on this item. The limited natural resources are next to the limited financial resources and a relatively small local market in the country, the major constraints for the construction industry in Costa Rica. Some 32% of the total imports in the country involve the imports of raw materials; 17% of total imports involve the imports of capital goods. The building material that is in majority applied in dwelling construction at present is the concrete (92,7% of all walls 1995 est. DGE Costa Rica) Also for the majority of floors concrete is used (63,6%). The cement is produced locally. All metal products -like the reinforcement steel and metal roofing sheets-are basically imported, while for roofing the metal roofing sheets are being used in 99% of the cases. In Tanzania the major building materials for dwelling construction for the lower income households still are the local mud and poles.

The technology infrastructure

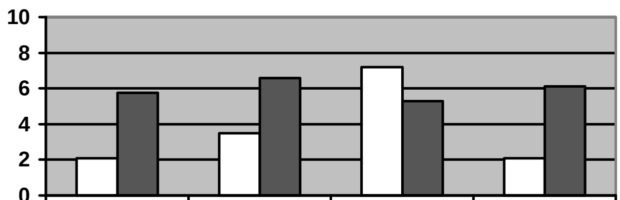
The status of the technology infrastructure represents the performance of the individual actors in the network of the sector as well as the strength of their inter-linkages. The actors include the private and public investors, the consultants, materials and equipment suppliers, R&D institutes, educational institutes, financing organisations, government, branch organisations, labour organisations.

In Tanzania various actors in the technology infrastructure have to face bottlenecks with regard to their own operations as well as with regard to the mutual relationship between them. This implies that technologies are not diffused among the actors, no mutual support is given and received to execute the construction tasks more effectively and efficiently. The project executing parties in Tanzania have predominantly connections with the informal sector organizations.

In Costa Rica the participating actors perform better, though still not optimal. The *technology infrastructure* of the dwelling construction industry in Costa Rica is better developed than in Tanzania. This might be due to the relative small size of the country and its population and the education system in the country. The role of the Camara Costaricense de Construccion (the Chamber of Commerce for Construction) as liaison between the various actors is indispensable. Despite this, it needs improvement by giving a better access for the smaller contractors to this branch organization.

Conclusions on the Technological capabilities: the total complex of national resources

From the comparison of the status of the technological capabilities in the dwelling construction industry in Tanzania and Costa Rica can be concluded that the stock of national resources that can be committed to the dwelling construction industry is not optimal in both countries. However the Costa Rican technological capabilities are more promising than the Tanzanian. The major strength and weaknesses of the technological capabilities can be noticed in figure 4. These are hold responsible for the technology status in the dwelling construction industry and the resulting TPP.



	Tech stock	HR stock	NR stock	Tech infra
Tanzania	2,1	3,5	7,2	2,1
Costa Rica	5,75	6,6	5,3	6,1

Fig 4 Technological capabilities for dwelling construction in Tanzania and Costa Rica

THE SECTORAL SOCIO-ECONOMIC PERFORMANCE IN TANZANIA AND COSTA RICA

The Technological Capabilities, the status of technologies in the construction projects and the resulting TPP are considered to be reflected in the *socio-economic performance* of the dwelling construction industry. Dwelling construction contributes to a large extent to the economic performance of the construction industry in Tanzania and Costa Rica. This does not become clear from the official statistics in Tanzania since the majority of the dwelling construction projects (95%) take place in the informal sector. In Costa Rica an average of 71% of all construction output (m2) is in dwelling construction. The sector’s contribution to GDP, GFCF and employment in Tanzania may be higher for the construction sector when the informal activities are also taken into account. From the figures on cement consumption can be concluded that the application of relatively newer materials like cement and cement products are higher in Costa Rica than in Tanzania. This is in line with the data on the building materials and construction systems which still are in majority used in Tanzania, which are the mud-and-poles construction systems. Only in urban areas like Dar es Salaam sand-cement block masonry is more applied in dwelling construction. Both countries import a large percentage of their building materials. In Tanzania this is due to the low exploitation level of the available natural resources. In Costa Rica the limited availability of local natural resources is debit for the relatively high import content of building materials in building construction projects. In both countries this enhances a vulnerability of the construction industry to international market dynamics.

The figures indicate the importance of the dwelling construction sector as a part of the construction industry and the strengths and weaknesses of its contribution to meet the socio-economic needs in both countries. (Appendix table 2).

THE NATIONAL SETTING OF TANZANIA AND COSTA RICA

The production performance in any production sector in a country is influenced by the particular conditions in the national setting. Tanzania and Costa Rica are both located near the equator with more or less the same tropical climatological circumstances and with the same kind of differences in height. A constraint in Costa Rica is formed by natural disasters due to frequent volcanic outbursts, earthquakes, land slides after heavy rains and hurricanes. Both countries were colonized, which is reflected in various aspects of the national culture - although Costa Rica became 140 years before Tanzania an independent state. The rate of *urbanization* is higher in Costa Rica than in Tanzania. This puts Costa Rica in a backward position compared to Tanzania in terms of the pressure to meet the demand for houses in the towns.

The status of the *physical infrastructure* forms a real constraint for an improvement of the TPP in Tanzania. This situation is better in Costa Rica although it is not optimal -compared to the level in other countries in the world- to benefit the TPP in various sectors including the construction industry.

The *economic situation* forms a real problem in Tanzania. Although in Costa Rica the situation is better still the investment capacity is not sufficient to provide for all social needs like education, housing and improvement of the physical infrastructure in the country. This on its turn has a negative impact on the construction industry.

The *political orientation* in both countries has a socio-democratic signature with an open market economy in which not all protective measurements for the local production activities have been abandoned. Tanzania has formulated development policies for the construction industry and the building materials industry, but the country lacks the (economic) power to implement all necessary strategies. In Costa Rica the construction industry has not been given particular attention in the national policy plans, only policies on other sectors -like the national housing plans- implicitly have an impact on construction.

From the *human development index* (HDI) of both countries (Tanzania 0,268 and Costa Rica 0,842 in 1993) can be concluded that the national setting of Costa Rica offers more opportunities for improved dwelling construction than the Tanzanian setting (Appendix table 3).

Most promising factors of the national setting in Costa Rica are the relatively small size of the country and its population and the relatively highly educated population. A most constraining factor in this country is its lack of *natural resources*, the high reliance on the agricultural sector production and the relative low industrialization, predominant production of consumer goods, although industrial production has increased during the last decades. In Tanzania the promising factors are the abundance of land area, the low density of population and the relatively large potential of natural resources. A burden in Tanzania is the investment potential, the rather low level of industrialization - reflected in the electricity consumption per capita- and the relatively low education level of its population. This makes it rather difficult to break the vicious circle of low level development, low level of TPP, such as that in the construction industry, and the increase of social needs like education and decent housing.

The countries industrial and TPP also depend on the interaction of the conditions of the home country and the country's overall performance in the global setting (Porter 1986). In terms of international trade Costa Rica scores better than Tanzania. Both countries have good international relations. This becomes visible in the support from international funds for the local investments.

CONCLUSIONS AND IMPLICATIONS FOR RESOURCE MANAGEMENT IN CONSTRUCTION

Tanzania and Costa Rica have to face a tremendous *housing problem***.** This housing problem can to a large extent be attributed to the diminishing volume of resources that are necessary for the construction of adequate shelter for all sections of society. In both countries the *TPP* is not sufficient to meet the actual need for housing in particular for the lower income households. This TPP results from the *status of technologies (STP)* that are used in the construction projects. The present *TPP* at construction project level can be attributed to the *status of technological capabilities (STC)* in the sector**.** The status of technological capabilities (STC) is equated with *the stock of national resources* that can be committed to the dwelling construction industry

From the foregoing can be concluded that the stock of national resources (technological capabilities) that is hold responsible for the TPP in the sector is not optimal. (0<TCAP<10). This status of the technological capabilities becomes evident in the limited scores for the TPP in the sector. (whereby 0<TPP<10)

		STP		*TCAP*					*HDI*
	TPP	Teffect	Tefficy	**Total TCAP**	Tstock	HR	NR	Tinfra	
Tanzania	**1,27**	0,12	10,6	**3,7**	**2,1**	**3,5**	**7,2**	**2,1**	26,8
Costa Rica	**4**	0,14	28,6	**6**	**5,75**	**6,6**	**5,3**	**6,1**	84,2

The situation as described is noticeable in the socio-economic performance of the construction industry in the countries. The dwelling construction industries in both countries take a relatively large percentage of all construction activities. But their socio-economic performance requires improvement. The national technology setting in both countries is not favorable for an optimal performance for the construction industry particularly in economic sense. The socio-economic development status in Tanzania is remarkably lower than in Costa Rica given the HDI figures.

Implications for Resource Management

It is clear that the construction industry in both countries is encountering serious problems in providing adequate shelter. Given the limited status of technological capabilities a most obvious route to improvement of the performance of the dwelling construction sector should be sought in technological capability building. It is recommended to increase the quantity and quality of the total complex of national resources that can be committed to the construction sector.

This means that resource management in the construction industry in both countries should be focussed on the following:

1. Upgrading of the Technology Stock (Tstock).
2. Development and more efficient and effective utilization of the available stock of Human Resources (HR).
3. Development of more efficient and effective utilization of the available stock of Natural Resources (NR).
4. Improvement of the performance of the individual actors in the Technology Infrastructure of the sector as well as improvement of the relationship between them (Tinfra).

It should be stated that these recommendations comprise a complex set of actions that are largely interrelated. The Tanzanian situation points at an opportunity for resource management to emphasize the development of a more efficient and effective utilisation of the available stock of natural resources that is in abundance.

In Costa Rica, the availability of a stock of human resources with a relatively high education level gives an opportunity for resource management to emphasize on a more efficient and effective utilization of these human resources for a further development of the technology stock.

The national setting of the countries, that is not very favourable in both cases, is largely determined by factors that are not directly manageable at the sectoral level. This has to be taken into account for the implementation of the technological capability building efforts. This implies that aspects of an economic and political-regulatory nature have to be considered and that additional socio-economic studies have to be carried out complementary to the technology mapping studies. Technology mapping studies give a clear direction of priorities to be set to achieve improved living conditions for the population.

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Note: The majority of data is taken from:

Egmond, E. van *Technology Mapping for Technology Management*, PhD Thesis, Delft University of Technology, 1999 (forthcoming)

APPENDIX

Table 1 Human resources stock

	size (mill)	% <15yrs	literacy % pop	second. enrollm %	tertiary enrollm %	vocational training	nr of teachers	training opportunity %	R&D staff %
Tanzania	30	40	79	5	0,02	3	10	10	26
CostaRica	3	33	98	43	28	5	30	50	60

Table 2 Socio-economic performance of the construction industry (1991)

	%GDP	%GFCF	% dwelling constr. m2	employm %t	cement prod ton/yr	cement consumption ton/cap	% import blg material
Tanzania	3	8,5	95	2	64	25	30
Costa Rica	3,8	37	71	6,5	66	220	60

Table 3 National technology setting in Tanzania and Costa Rica

	gdp/cap	growth %	GFCF %	inflation	pop-size	urbanization	HDI
Tanzania	105	3,9	38	19,4	30	23	26,8
Costa Rica	2343	6,1	20	17	3	49	84,2

The Construction Industry in Low Income Countries: An agenda for research

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Abstract

Much attention has focused on the role of construction in economic development. But in the past few decades, economic development has been restricted to only a few countries. Many low-income countries, notably in sub-Saharan Africa, have experienced economic stagnation or decline. This paper documents some recent developments in the construction sector in two low-income countries, Kenya and Tanzania. It is shown that a fall in public sector construction, accompanied by a reduction in effective regulation, has created a space for the growth of the informal sector. The various aspects of informality in construction are discussed and the implications for research assessed.

Keywords: *Construction, informal, Kenya, Tanzania, training.*

INTRODUCTION

Since the pioneering work of Duccio Turin in the 1960s much attention has been paid to the role of construction in the process of economic growth and development. On the basis of cross section of data from a large number of countries at various levels of development, Turin (1969) argued that there is a positive relationship between construction output and economic growth. Furthermore, as economies grow construction output grows at a faster rate, assuming a higher proportion of GDP. Writing at about the same time, Strassman (1970) found that the growth of construction output is particularly marked as economies pass from low to middle income, giving rise to what has become known as the 'middle income bulge'.

In a recent article Drewer (1997) returns to the 'construction and development' debate. Using data for 1990 similar to that assembled by Turin for 1970, he shows (see Table 1) that global construction output has become increasingly concentrated in the developed market economies. He goes on to argue that this new evidence does not support Turin's propositions. It is hard to see why this should be the case. The dominant role of the developed market economies in global construction is not in dispute - although it may be exaggerated by the poor quality of data in developing countries, in particular the failure to capture the now considerable output of the informal sector (see below). But the increased concentration in 1990 is largely due to the demise of the developed centrally planned economies. The share of the developing market economies in global output has actually increased over the period, although only from 8% to 12%. It seems probable that the failure of the developing economies to improve their position further is a reflection, not of the weakness of the relationship between construction and growth, but rather of the continued concentration of wealth in the developed market economies and very limited economic growth in the rest of the world.

In the period between 1970 and 1990 economic growth has been restricted to a very few countries - the Newly Industrialised Countries (NICs) and the oil producers. The vast majority of countries (comprising two thirds of the world's population) have not seen any sustained increase in per capita GDP. Many in sub-Saharan Africa in the 1980s saw GDP per capita actually decline, in what has been described as 'the lost decade for development'

(World Bank, 1989). The situation has hardly improved in the 1990s. In this context it is not surprising that global construction output should have become more concentrated in the richer countries

Table 1: Distribution of Global Construction Output, 1970 and 1990

	*% 1970 **	*% 1990 ***
Developed Market Economies	58	78
Developed Planned Economies	31	8
Developing Market Economies	8	12
Developing Planned Economies	3	2

Source: Drewer 1997

* 1970 figures are Turin's estimates ** 1990 figures are averages for 1988 to 1992

It is however surprising that so much attention is still focused on the role of construction in development - and so little on the nature and extent of construction activity in those countries (containing two thirds of the world population) that are still in a state of underdevelopment. This is particularly so in view of the fact that the least developed countries are now witnessing the most rapid rates of urbanisation in history. This paper aims to redress the balance by examining construction in two neighbouring East African countries, Kenya and Tanzania. The focus of the paper is on building activity in the cities. While the cities are growing rapidly the economies (of Kenya and Tanzania) are not. Economic stagnation and structural adjustment policies have severely reduced the public resources available for urban infrastructure and services (Stren *et al*, 1994). In both countries, public-sector building has virtually collapsed. Yet building in the private sector appears to be buoyant. Much of it is unrecorded and takes place in the informal economy. The paper unravels the various dimensions of the shift to informal construction and suggests an agenda for research.

CONSTRUCTION OUTPUT TRENDS IN KENYA

Published data on per capita GDP and construction output in Kenya for the period 1989 to 1995 are presented in Tables 2 and 3. It can be seen from Table 2 that per capita GDP fell by about 10% over the six year period. Construction output in the monetary economy also fell by 10%, with its share in GDP dropping from 3.2% to 2.5%. If estimates for building in the non-monetary economy are included, the share of construction in GDP looks a little better, but it still fell from 5% to 4.4% over the period.

Table 2: Kenya: GDP and Construction Data, 1989-95

	1989	***1990***	***1991***	***1992***	***1993***	***1994***	***1995***
GDP/capita (K£)	189	191	176	172	167	168	171
Construction GDP (K£ million)	131	134	129	122	112	113	117
Constr/GDP (%)	3.2	3.2	3,0	2.8	2.6	2.5	2.5
Non-monetary constr/GDP (%)	1.8	1.7	1.7	1.7	1.8	1.8	1.9
Total construction /GDP (%)	5.0	4.9	4.7	4.5	4.4	4.3	4.4

Source: Republic of Kenya, Statistical Abstract 1996, Government Printer, Nairobi

The fall in construction output in the early 1990s was particularly sharp in the building sector and in publicly funded projects. Table 3 shows various indices of construction output over a five year period in the 1990s. The use of 1982 as the base year, also enables comparison with the early 1980s. It can be seen that there was a very sharp decline (in real terms) in the value of both private and public buildings completed in the main towns between 1991 and 1995. In the case of public building this was a continuation of a past trend, with building in

1991 only 10%, and in 1995 only 3%, of what it had been in 1982. The decline in the value of private buildings completed was not quite so steep. But it still fell by 50% during the five-year period to only 37% of the 1982 level by 1995.

Table 3: Kenya: Indices of Building Output, 1991-96 (1982=100)

	1991	***1992***	***1993***	***1994***	***1995***	***1996***
Private building index *	81.7	66.2	44.5	34.9	37.6	
Public building index *	9.6	7.8	5.5	3.8	2.9	
Index of cement consumption	193	193	154	148	184	200
Index of employment	119.9	121.5	120.4	120.9	126.3	130.5

Source: Republic of Kenya, Economic Survey, 1996 and 1997, Government Printer Nairobi
* Index of private/public building work completed in main towns (average of 2 consecutive years)

Cement consumption also fell in 1993 and 1994 but then recovered in 1995. Provisional figures for 1996 indicate a continuation of the upward trend. The recovery of cement consumption in the mid 1990s while building output continued to decline requires explanation. As does the fact that cement consumption in 1996 was double the 1982 level, while the combined index of public and private buildings completed was only 20% of what it had been in 1982. An explanation is also needed for the maintenance of employment levels in the face of declining output. Employment in construction increased by 30% between 1982 and 1996.

The most likely explanation would seem to be that, while recorded building activity in the main towns has declined, there has been an expansion of unrecorded activity. In principle, anyone wishing to build in the urban areas of Kenya is required to submit their building plans, together with proof of title to the land, to the local planning authority (generally the city council). Permits are only issued for building on planned and serviced land. If the application is approved, the applicant will be issued with a building permit. When the building is completed it is inspected and the owner issued with a certificate of occupancy, stating that the building is fit for habitation. The data in Table 3 on the value of private buildings completed in the main towns is compiled from details of occupancy certificates issued by the city councils. However, it is now a widely recognised fact that occupancy certificates are issued for only a small fraction of the buildings completed each year. According to Syagga and Malombe (1995), 60-80% of the housing constructed in the urban areas of Kenya between 1985 and 1995 was constructed without a permit, in unplanned settlements. But building in the urban areas without a permit is not confined to housing, or to low-cost building in unplanned areas. Many buildings are today constructed without permits, including large projects and high-cost houses.

The scale and extent of unrecorded building activity in Kenyan cities is unknown. But it could be gauged from the data on cement consumption. From Table 3 it can be seen that between 1982 and 1996, cement consumption doubled (1982=100), while private recorded building activity fell by 63% and public building activity virtually collapsed. The fall in the combined index of public and private building was around 75%. This means that unrecorded building activity must have expanded by 175% to compensate for the fall in recorded activity and increased cement consumption.

CONSTRUCTION OUTPUT TRENDS IN TANZANIA

The method of collecting data for national accounts in Tanzania has recently been revised with the assistance of the World Bank. Revision was considered necessary because "some structural changes took place in the economy, which were not reflected in the available statistics, resulting in an underestimation of the national accounts" (URT, 1997:1). The main 'structural change' has been the growth of the informal economy and the collapse of government regulation and record keeping, which has led to a weakening of the 'normal data sources used by national accountants'. One such source is building permits. The document recognises that permits are not always taken out by builders and hence this is an unreliable source of data on construction output (URT, 1997). In fact this is an understatement. In Tanzania, planning and building regulations have only ever been implemented in a very restricted area of the city centres where there are serviced plots. In recent years the capacity to regulate has diminished further.

The revised methods adopted (under the tutelage of experts funded by the World Bank) incorporated new data from a number of sources including the National Informal Sector Survey (URT, 1991) covering enterprises with fewer than 5 employees; and a special survey of enterprises with more than 5 employees in the sectors of Construction, Trade and Transport (URT 1996). The revised accounts incorporate findings from these two surveys, with a whole new section on GDP in the non-monetary sector. The incorporation of these new data raised the estimate of GDP for 1993 by 100% (URT, 1997).

Table 4 shows selected data from the revised national accounts. It can be seen that GDP per capita (still one of the lowest in the world) rose slightly in real terms in the early 1990s and then fell back again. Construction output in the monetary economy followed a similar pattern, rising quite dramatically in the late 1980s to reach a peak in 1990, when it was 6.5% of GDP, before declining again to only 4.2% in 1996. However, it would be wrong to attribute the change in construction output to changes in GDP, or vice versa. In the revised national accounts, construction output in the monetary economy comprises two elements: (1) the actual value of large projects in the public sector; and (2) an estimate for private-sector construction. Public construction is heavily dependent on the level of government and aid funded expenditure. Aid inflows fluctuate widely from year to year and have been declining since 1992, and it is the fall in aid expenditure which led to the decline in construction output in the mid 1990s (URT 1997). Private construction, on the other hand, is estimated on the basis of population growth and therefore shows a regular increase from year to year.

Table 4: Tanzania: Selected Data from Revised National Accounts

	85	***86***	***87***	***88***	***89***	***90***	***91***	***92***	***93***	***94***	***95***	***96***
GDP/cap.(000shs)	49	49	49	50	50	51	51	51	50	49	49	50
Construction GDP (shs billion)	27	30	40	52	43	59	54	57	47	48	39	42
Constr/GDP (%)	*3.6*	*3.9*	*5.1*	*6.3*	*5.1*	*6.5*	*5.8*	*6.1*	*5.0*	*5.0*	*4.0*	*4.2*
Non-monetary con (shs billion)	9.9	10	10	11	11	11	11	12	12	12	12	12
Owner-occupied (shs billion)	45	46	48	49	51	52	54	56	57	59	61	63
Total constr/total GDP (%)	8.0	5.6	9.2	9.9	9.3	10	9.5	9.8	9.1	9.2	8.3	8.4

Source: Revised National Accounts of Tanzania: United Republic of Tanzania 1997

Construction in the non-monetary economy is also estimated on the basis of population growth. The estimates are shown in rows 4 and 5 of Table 4. The meaning of the data in row 5 (owner-occupied buildings) and how it differs from that in row 4 (non-monetary construction) is not clear. Also, the estimates are very high. It would seem that Tanzanian statisticians (or the World Bank) have over-compensated for earlier neglect and have now exaggerated the annual output from unrecorded construction activity. The assumption underlying the revised estimates that construction output increases each year roughly in line with population (although allowing for some increase in overcrowding) is particularly questionable. Recent research has shown a strong statistical relationship between construction output (proxied by cement consumption) and economic growth in Kenya, and between construction and aid inflows in Ethiopia (Mamaru 1997). In neither country is population growth a significant factor affecting construction output. The estimation of construction output in national accounts on the basis of population growth also renders meaningless the examination of national accounts data to detect relationships between variables. Nevertheless, the discovery in the revised national accounts of Tanzania of a large amount of building activity that was previously unrecorded and undetected does draw attention to the fact that we really know very little of what is happening in the construction sector of low income economies. Attention is now turned to unravelling the factors leading to the growth of construction in the 'informal economy'.

THE GROWTH OF THE INFORMAL SECTOR

If all construction activity carried out without a building permit and outside of the system of planning control is regarded as 'informal' then there has clearly been a large expansion in informal construction in Kenya and Tanzania in recent years. Some authors do define 'informal construction' to embrace all unplanned or unregulated housing or building activity (see for example UNCHS/ILO 1995, Syagga and Malombe 1995). As the essence of the concept 'informal' is 'unregulated', this is perfectly reasonable. However, regulation can take a variety of forms. Planning and building controls are only one form of regulation; hence failure to comply with these regulations is only one aspect of informality.

Other types of regulation by governments relate to the actors involved in the construction process. Governments often attempt to control enterprises through registration or to offer protection to workers by regulating the terms and conditions of work. Hence informal construction would be that carried out by unregistered enterprises and/or unprotected workers. Other rules and regulations are set, not by government, but by the industry itself through its representative bodies. For example, in East Africa, complex rules and procedures are in place (following the British model) for the registration and appointment of consultants and contractors. Informal construction can therefore also be interpreted as that which by-passes these rules and procedures.

The informal sector concept was originally used with reference to employment situations (Hart 1973). Thus there are formal-sector jobs where the terms and conditions of employment are regulated and workers receive some protection from the law, and there are informal sector jobs where workers are mostly self-employed with little regulation or protection. But the concept is also commonly applied to enterprises: informal sector enterprises are unregistered and generally small enough to escape detection and regulation: they operate with little capital in unregulated and competitive markets. In practice it is difficult to measure some of these characteristics and the size of the establishment is usually taken as the only criterion for inclusion in the informal sector, with the cut off point being 5 or 10 employees. The first meeting of the CIB Task Group 29 (held in Arusha in September 1998) adopted a definition of the informal construction sector that is generally in line with these approaches. Thus the informal construction sector was defined to embrace small, unregistered enterprises and individual, unprotected workers.

Small enterprises and individual, self-employed workers have always been important in construction. In developing countries they have traditionally undertaken much of the work of house construction, maintenance and repair. A number of authors have documented the process in Dar es Salaam (Tegelaers,1995: Treffers,1996: Wells *et al*, 1998). However, there is evidence from both Kenya and Tanzania to indicate that the informal sector may be growing in importance, as the small enterprises and individuals that comprise the sector take on new tasks. The developments are complex but take two main forms.

First, in the face of declining workloads many main contractors have shed their permanent workforce, preferring instead to employ workers on short-term contracts when they need them. This has opened up new opportunities for small enterprises and self-employed workers in the role of subcontractors and labour suppliers to the formal sector. Researchers in Tanzania have found that some enterprises in the private, low-income house building sector (the traditional realm of the informal sector) may also work as subcontractors supplying labour to other firms (Mwaiselage,1991: Tegelaers,1995). One of the most notable developments in Dar es

Salaam is the growth of specialised enterprises offering labour and equipment for common tasks such as concreting or block laying (Mlinga 1998). Similar developments are reported from Nairobi (Ngare, 1998).

The second development is perhaps even more significant. With the increase in subcontracting by the larger firms, and in a context of reduced effective regulation of the building and planning process, an increasing number of private-sector clients are choosing to bypass the larger firms and the more formal procedures for awarding contracts, in favour of commissioning directly small firms and individuals in the informal sector. The usual practice is to engage these enterprises or individuals on a 'labour only' basis, while building materials are purchased by the owner himself or herself. Plans may be purchased 'off the shelf' or commissioned for a small fee from architects, engineers, planners or technicians - who may be unqualified and operating entirely in the informal sector or qualified professionals offering their services in their spare time for a reduced fee.

This method of procuring buildings has been described as the 'informal construction system' (Wells, 1998). In the informal system various aspects of informality (or absence of regulation) come together. Thus the term 'informal' may be applied to the lack of regulation of the employment conditions (most workers are self-employed) and the enterprises involved (mostly small and unregistered). There is also informality in the failure to adhere to the rules and procedures set by the industry for commissioning the services of contractors and consultants. Many buildings in the informal system also fail to comply with planning procedures. However, this is not always the case. Some buildings procured through informal methods do have planning consent, while some that are built using more formal methods do not.

The method of building described as the 'informal construction system' is the traditional way for individuals to build their houses in low income countries. While the practice of engaging directly with the informal sector is still most common in the case of individual house construction, it is no longer restricted to this type of client, or to house building. In Kenya and Tanzania, quite large projects are now being commissioned in this way, including multi-storey residential blocks, up to 8 storeys high.

The shift from formal to informal methods of building is captured to some extent in published data. In Kenya, the Economic Survey of 1996 noted that the informal construction sector "continued to create more additional jobs than the modern sector" (ROK, 1996:165). Between 1992 and 1995, informal construction employment increased by 75% while formal (private sector) employment rose only slightly. However, in 1995 formal construction employment (at 47,000) was still larger than informal.

The opposite is the case in Tanzania. The National Informal Sector Survey of 1991 found 163,438 operators and employees working in informal construction enterprises (those with fewer than 5 employees) although not all were working all of the time (URT, 1991). By comparison, the number of employees in formal construction enterprises in 1994 was only 22,000 (URT, 1996). The 1991 survey estimated that 75% of the value added in construction was contributed by industries and enterprises in the informal sector. Clearly, the informal construction sector is now too important to be ignored.

THE IMPLICATIONS FOR RESEARCH

The shift from formal to informal construction would seem to have brought with it a number of benefits.

For building owners or clients there are a number of advantages in building in the informal system. First, the separation of the provision of materials and labour, and commissioning of labour for specific tasks, allows the owner the flexibility to build in stages as and when funds allow; with interest rates at a high level and loans generally unobtainable, this is very important. The purchase of materials directly by the client also gives him/her full control over the money spent, so that he or she cannot be cheated by the contractor. In Kenya and Tanzania many building materials industries have also been 'informalised', so purchasing materials in small quantities is no longer a problem. The informal system may also offer lower costs than the formal system. This is not necessarily because of lower wages (in fact there is evidence that earnings may be higher in the informal sector) but because the client accepts more of the risk and responsibility, there are no contractors profits, and the fees paid for design and engineering (if any) are at a more realistic level. In sum, this method of building would appear to offer building owners both greater flexibility and lower costs.

The informalisation of construction has also brought some benefits to the industry. While both consultants and large contractors have lost out in some areas of work, the latter have benefited from the informalisation of employment. By using the informal sector as labour subcontractors they too have been able to reduce their costs and increase their flexibility. At the same time, the subcontracting of labour and preference of clients for the informal system have opened up many new opportunities for small enterprises to operate as labour contractors. Labour contractors, whether working as subcontractors or directly for clients, do not need a large amount of working capital, hence one of the constraints to the development of small firms has been removed. While labour contractors have less opportunity than general contractors for making profits there is evidence that accumulation is taking place and at least some of these enterprises are able to grow.

However, common sense tells us that there must also be problems in the shift from formal to informal construction. Unfortunately, there has been very little research on the informal construction sector and even less on the issues that arise from its recent growth. Hence, it is very difficult to say with certainty what these problems are. But anecdotal evidence and (reading the newspapers) would point to two major areas of concern. These relate to: (1) the quality of the workmanship on buildings; and (2) the quality and suitability of designs. These problems are usually raised in the context of building in the informal system, although they may well be applicable to the industry as a whole.

The quality of workmanship on a building depends on two factors: the level of skill and the incentive system. Both require investigation. There is little doubt that the informalisation of construction has led to a general lowering of the level of skill. Even more serious is the fact that it has also severely reduced the opportunities for acquiring skill. The traditional method of acquiring skills in the construction industry is through formal apprenticeship, or by learning from more experienced workers 'on the job'. The switch to the use of contract labour has dramatically reduced the number of people in permanent employment which has led to a dramatic fall in the number of apprenticeships, and also reduced the opportunities for 'learning by doing'. While there is, in most countries, some sort of informal apprenticeship system, the level and range of skills acquired in this way is usually quite narrow. The problem has been exacerbated by the decline in government involvement in construction and fall in opportunities for employment and training in the public sector.

In this context, there is an urgent need to find practical and inexpensive ways of injecting additional skills into the system. Research should be directed towards identifying the skill requirements of particular groups of workers: devising training packages: and investigating how this kind of training might be financed, targeted and delivered.

To achieve these objectives, research will need to focus on the individual worker rather than the enterprise. The enterprises that operate in the informal system often have no premises, equipment or permanent workforce. They are mostly ephemeral, comprising a few workers who come together for the duration of the project. The project therefore seems to be the most sensible entry point for the study of construction workers.

Close analysis of the people involved in construction on a number of projects would enhance our understanding of the skills and skill requirements of construction workers operating in the informal system. It would also teach us a lot about how the informal construction sector operates, the relationships between participants, and the incentives that they face. Incentives are important in achieving high quality work. Research should therefore also be directed towards examination of the incentives in informal systems in order to see how these might be improved. The various alternative methods of organisation, supervision and payment of workers in the informal system need to be documented and examples of good practice disseminated.

The second problem – the poor quality of building designs – may also be partly a question of a lack of knowledge or skill. This is not just a problem of aesthetics. Poor design may produce buildings that are not only unpleasant to look at: they may sometimes also be unhealthy, even unsafe, and in extreme circumstances they may collapse. It could be that a little extra knowledge on the part of those undertaking the design function could lead to improved design at no extra cost (for example by incorporating simple and cheap methods of ventilation into the buildings). Research is therefore needed to investigate the skills and assess the training needs of those responsible for building design in the informal system – whether they be architects, engineers, draftsmen, technicians or builders – and to devise effective methods of imparting knowledge and skills to those who need them.

However, many aspects of bad design result not from ignorance but from choice – building owners trying to cut corners or landlords trying to maximise their returns. Some form of regulation is therefore needed. Building regulations were originally introduced in many cities to protect tenants from unscrupulous landlords. The breakdown of effective regulation of new buildings in East Africa (where the vast majority of the urban population rent accommodation) is therefore serious. It is particularly serious in the context of multi-storey building - some of which have collapsed and people have been killed.

Research is needed into the factors preventing effective implementation of planning and building regulations. It may be that these regulations are restrictive and outdated and this could be a factor in the breakdown of the system: in which case work needs to be done (in fact much work has been done) on the development of more appropriate regulations. However, it is probably more likely that the capacity to regulate new building activity has been severely diminished as a result of a combination of decreasing resources and corruption. In this situation the direction for research should be towards the development of priorities for regulation and devising a regulatory system that is far less costly to implement. A good starting point would be to investigate the `informal' rules and norms that influence the design and layout of buildings in unplanned areas of the cities.

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Technological Transition of Housing Construction in Hong Kong

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Abstract

The construction industry in Hong Kong is prudently conservative in comparison with other disciplines, especially where changes in technologies, design and methodology in the construction industry are slow to desire. Not until 1981 (Construction & Contract News, 1983) did the Housing Department stimulate the use of semi-mechanised and fully-mechanised systems for housing construction in the Housing Authority projects, then the local building contractors recognised the benefits of using more advanced techniques in building projects, with particular reference to the improvement in the quality of works and stringent demand on labour requirement.

Along with the increasing complexity in building construction and huge demand of housing needs over the years, mechanisation and industrialisation were gradually employed in various degrees for the design and construction of housing blocks. In this chapter, the development of public housing construction in Hong Kong will be reviewed, with particular emphasis on the technological aspect - from the use of traditional formwork system in 1950s to the prefabrication of concrete components in 1990s. The study also evaluates the effectiveness of different technologies in associated with the housing design to cope with the changing living standards over the years - from the resettlement blocks in 1950s to the harmony blocks in 1990s.

Keywords: Public housing; construction method; standardisation; mechanisation; prefabrication.

Figures and footnotes referred to throughout the document can be found from page 17 onwards.

BACKGROUND INFORMATION

In response to an urgent need to accommodate 53,000 fire victims rendered homeless on Christmas Eve in 1953 (Figure 1), the provision of massive public housing programme has been expanding rapidly. To date, the official figures (HKSAR Government, 1999) revealed that Hong Kong's population as 6.627 million with 3.353 million living in housing either built by the government or financed by the government-aid schemes. This means that more than 50% of the population is housed in some forms of public housing, the remainder being accommodated in privately owned or temporary dwellings. The vast majority is accommodated in 706,000 public rental flats and 257,000 subsidised sale flats, which totally account for 46.2% of permanent living quarters in Hong Kong (HKSAR Government, 1999[3]).

Being the major developer and landlord, the Hong Kong Housing Authority has made significant influence on the design and construction of buildings, leading the local construction industry from building traditionally towards the era of rationalization. By reviewing the development of building methods for public housing construction, the situations of building construction in the past can be visualised, from which it can also be treated as the milestones for formulating the future development of building construction.

PUBLIC HOUSING IN HONG KONG

Before 1953, the great majority of people were living in overcrowded and unhealthy conditions in either tenements or squatter areas. There was virtually no tradition of positive government assistance in housing provision and there was a marked reluctance to make any substantial investment whilst the trade embargo was depressing government revenues.

On Christmas Eve 1953, the worst fire in the history of the Territory broke out in the overcrowded squatter areas at Shek Kip Mei. Within few hours, 53,000 people became homeless. The usual emergency relief measures were put in hand at once but it was immediately clear that ordinary methods of resettlement would be quite inadequate to deal with a disaster of this magnitude. A major change in policy was made and it was decided to put in hand at once the construction of emergency two-storey buildings on the fire site for re-housing the fire victims as well as meeting the cost from public funds (Figure 2). Within two months, a number of two-storey structures were constructed by loadbearing hollow concrete-block walls on strip footings supporting in-situ reinforced concrete verandas with precast reinforced concrete hollow floor slabs for the upper floors (Will, 1978). The structures came to known later as "Bowring Bungalows", named after the Director of Public Works at that time (Hong Kong Housing Authority, 1993[5]).

Meanwhile, the Urban Council appointed an Emergency Sub-Committee on Resettlement to consider the measures necessary for re-housing fire-victims and to propose solutions for mitigating the squatter problem as a whole. The solutions proposed included the construction of six- or seven-storey buildings by the Government, and the establishment of a new department responsible for all matters connected with the clearance of squatters and their resettlement. Such proposals were accepted by the Government and the Resettlement Department was established by early June 1954.

During the early years since 1954, whilst the Resettlement Department was hastily erecting large numbers of basic accommodation for those made homeless by natural disasters, another organisation was formed to provide self-contained flats for low-income families living in overcrowded or unsatisfactory conditions of private tenements. This was the former Housing Authority established under the Housing Ordinance in 1954.

In 1961, the Government, disappointed with the progress in relieving the housing problem and clearing unsatisfactory private tenements, commenced another programme of housing at very low rentals for people with family income lower than the Housing Authority tenants. These self-contained estates, which was let and managed by the former Housing Authority, were termed as Government Low Cost Housing Estates.

Later, in 1965, the Housing Board was established with the responsibility for surveying the total housing effort, public and private, and advising government on the size and scope of the future housing programme and on such matters as rent levels and eligibility for public housing. However, the Housing Board, as an advisory body, was not accountable for the implementation of their recommendations. That is, the basic problem that there was no single organization having the overall responsibility for housing policy and for implementing the public housing programme still existed.

In October 1972, the Governor, Sir Murray MacLehose, introduced a ten-year housing development programme with a target of providing permanent self-contained accommodation, in a reasonable environment, for 1.535 million people in Hong Kong, which was equivalent to an average annual production of 35,000 units for the ten-year period (Hong Kong Housing Authority, 1993[5]). Besides, the Governor announced the creation of a new housing organisation to achieve greater co-ordination in government programmes.

On 1 April 1973, the reconstructed Housing Authority was formed by combining the Resettlement Department, the former Housing Authority and the Government Low Cost Housing. It is a statutory body responsible for advising the Governor on matters relating to housing, and the planning, construction, management and co-ordination of all aspects of public housing and associated amenities.

Following the complete review of Government's housing policies in 1987, the Long Term Housing Strategy was introduced in 1988 with the aim of providing a home for all those in need by 2001 and it was equivalent to an average annual production of 40,000 units (Hong Kong Housing Authority, 1993[5]). In 1993/94, a Mid-term Review on Long Term Housing Strategy was conducted and it recognized the need to increase the housing supply and the mobility of the siting tenants by compressing the construction lead time for new flats to 27 months and time for refurbishing vacated flats from six months to about 3 months, which is equivalent to an average annual production of 48,000 units (Hong Kong Housing Authority, 1995[6]) or 6 units per hour over the next few years.

TECHNOLOGICAL TREND FOR HOUSING CONSTRUCTION

Throughout the years, the housing portfolio comprises several standard building designs with different heights and plan forms to suit various site locations and layouts. The standard designs have been reviewing from time to time to meet the changing environment and higher aspirations and expectation of a prosperous populace of Hong Kong.

From an extensive literature review on the design of the housing blocks by this study, the degree of advancement on the methods of building construction throughout the years can be captured by grouping into the universal classification of building production (Foster, 1994[7]):- Traditional Building and Rationalized Building.

Traditional Building

Different forms of construction are, fundamentally, organisational devices used for economic reasons. They vary with the availability and the relative costs of building resources, especially of labour and methods and develop for reasons of economy of time, labour and materials.

In re-housing the victims of Shek Kip Mei's fire in 1953, it was (Will, 1978) reported that *"the first form being considered was single storey buildings with maximum use of prefabricated units, but the drawback was that the ground coverage would have been too high and less than one third of the homeless could be accommodated on the site cleared by the fire"*. Considering the potential growth of population and economic resources along with the limited building sites and infrastructure in tiny Hong Kong, direction was given toward the construction of multi-storey public housing blocks. As an emergency relief, a compromise was made of the quickly erection of two-storey blocks along with several six-storey reinforced concrete blocks (Figure 3) and they not only started off the extensive public housing programme in Hong Kong, but also the direction of building production towards rationalisation.

Construction of two-storey block was in a form of load-bearing hollow concrete-block walls on strip footings supporting in-situ reinforced concrete verandas with precast reinforced concrete hollow floor slabs for the upper floors. Concrete and concrete based products formed the major components of the structure for their availability, low maintenance and compatibility for precasting. As recorded (Will[4],), the first two-storey block measuring 51.7 m x 8.5 m with 68 back-to-back rooms and external access balconies on upper floors was completed in 22 days and from then onwards blocks were finished at the rate of two every three days. A total of 3,074 rooms with total floor area of approximately 65,000-sq. m were completed just over 10 months for housing 13,000 people, or equivalent to 5-sq. m per person.

Simultaneously, the plans went ahead for a basic six-storey H-shaped block containing 128 rooms per floor along the long arms of the H with six communal flush latrines per sex, two water standpipes and an open communal clothes washing space situated in the cross-piece service core. Construction was of concrete throughout and the rigidity of a modular unit dictated that the long sides of the H are constructed as a cellular form. Since no services were provided within the cubicles and each initial tenant was provided with that of amounted to simply a fire-proof, typhoon-proof and relatively hygiene shelter with a space of 2.23-sq. m, construction was simple and the main component being the cheap and hardworking labour force. The construction time for the H-shaped block, later known as Mark I Block (Figure 4), was extremely short and the time for erecting a six-storey block with 840 rooms was eight weeks (Will[4]).

After the initial 2,000 persons six-storey blocks at Shek Kip Mei were completed, examinations on how to improve the reasonable modification were made which led to the development of Mark II Block to Mark IV Block (Figure 5 and Figure 6) until 1974. During this period, quantity prevailing over quality and the local contractors were well experience in the know-how of the traditional methods of construction, i.e. the use of timber formwork and bamboo scaffolding. The situation continued for the abundance of cheap and hardworking semi-skilled/skilled labours during the fifties through seventies (Chan, 1990[8]), despite of the fact that most of the housing blocks were standardised in design. The adoption of competitive tendering system by Housing Department further enhanced the use of most economical means of traditional building construction by the successful lowest tender.

Nowadays, the traditional timber formwork is still in used for low-rise housing blocks and non-typical design of building components such as the corridor and ground floor slab and wall.

Rationalised Building

Rationalisation seeks to achieve a properly integrated system of design and production leading to continuity in all the production operations (Foster, 1994[7]). Work is planned to ensure that all the operations fit into a continuous time sequence so that the construction proceeds can be treated as a continuous operation. This approach requires a thorough organization of the whole construction process to ensure a proper flow and availability of labour and materials. Standardisation and prefabrication of components as far as possible and the introduction of mechanical plant to increase continuity and reduce labour content are used to achieve this target.

With the announcement of a ten-year housing policy and the integration of various public housing agencies in 1972 and 1973, it was clear that the emphasis of the housing policy was shifted from quantitative emergency relief and squatter-clearance to a more quality-oriented. Thus, a system approach was strategically set up for the public housing in Hong Kong and they can be grouped under the headings of standardisation, mechanisation and prefabrication.

Standardisation

Since 1st April 1973, all new public housing estates were planned as neighbourhood standard units with their own ancillary facilities such as shops, market stalls, restaurants, schools, clinics and the like. The blocks are generally shear wall construction with walls and floor slabs in solid in-situ reinforced concrete with screed finished to all floor areas. Lifts were provided for buildings higher than eight storeys and all units were self-contained. The minimum space standard was set at 3.3-sq. m per person and now increased to 7.7-sq. m (Hong Kong Housing Authority, 1993[5]).

Since then, the design of new public housing estates has been standardized and fully equipped with all the basic domestic and community facilities, attractive landscapes and recreational facilities. In general, the new public housing estates have been substantially improved in comparison with the Mark Blocks in 1950s and are even better than those of the private housing estates.

Combining the upgrading of the quality of the public housing units and the mass production of low-cost housing with better use of limited space, new designs were incorporated into the housing estates. Namely, Twin Tower Blocks, Cruciform Blocks, Double H Blocks, I-Towers, Linear Blocks, Trident Blocks and Flexi Blocks (Figure 7 to Figure 9). As a whole, the design principles have been governed basically by the economic efficiency and the standardisation of production.

Although the standard design of all the above-mentioned housing blocks enabled the repetitive use of formwork to economise the construction cost, different configuration of each block and layout of domestic units made it difficult and uneconomical to use the same set of system formwork from one block type to another. In 1989, a new series of public housing blocks were introduced and named as Harmony Blocks (Figure 10). The design of Harmony Blocks adopted an approach of modular and dimensional co-ordination based on improved standards of space requirements for the living and service areas (Hong Kong Housing Department, 1996[9]). The concept of modular 1-bedroom, 2-bedroom, 3-bedroom and 1-Person flats have been introduced in Harmony Blocks and by combining these standard modular flats, various building forms together with the opportunity of different flat mixes are available such as Harmony 1, Harmony 2, Harmony 3 and Harmony R housing blocks. The new design not only enhances the potential of inter-changeability, modularization, optimum land use and efficient method of construction, but also encourages the contractors to offer a competitive tender price through the adsorption of capital investment in proprietary method of construction over a few year period.

Considering the successful application of standard flat module concepts in Harmony Blocks, the Hong Kong Housing Authority announced a new series of Home Ownership Scheme block types called the "Concord Blocks" (Hong Kong Housing Authority, 1995[6]) (Figure 11 and Figure 12). The new blocks are expected to be used in new building tenders from late 1996 and will be available for occupation in mid 1999.

The designs of both Harmony Blocks and Concord Blocks are in standard flat modules that take advantages of using standard factory produced components and an efficient and simple construction sequence through extensive use of system formworks.

Mechanisation

The mechanisation of public housing construction in Hong Kong (Figure 13) should be made much progressively if there was no delays in the design programme for the construction of Ping Shek Estate by slip-forming in the early 1970s (Will[4]) or if the response was positive when the recommendation of using semi-mechanised construction method as stated on the tender notice by the Housing Department in 1973.

With the growing stock of housing units, maintenance cost kept on increasing for the poor workmanship and inherent limitation of traditional building method (Chan, 1990[8]). Honeycombing, misalignment and bulging of finished concrete were often found when the traditional timber formwork was employed. The situation went worse for the substantial shortage of skilled labour in early 1980s when Hong Kong experienced a construction boom. In view of increasing maintenance costs, prevailing labour shortage and upgrading standard and quality of living, the Housing Department took a big step to show their determination on a selective basis to use mechanized building methods for the construction of new public housing blocks, as stated in the Gazette in July 1981 (Construction & Contracts News, 1982[10]). To enhance the competitive edge of the contractors and enjoy the continuity of housing projects, 26 contractors in which 14 are local contractors with the remainder from overseas were qualified for tendering these pilot projects.

Mechanisation of public housing construction in various degrees has been conducted experimentally by the extensive use of large panel formworks, tower cranes, concrete pumps and other mechanical plant or equipment as illustrated in the construction of Kwong Fuk Estate Phase III in 1983 (Construction & Contracts News, 1983[1]).

Construction of Kwong Fuk Estate Phase III

"Kwong Fuk Estate Phase III is a typical example of the Housing Authority's switch from conventional to semi-mechanised method of construction …… Being the first of a series of public housing projects awarded to a mechanized contractor, …… After erecting the structural walls the precast floor slabs (each 125 mm thick) are placed into position by tower cranes …… Units of precast pre-slab (each 70 mm thick) are placed into position by tower cranes…… Concrete is ready mixed and delivered to working floors by concrete pumps. Construction of the superstructure such as floor slab casting, table form erection, steelwork and in-situ concrete topping are carried out simultaneously. Concrete cycle of the slab block is 6 days per floor, while 8 days per floor are needed for the Trident."

With the encouraging results of using large panel formwork, the Housing Department made them mandatory in all housing contracts since 1985 and it has been stated in Clause 4.11 (Hong Kong Housing Department, 1989) of the General Specification.

Clause 4.11 of the General Specification of Materials & Workmanship for Hong Kong Housing Authority Contracts

1. "Use large panel formwork for all structural walls between first domestic floor level and main roof level for all domestic blocks. For the purpose of this clause, large panel wall formwork is deemed to be formwork so fabricated that the following requirements are complied with: -

   (a) For walls not exceeding 7.5 m long, the whole of the formwork assembly for one face of the wall per storey to comprise one complete reusable panel.

   (b) For walls exceeding 7.5 m long without door/windows openings, the whole of the formwork assembly for one face of the wall per storey to comprise one or two complete reusable panels.

   (c) For walls exceeding 7.5 m long with door/window openings, the whole of the formwork assembly for one face of the wall per storey may comprise a number of panels provided that joints between panels fall within the width of the door/window openings…"

The mandatory requirement on the use of large panel formwork in this method-oriented specification does, in fact, prompt the contractors to use the reusable, durable and efficient system formworks to a larger extent. To date, different formwork systems have been widely employed by local and overseas contractors for constructing standard housing blocks and they are mainly: -

(a) Wallform

Since all the wall formwork (Figure 14) less than 7.5 m long has to be cast in one piece, it minimizes the number of joints between formwork panels; and therefore, less chance of grout leakage, stepped joints, plywood pealing off or bulging of concrete surfaces which are usually a norm for traditional timber formwork (Mak, 1998). For the durability and ease of maintenance of steel formwork, one set of formwork can repetitively be used throughout the block. For instance, one wing set of wallform is cyclically employed for the construction of Harmony 1 housing block with four wings.

(b) Tableform

Standard modules of housing blocks are relatively large in span and large tableforms (Figure 15) are widely used for its less time for assembly, reduction in the number of joints and better surface finishes. The off form surface finishes of the slab are of sound quality that the necessity for touching up and plastering is significantly reduced. Forms can be made of steel or aluminum supported either on rails along the shear walls or the previous cast slab.

(c) Tunnel Form

Unlike the wall-forms and tableforms, the tunnel forms (Figure 16) had scarcely been used until the experimental uses in the construction of Hang On Estate Phase I in 1984 (Lee *et al.*, 1987[13]) and Cheung On Estate Phase II in 1986 (Construction & Contracts News, 1989[14]). Like the wallforms and tableforms, it not only reduces the number of joints, improves the assembly time and quality of surface finishes, but also facilitates the casting of walls and slabs in one operation in one day.

(d) Other Formwork Systems

The mechanised construction of housing blocks by the above formwork systems are by way of tower crane which is heavily occupied in lifting and delivering the formwork and other construction materials. To save the crane time for other construction operations, "Climbform" and "Jumpform" which have generally been employed for the construction of commercial and office buildings were firstly introduced to the residential building construction in late 1998 for expediting the construction of central core walls and domestic structural walls.

Prefabrication

Besides the use of large panel steel formwork system, the concept of prefabrication was gradually adopted since 1953. As mentioned before, the first form of construction for re-housing the fire victims at Shek Kip Mei was two-storey blocks with the upper floors constructed by precast reinforced concrete hollow floor slabs. It was the first application of prefabrication in public housing in Hong Kong, followed by the use of large precast slabs and precast pre-slabs for the construction of Kwong Fuk Estate Phase III in 1983 (Construction & Contracts News, 1983[1]).

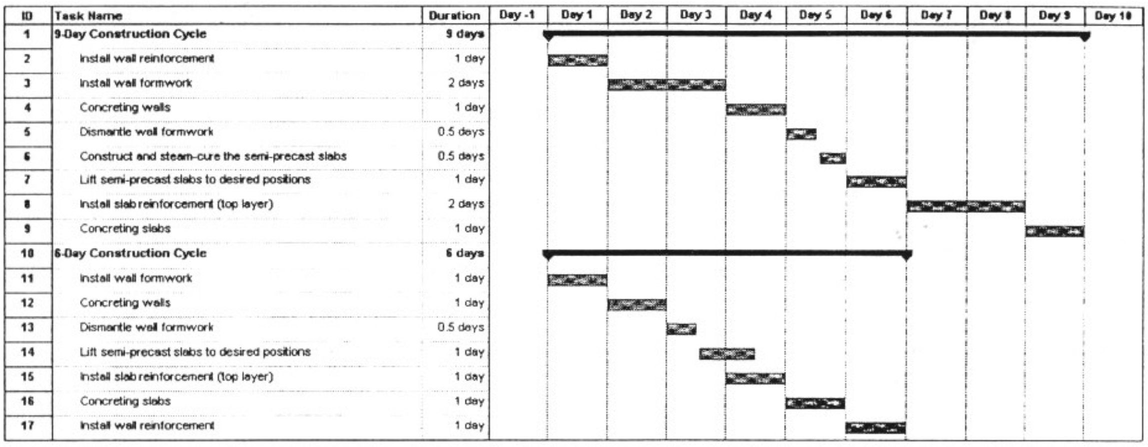
Unlike the traditional methods of construction, prefabrication guarantees the production of high quality building components and facilitates the fast track construction by removing those concreting works from critical path into non-critical and dirty in-situ works into clean all-weather precast factory production, leaving the assembly work to be performed on site. To date, the extensive use of prefabrication includes the production of precast façades, precast staircases, semi-precast slab, precast partition wall and fabric reinforcement (Figure 18 to Figure 19).

As part of the continuing drive towards achieving better quality in construction, the Hong Kong Housing Authority's Building Committee has formally approved the implementation of precast façade as a mandatory requirement on an incremental basis from March 1991 and with a view to achieve full precasting by 1994/95 (Hong Kong Housing Department, 1994[15]).

Speed of Construction

Speed of housing construction is in line with the government strategy to increase the production of housing units. Since the launch of Long Term Housing Strategy in 1988 aimed at producing 40,000 public housing units annually, the building contractors generally took 10 working days to complete one typical floor. With Mid-Term Review on Long Term Housing Strategy in 1993/4 and further implementation of mechanisation, standardisation and prefabrication in housing construction, the contractors generally took 9 working days to construct a typical floor. Since late 1996, 6-day construction cycle has been widely achieved by compressing the construction schedule, adding one more tower crane and integrating different advanced construction methods such as the extensive use of prefabrication techniques – precast façades, semi-precast slabs, precast staircases, precast dry wall partitions and the like.

Figure 20 illustrates the difference of construction cycles for constructing a typical Harmony One housing block with the employment of the same building construction techniques - semi-precast slabs, wallforms, precast façades and precast staircases. The rationales behind the dramatic difference of these construction cycles are the separation of non-critical activities and the compression of the construction schedule by allowing tasks to be executed in parallel. In the 6-day construction cycle, the construction and steam-curing of semi-precast slabs will be performed separately and the slab reinforcement will be commenced when the lifting of semi-precast slabs is 50% completed.



- Figure 20 - 9-day and 6-day construction cycles of Harmony One housing block (built by semi-precast slabs, wallforms and precast façades)

CONCLUSIONS

For a tiny Hong Kong, the extensive public housing programmes from the average annual production of 35,000 units in 1972 to more than 48,000 units for the next few years (HK SAR Government, 1997[3], HK SAR Government, 1997[16] and Tung, 1997[17]) is an extremely tight development and construction programme undertaken by any public sectors in the world. Despite the proposed adoption of a streamlined process for public housing production by the Steering Committee on Land Supply for Housing (HOUSCOM)[vii] in 1998 (Wong, 1997[18]), little emphasis has been laid on the re-engineering of building construction process. Together with the shift of housing philosophy from quantity prevailing over quality in 1950s and 1960s to quality-oriented during 1970s through 1990s, the stringent construction programme can only be made possible if more advanced building construction methods and efficient planning tools are introduced through the mutual co-operation of contractors and Housing Authority.

To accelerate the standard construction periods, the Hong Kong Housing Authority is now carrying trials on various tendering methods, including offering contractors the opportunity of proposing alternative tenders with shorter construction time, negotiated fast track contract for shorter construction time and pre-qualification for fast track contract for innovative contractors (Mak, 1994[19]).

(i) **Subsidized Sale Flats** include living quarters built under the Hong Kong Housing Authority's Home Ownership Scheme, the Private Sector Participation Scheme and Middle Income Housing Scheme, and Hong Kong Housing Society's Flat for Sale Scheme and the Sandwich Class Housing Scheme.

(ii) **Rationalization** refers to a method of building which organizational techniques used in the manufacturing industries are applied to the erection process without involving a radical change in the form of construction or necessarily in techniques of production in current use.

(iii) **Self-contained accommodation** is defined as a whole living quarter with its own entrance, water supply, kitchen, toilet and/or bathroom and occupied by one household.

(iv) **Large panel formwork system,** as defined by K.L. Chan, is a system whereby prefabricated formwork much larger than the traditional formwork, can repetitively be erected, struck and re-erected. The panel itself comprises sheathing and backing support mechanism.

(v) **More than 48,000 housing units** – On 1st July 1997, Chief Executive of Hong Kong Special Administrative Region (HKSAR) Government, Honorary Tung Chee Hwa, pledged to provide 85,000 housing units (in which 36,000 housing units will be produced by the private sector) a year over the next decade, with effect from 1999. Consider the rate of producing permanent living quarters in 1995 and 1996 (54,800 and 46,000 units), it appears that there is an emergency need to increase the revised annual production of public housing units to 49,000.

(vi) **Housing Bureau of HKSAR Government** decided to adopt **a streamlined process for public housing production** under which the average planning and development time will be reduced from 62 months to 47 months for the Hong Kong Housing Authority and from 52 months to 46 months for the Hong Kong Housing Society.

(vii) **The Steering Committee on Land Supply for Housing (HOUSCOM)** has been set up under the chairmanship of the Financial Secretary of HKSAR Government to provide a high level form within the Government for setting priorities and making decisions on land supply for housing. Besides, it will review the housing development procedures to increase the efficiency of housing production.

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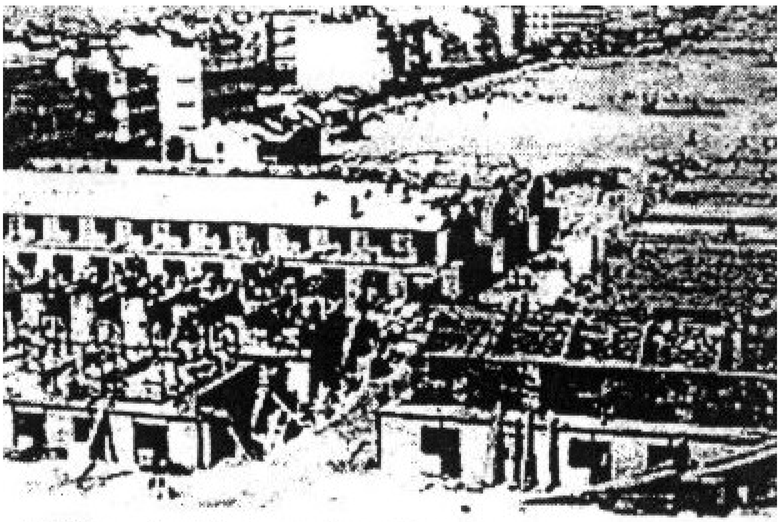
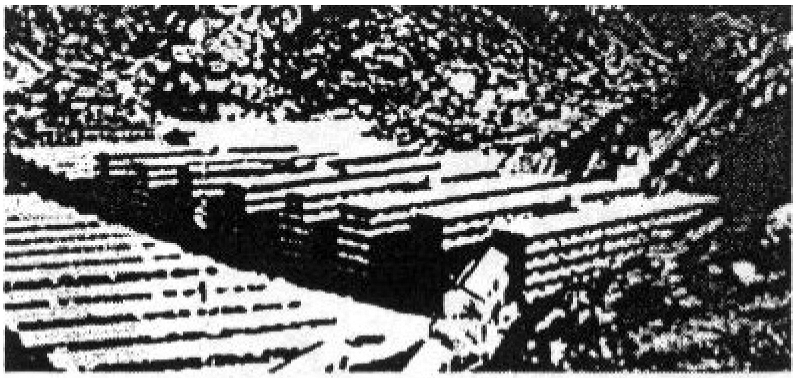
FIGURES: 1 – 19:

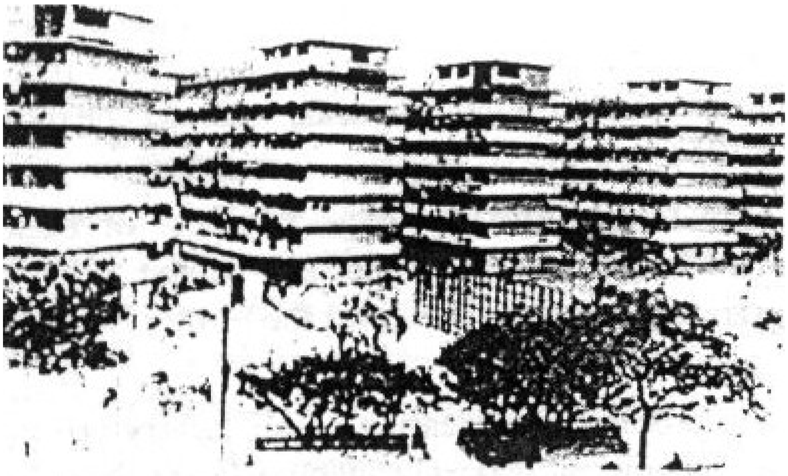
• Figure 1 - Fire swept through the Shek Kip Mei squatter area



• Figure 2 - Construction of two-storey blocks

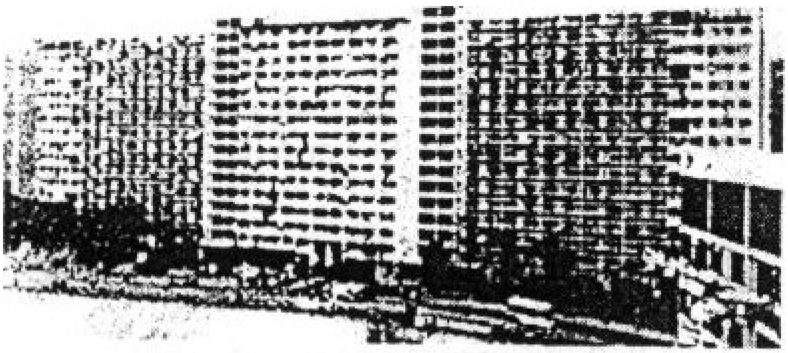


• Figure 3 - Quickly built two-storey blocks to the left and the first eight resettlement blocks to the right



• Figure 4 - Mark I Resettlement Block

• Figure 5 - Mark III Resettlement Block



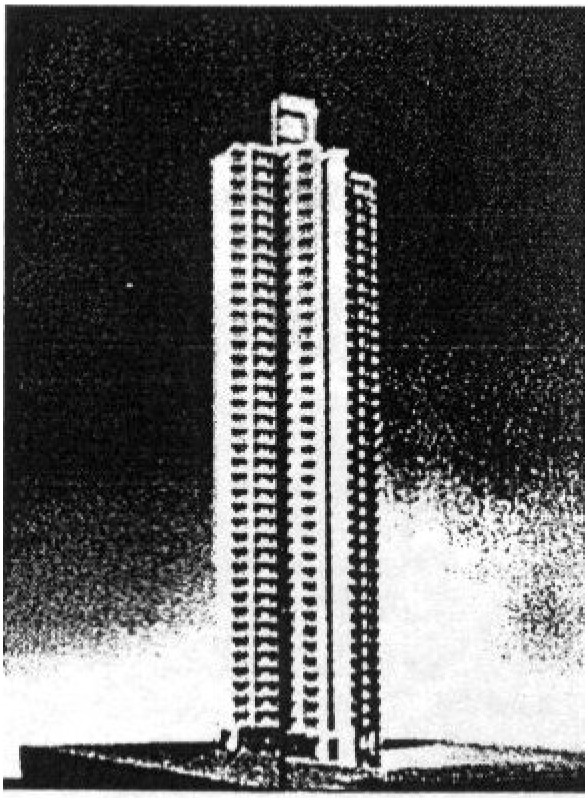
• Figure 6 - Mark VI Resettlement Block

• Figure 7 - Double H Block

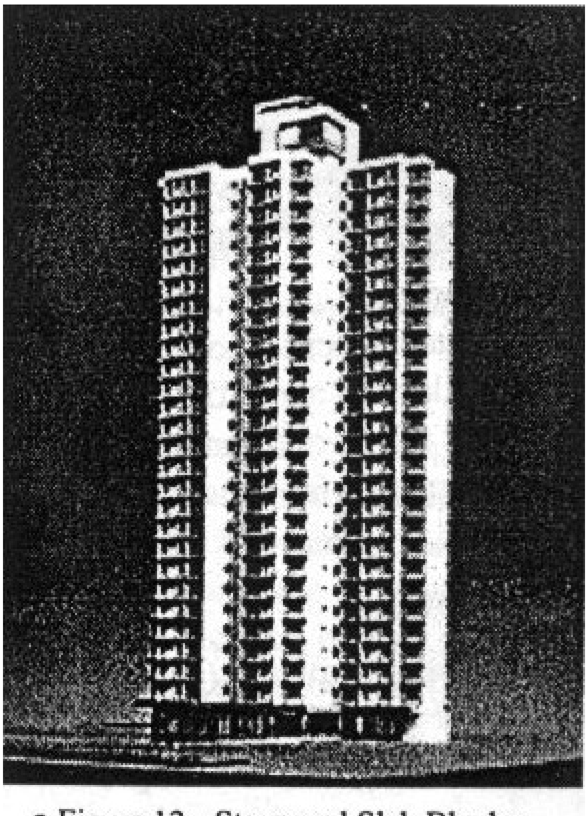
• Figure 8 - Linear Blocks

• Figure 9 - Trident Blocks

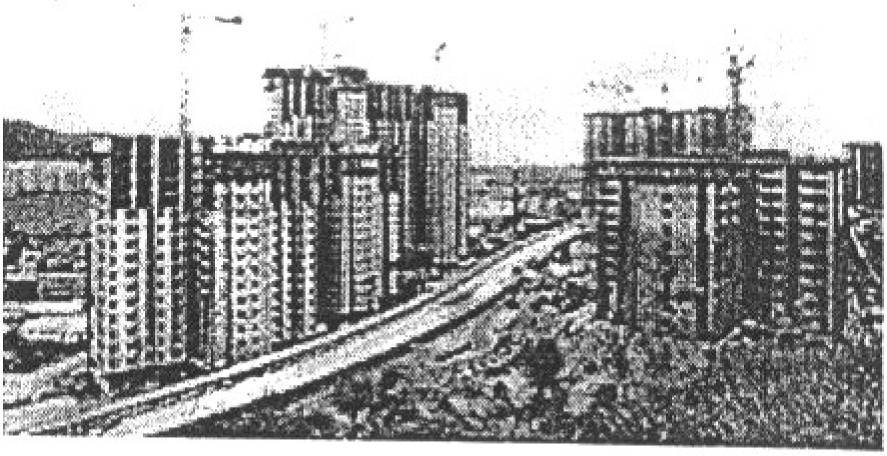
• Figure 10 - Harmony Blocks



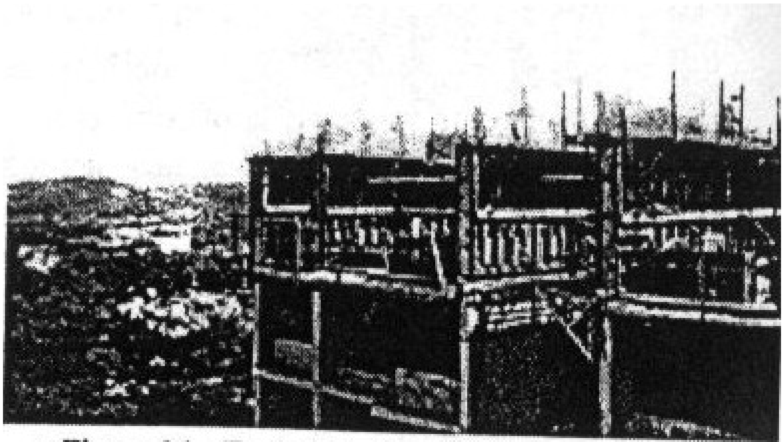
• Figure 11 - Point Blocks



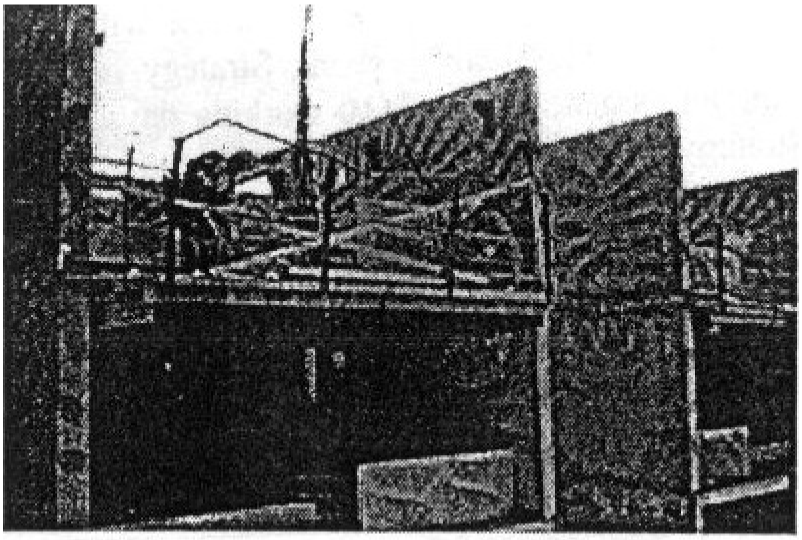
• Figure 12 - Staggered Slab Blocks



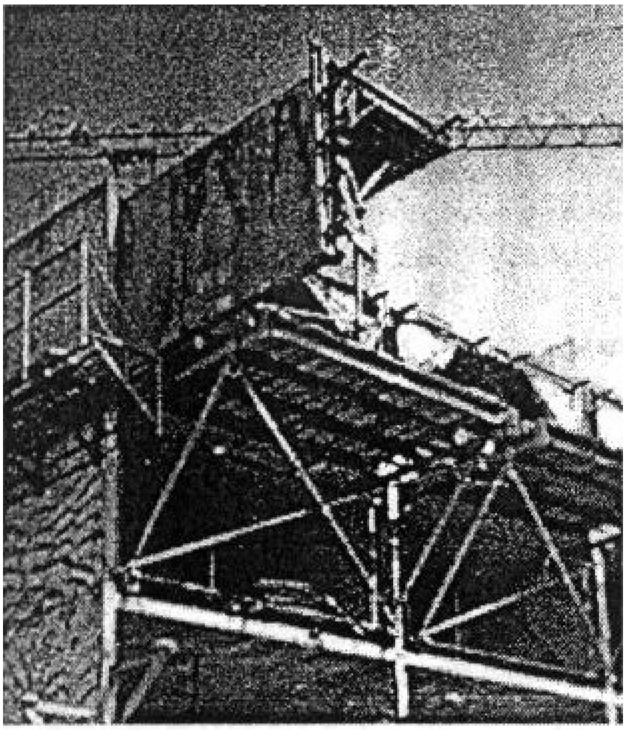
- Figure 13 - Typical public housing construction sites in Hong Kong



- Figure 14 - Typical steel wallform

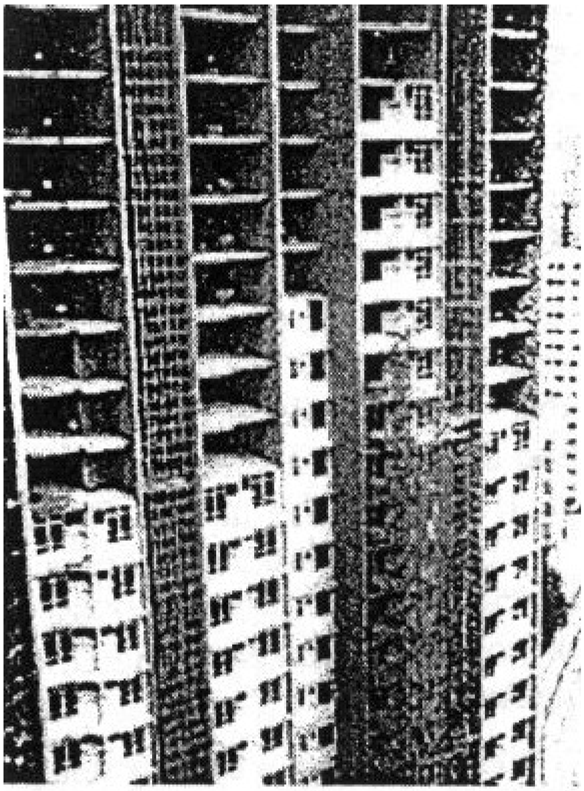


- Figure 15 - Typical steel tableform

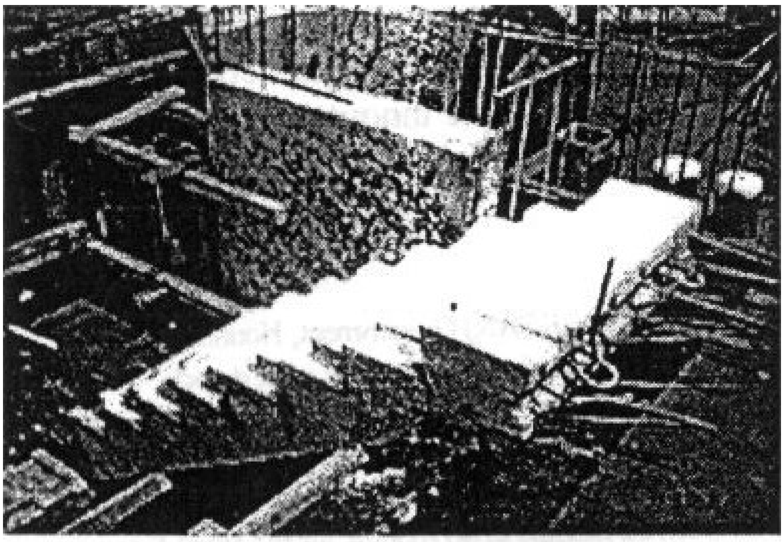


• Figure 16 - Typical steel tunnel form

• Figure 17 - Semi-precast slab construction



• Figure 18 - Installation of precast façade



• Figure 19 - Precast staircases

Classification of Construction Methods for Housing Construction in Hong Kong

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INTRODUCTION

Different forms of construction techniques are, fundamentally, organisational devices used for economic reasons. They vary with the availability and the relative costs of resources, especially of labour and methods, and develop for reasons of economy of time, labour and materials (Yau).

Public housing flats account for 46.2% of permanent living quarters in Hong Kong (HKSAR Government, 1999). The design of public housing blocks has been gradually standardised and modularised in recent years and it has lead to the development of Harmony Blocks and Concord Blocks. The Harmony Blocks, for example, make full use of modularisation and standardisation of building design and these facilitate the use of different advanced construction methods such as prefabrication and large panel formwork systems.

Standardised building design of Harmony Blocks makes its construction process rather typical compared with the private housing development. Its highly repetitive construction process generally requires only 4-10 days to complete one construction cycle. The significant difference of its construction cycle is mainly attributable to the adoption of alternative construction methods and the addition of physical resources such as labour and plant.

Through analysing the design and construction methods of the Harmony Blocks, the logical sequence of operational construction works can be systematically formulated and an optimal construction method can be chosen with particular respect to the features, constraints, the availability of resources and the construction methods of different building components.

Keywords: Public housing; building design; construction method; construction planning; method statement.

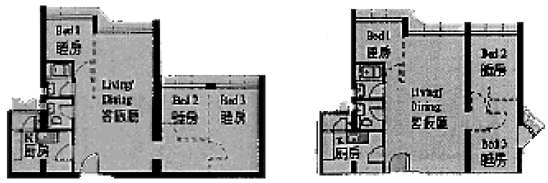
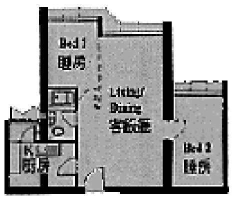
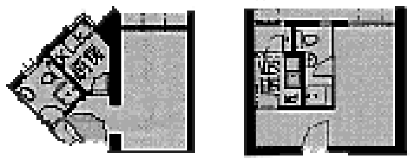
DESIGN OF HARMONY BLOCKS

The first Harmony Block building contract was commenced in late 1989 and completed in late 1992 (Hong Kong Housing Authority, 1993). The design of the Harmony series of standard blocks has adopted an approach of modular and dimensional coordination based on improved standards of space requirements for the living and service areas. A coordination grid has been established which includes structural zones, spaces and storey heights, along with key dimensions and various standard component details.

Modular Flats

Solutions for 1-bedroom (1B), 2-bedroom (2B), 3-bedroom (3B) and 1-person (1P) flats have been developed and by combining these standard modular flats (Table 1), various building forms / options together with the opportunity of different flat mixes are available which, in turn, generate different Harmony Blocks such as Harmony 1, Harmony 2, Harmony 3 (Figure 1 to Figure 3) and Harmony R (Generally speaking, Harmony R is designed for rural areas and its design varies from project to project; in view of its limited usage, its design will not form part of this discussion).

Table 1 - Design layout of modular flats

1-bedroom Flat	3-bedroom Flat
	
2-bedroom Flat	**1-person Flat**
	

Through the design of these modular flats, it is possible to standardise many of the building components, namely, external facades, staircases, floor slabs as well as loadbearing and non-loadbearing walls. Standardisation of building components thereby enables fabrication of these components off-site allowing greater scope of quality control in the whole process of production. In addition, modularisation of flats enhances the degree of interchangeability of building components within the Harmony Blocks construction. Because of this repetitiveness of modular flats, the system formwork can be deployed and transferred from one wing to another and the number of prefabricated components can also be reduced to a small number of types.

The typical sizes of different modular flats are listed in Table 2 for reference.

Table 2 - Typical flat sizes for modular flats of Harmony Block (Hong Kong Housing Authority, 1996)

Type of Modular Flats	Saleable Floor Area / m^2	Gross Domestic Floor Area / m^2
1-bedroom flat (1B)	39.9	53.5
2-bedroom flat (2B)	49.7	66.6
3-bedroom flat (3B)	55.5	74.4
1-person flat (1P)	19.7	26.4

•

Harmony Blocks

Harmony Blocks are standard housing towers designed to be constructed on a repetitive basis, at various sites throughout the Territory of Hong Kong. In view of this, different design options are available for Harmony Blocks and for modular flats. For instance, there are five options available for Harmony 1 Block (Figure 1).

Where possible, wall sections and slab soffits have been maintained as plain surfaces to facilitate the use of large panel formwork system. To complement this, the internal walls forming the kitchens and bathroom areas, and the external façade panels to the living and bedroom areas are non-structural elements, which may be added at any stage in the construction process. In other words, the construction process for these elements is not critical.

The internal non-structural walls are constructed of full height precast partition panels, 75mm, 100mm or 150mm thick as required. They are installed manually and are capable of receiving emulsion paint finish or tiles fixed with approved adhesive, thus eliminating the wet trade applications and reducing site labour content.

Harmony Block is a reinforced concrete building structure designed to act as a fully integrated unit from the viewpoint of structural design. The lateral stability of Harmony Block structure is provided by shear walls and cores acting in conjunction with floor slabs and beams. Then the lateral loads are transferred to the foundations. The floor slabs are designed as one-way or two-way spanning plates supporting by the shear walls.

Harmony 1

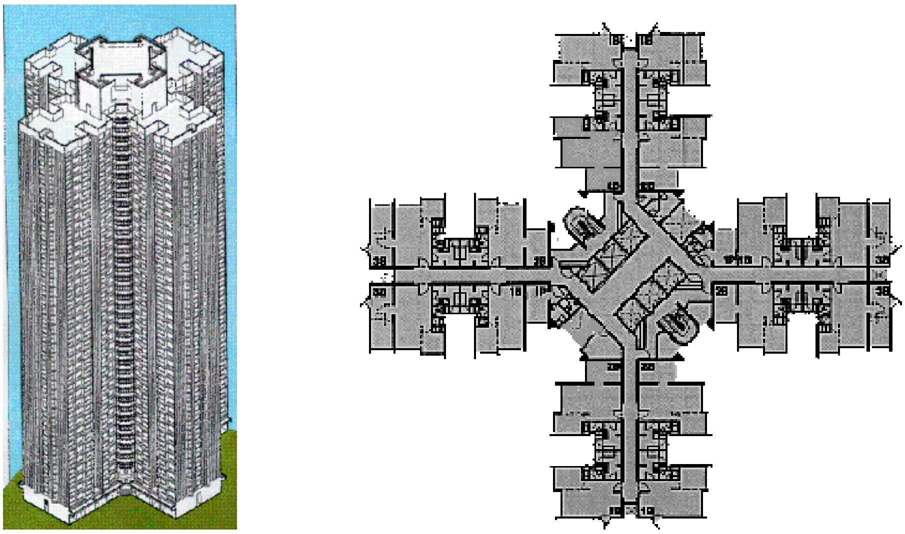


Figure 1 - Design of Harmony 1 Housing Block

Harmony 1 Block (Figure 1) comprises 38 or 40 domestic levels of typical design with the ground-floor non-domestic storey designed to accommodate ancillary facilities. The 16 to 20 modular flats per floor are arranged in four groups in a cruciform configuration attached to the central core where building services, lifts and staircases are located. This configuration satisfies the maximum travel distance of 36m within which not more than 24m shall be along a corridor (Building Ordinance Office, 1986).

Public areas on each floor such as lift lobbies and corridors are designed for maximum natural lighting and ventilation. All the corridors have been designed with open ends to meet this purpose and improved measures of security.

The compact form of Harmony 1 Block makes it suitable for use in smaller urban area redevelopment sites. Its rectangular shape also fits into the rectilinear grid of urban area and integrates well with the surrounding buildings.

Harmony 2

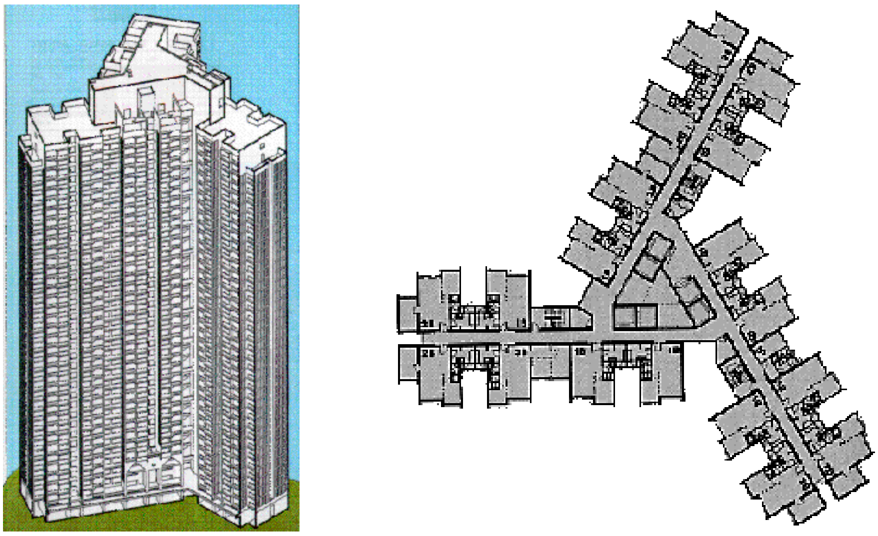


Figure 2 - Design of Harmony 2 Housing Block

Harmony 2 Block (Figure 2) comprises three wings of 36 or 40 domestic levels radiating at 120 degrees to each other from the central core where building services, lifts and staircases are located. The 18 to 21 modular flats per floor are arranged in three groups as a Trident configuration.

Derived from the modular flat design, all flat units are grouped in three identical wings. This arrangement, in large panel construction terms, enables rotational and repetitive use of formwork without the need to ground any formwork not being used in the next concrete pour.

The flat layout at the middle of the wing allows considerable flexibility of flat mixes. The 3-bedroom / 1-bedroom (3B/1B) combination is easily converted to 2-bedroom / 2-bedroom (2B/2B) or 1-bedroom / 1-person / 1-bedroom (1B/1P/1B) combinations to suit different planning brief requirements.

The configuration of Harmony 2 Block is most suitable for use in large sub-urban area sites.

Harmony 3

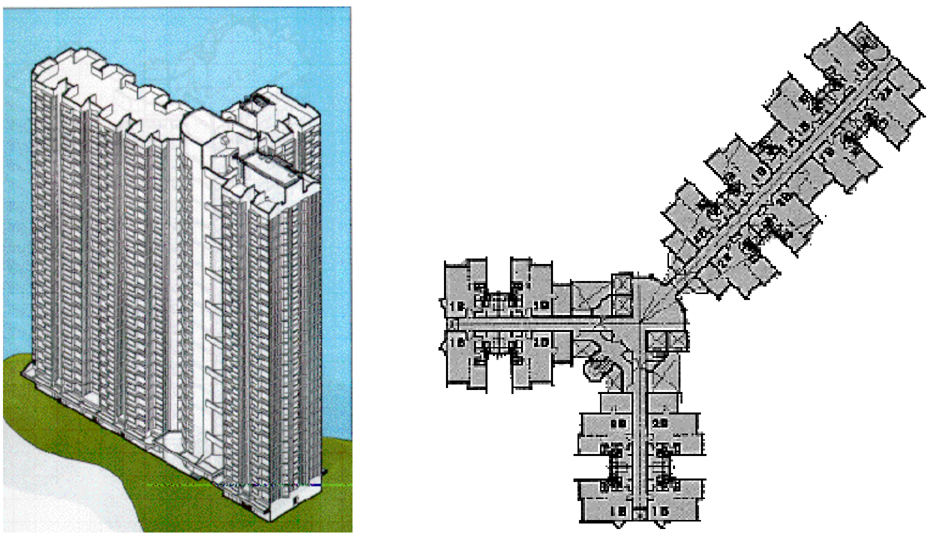


Figure 3 - Design of Harmony 3 Housing Block

Harmony 3 Block (Figure 3) with a maximum of 31 storeys (30 domestic floors) is designed to complement the Harmony 1 and Harmony 2 Blocks and to recognise the particular needs of height restrictions, restricted site conditions and specific needs of redevelopment sites. To fulfill these aims by using the standard modular flats, a "flexible" building design is introduced and it comprises two major elements: -

- Service Module; and
- Flexible Wing.

The flexible wing is capable of rotation around the service module at pre-determined angles. With optimised circulation and servicing, this concept enables forms adaptable to the varying sizes and shapes of the site, giving the opportunity to complement the geometry of Harmony 1 and Harmony 2 Blocks and optimise the site layout and land use potential.

CONTRACT PERIOD FOR HARMONY BLOCK CONSTRUCTION

The contract period for one 41-storey (40 domestic floors) Harmony 1 / Harmony 2 Block is shown in Table 3 (Hong Kong Housing Department, 1996 and 1994).

Table 3 - Contract period for Harmony 1 / Harmony 2 Block

Major Activities	Months
1. Piling and pile caps	9
2. Mobilisation and setting out	1
3. Ground floor construction	2
4. Typical floors construction (F1-F40)	12
5. Main roof construction	1
6. Upper roof construction	1
7. Lift installation and finishing work	9
Total	35

•

The contract period for the full height 31-storey Harmony 3 is shown in Table 4 (Hong Kong Housing Department, 1997).

Table 4 - Contract period for Harmony 3 Block

Major Activities	Months
1. Piling and pile caps	9
2. Mobilisation and setting out	1
3. Ground floor construction	2
4. Typical floors construction (F1-F30)	9
5. Main roof construction	1
6. Upper roof construction	1
7. Lift installation and finishing work	8
Total	31

The contract periods shown above allow no mechanical working on Sundays and Public Holidays.

For internal planning purposes, the total construction period allows for a 2-month Extension of Time for inclement weather on top of the contract period.

Table 3 and Table 4 show that a period of 12 months is required for constructing a 40 typical floors of Harmony 1 / Harmony 2 Block; whereas 9 months for a 30 typical floors of Harmony 3 Block. In other words, one typical floor has to be completed within 9 days as stipulated [(12 months x 30 days ÷ 40 floors) for Harmony 1 / Harmony 2 Block, and (9 months x 30 days ÷ 30 floors) for Harmony 3 Block].

METHODS OF CONSTRUCTING HARMONY BLOCKS

Besides traditional construction by timber formwork, various methods have been introduced for constructing the reinforced concrete structural frame of Harmony Blocks in recent years in order to strive for better quality, enhanced construction process, cost effectiveness and efficiency of production. These advanced methods can be grouped by the method of construction and they are: -

1. Large Panel Formwork Systems
   - Wallform
   - Tableform
2. Precast Components
   - Precast Façade
   - Precast Partition Wall
   - Semi-precast Slab
   - Precast Staircases

With the mandatory requirement of using large panel formwork for wall construction as stated in the General Specification (Hong Kong Housing Department, 1989), Harmony Blocks can generally be built with the following combination of building techniques (Table 5): -

Table 5 - Different combination of building techniques for constructing Harmony Blocks (T - Timber Formwork; P - Precast)

Major Building Components	**Alternatives**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Domestic Walls	Wallform											
Walls (Lift Core)	Wallform											
Partition Walls	Precast											
Domestic Slabs	Timber Formwork				Tableform				Semi-precast			
Slabs (Corridor and Lift Lobby)	Timber Formwork											
Façades	T	P	T	P	T	P	T	P	T	P	T	P
Staircases	Timber		Precast		Timber		Precast		Timber		Precast	

By combining these building techniques in various degrees, and scheduling their activities sequencing, different construction cycles and floor cycles can be achieved in order to satisfy the specific project requirements on time, cost and quality. For instance, constructing a typical Harmony 1 Block with wallforms, tableforms, precast staircases and precast façades generally requires 9 days to complete one construction cycle; whereas with wallforms, semi-precast slabs, precast staircases and precast façades generally requires 6 days to complete one construction cycle.

Besides, the construction cycles and floor cycles differ with the design of Harmony Blocks, as illustrated in their respective method statements for construction.

Method Statements for Constructing Harmony Blocks

Method statements (The Chartered Institute of Building, 1991) can take one of two forms: -

a) A detailed record of the calculation and assumptions made in the preparation of a programme; construction methods, production output levels, resource levels
b) A broader description of the intended method of carrying out a project

In Hong Kong, method statements for construction are generally submitted for those specialised and sophisticated works such as the top-down building construction, curtain wall construction and precast façades installation. Although a public housing project is typical and repetitive in nature, the clear understanding of the construction activities and their sequencing is vital to the success of the project, particularly with the emphasis of reducing the construction period. In view of this, the method statement which provides a comprehensive appreciation of the way the contractor intends to manage and execute a project is widely adopted as part of the tender bid submission and as a procedure manual for the structural frame construction.

In fact, method statements are increasingly demanded by the developers, including the major property developer in the territory - Hong Kong Housing Authority - at the pre-tender stage as a means of shortlisting contractors eligible to tender for a building project. Besides, a well-prepared method statement for work implementation will provide a blueprint against which the success of the work can be judged (Works Branch, 1996). For these reasons, considerable efforts and cost are devoted to the preparation of method statements.

Method statements can be presented in the form of a descriptive essay, in bullet form or in tabular form. In descriptive essay form, information regarding the method of construction is described in detail whereas in tabular form, information is distinctively grouped under different headings for easy reference. However, method statement in bullet form is commonly used in the Hong Kong Construction Industry for its ease of writing up.

For ease of reference, method statements for typical activities involved in the construction of major building components of Harmony Blocks are expressed in bullet form accompanied by a Gantt Chart for illustration (Figure 4 to Figure 13) and they include:-

Structural walls construction (including domestic and lift core)

1. Setting out of walls at N^{th} floor in Wing A
2. Fix steel reinforcement for walls at N^{th} floor in Wing A
3. E&M installation for walls at N^{th} floor in Wing A
4. Erect metal wall formwork at N^{th} floor in Wing A
5. Pour concrete to walls at N^{th} floor in Wing A
6. Dismantle metal wall formwork at N^{th} floor in Wing A
7. Rotate metal wall formwork at N^{th} floor in Wing A to Wing B and then Wing C to Wing D
8. Move metal wall formwork to N^{th} floor in Wing D to $(N+1)^{th}$ floor in Wing A
9. Repeat the Step 1-8 after completion of slab construction at $(N+1)^{th}$ floor in Wing A

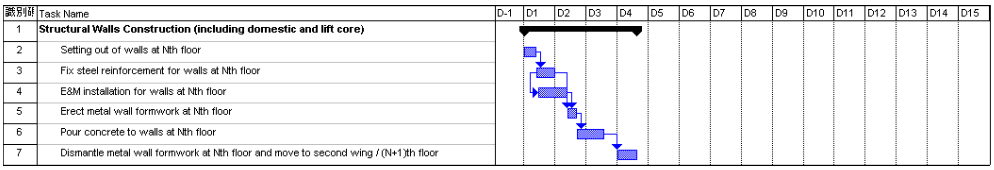


Figure 4 - Structural walls construction (including domestic and lift core)

Partition walls construction

1. Setting out of the partition walls at $(N-m)^{th}$ floor in Wing A, where $N>m$ and $m\neq0$
2. Erect precast partition wall panels at $(N-m)^{th}$ floor in Wing A, where $N>m$ and $m\neq0$
3. Repeat the Step 1-2 at $(N-m+1)^{th}$ floor in Wing A, where $N>m$ and $m\neq0$

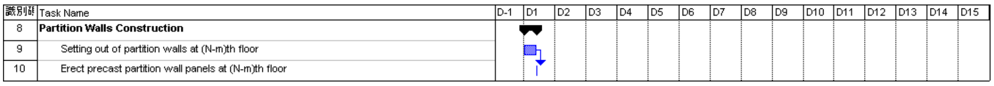


Figure 5 - Partition walls construction

Domestic floor slabs construction

<u>Timber Formwork</u>

1. Erect timber slab formwork at Nth floor in Wing A
2. Fix steel reinforcement for slabs at Nth floor in Wing A
3. E&M installation for slabs at Nth floor in Wing A
4. Pour concrete to slabs at Nth floor in Wing A
5. Dismantle timber slab formwork at Nth floor in Wing A
6. Install temporary supporting system to slabs at Nth floor in Wing A
7. Move timber slab formwork to (N+1)th floor in Wing A
8. Repeat the Step 1-7 after completion of wall construction at (N+1)th floor in Wing A

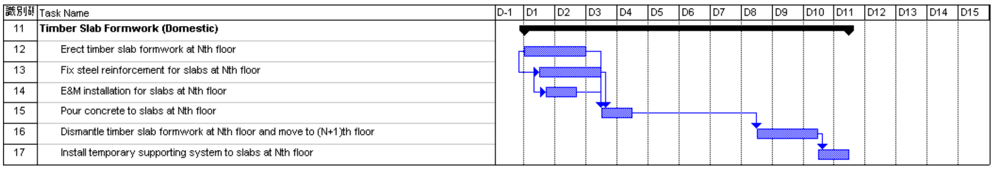


Figure 6 - Timber formwork for domestic floor slabs construction

<u>Tableform</u>

1. Erect metal slab formwork at Nth floor in Wing A
2. Fix steel reinforcement for slabs at Nth floor in Wing A
3. E&M installation for slabs at Nth floor in Wing A
4. Pour concrete to slabs at Nth floor in Wing A
5. Dismantle metal slab formwork at Nth floor in Wing A
6. Install temporary supporting system to slabs at Nth floor in Wing A
7. Move metal slab formwork to (N+1)th floor in Wing A
8. Repeat the Step 1-7 after completion of wall construction at (N+1)th floor in Wing A

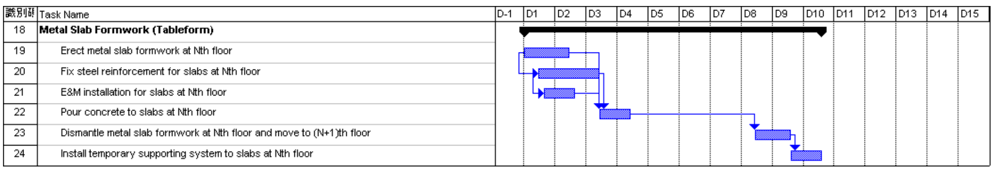


Figure 7 - Tableform for domestic floor slabs construction

<u>Semi-precast</u>

1. Install temporary supporting system to slabs at Nth floor in Wing A
2. Install semi-precast slabs at Nth floor in Wing A
3. Fix steel reinforcement for slabs at Nth floor in Wing A
4. E&M installation for slabs at Nth floor in Wing A
5. Pour concrete to slabs at Nth floor in Wing A
6. Repeat the Step 1-5 after completion of wall construction at (N+1)th floor in Wing A

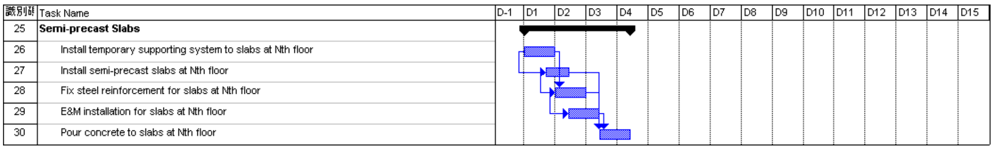


Figure 8 - Semi-precast slabs for domestic floor slabs construction

Non-domestic floor slabs construction (including corridor and lift lobby)

Timber Formwork

1. Erect timber slab formwork at Nth floor in Wing A
2. Fix steel reinforcement for slabs at Nth floor in Wing A
3. E&M installation for slabs at Nth floor in Wing A
4. Pour concrete to slabs at Nth floor in Wing A
5. Dismantle timber slab formwork at Nth floor in Wing A
6. Install temporary supporting system to slabs at Nth floor in Wing A
7. Move timber slab formwork to (N+1)th floor in Wing A
8. Repeat the Step 1-7 after completion of wall construction at (N+1)th floor in Wing A

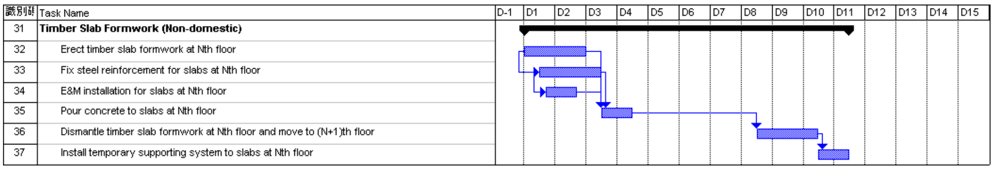


Figure 9 - Timber formwork for non-domestic floor slabs construction (including corridor and lift lobby)

Façade construction

Timber Formwork

1. Setting out of façades at (N-m)th floor in Wing A, where N>m
2. Fix steel reinforcement for façades at (N-m)th floor in Wing A, where N>m
3. E&M installation for façades at (N-m)th floor in Wing A, where N>m
4. Erect timber façade formwork at (N-m)th floor in Wing A, where N>m
5. Pour concrete to façades at (N-m)th floor in Wing A, where N>m
6. Dismantle timber façade formwork at (N-m)th floor in Wing A, where N>m
7. Move timber façade formwork to (N-m+1)th floor in Wing A, where N>m
8. Repeat the Step 1-7 after completion of slab construction at (N-m+1)th floor in Wing A, where N>m

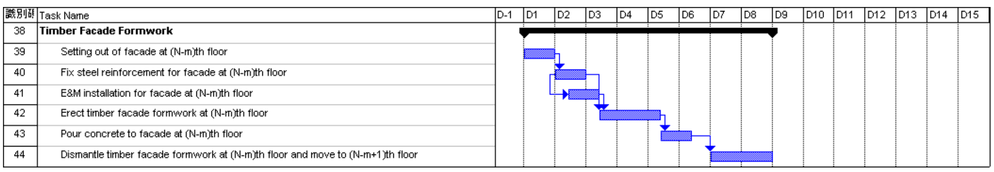


Figure 10 - Timber formwork for façade construction

Precast

1. Install precast façades at (N-m)th floor in Wing A, where N>m
2. Repeat the Step 1 at (N-m+1)th floor in Wing A, where N>m

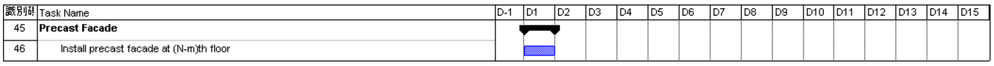


Figure 11 - Precast for façade construction

Staircases construction

<u>Timber Formwork</u>

1. Setting out of staircases at Nth floor
2. Erect timber staircases formwork at Nth floor
3. Fix steel reinforcement for staircases at Nth floor
4. Pour concrete to staircases at Nth floor
5. Dismantle timber staircases formwork at Nth floor
6. Move timber staircases formwork to (N+1)th floor
7. Repeat the Step 1-6 after completion of slab construction at (N+1)th floor

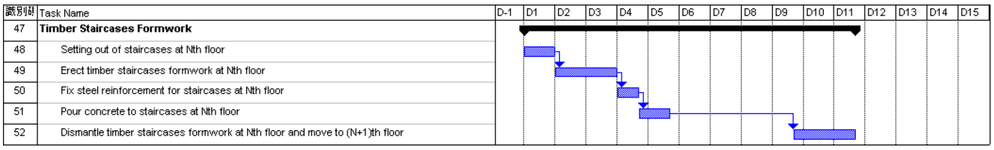


Figure 12 - Timber formwork for staircases construction

<u>Precast</u>

1. Install precast staircases at Nth floor
2. Repeat the Step 1 after completion of slab construction at (N+1)th floor

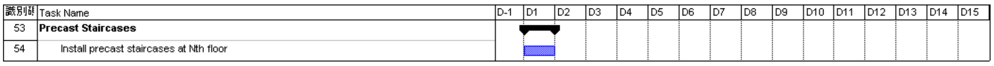


Figure 13 - Precast for staircases construction

Activities Sequencing

Depending on the different combination of building techniques and the corresponding constraints governing the overall construction duration, the content of method statement for a particular project varies, particularly the activities sequencing, as illustrated in the following sample Gantt Charts for constructing Harmony Blocks (Figure 14 to Figure 17 show the adoption of Alternative 1, 8 and 12 with different construction cycles for constructing a typical Harmony Block): -

Alternative 1

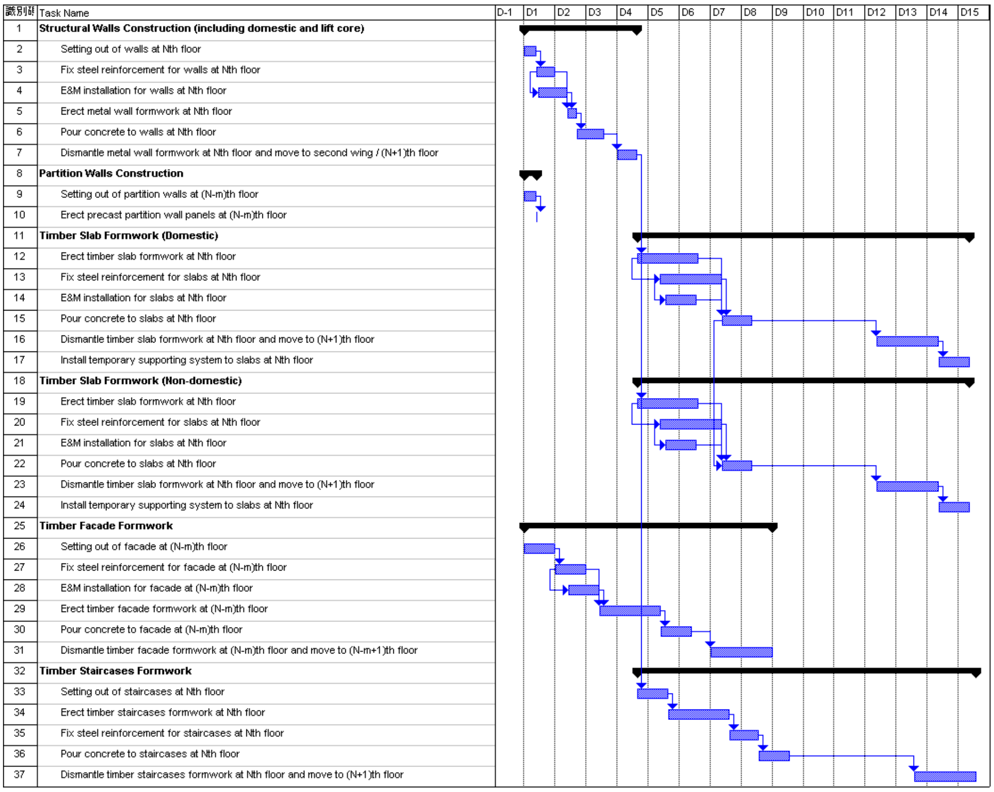


Figure 14 - Sequencing for constructing Harmony Block with "Alternative 1" (9-Day Construction Cycle)

Alternative 8

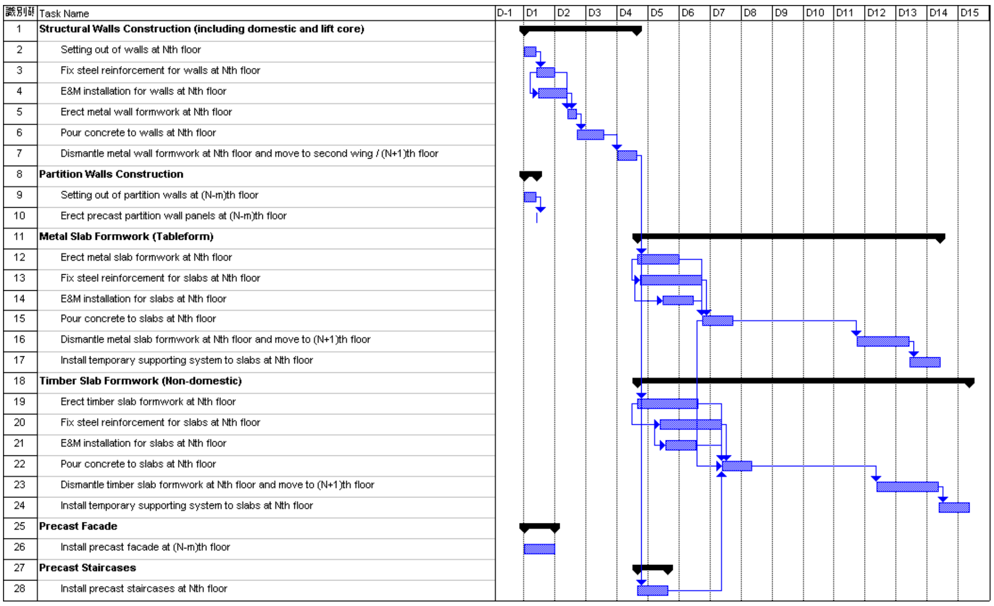


Figure 15 - Sequencing for constructing Harmony Block with "Alternative 8" (8-Day Construction Cycle)

Alternative 12 (8-Day Construction Cycle)

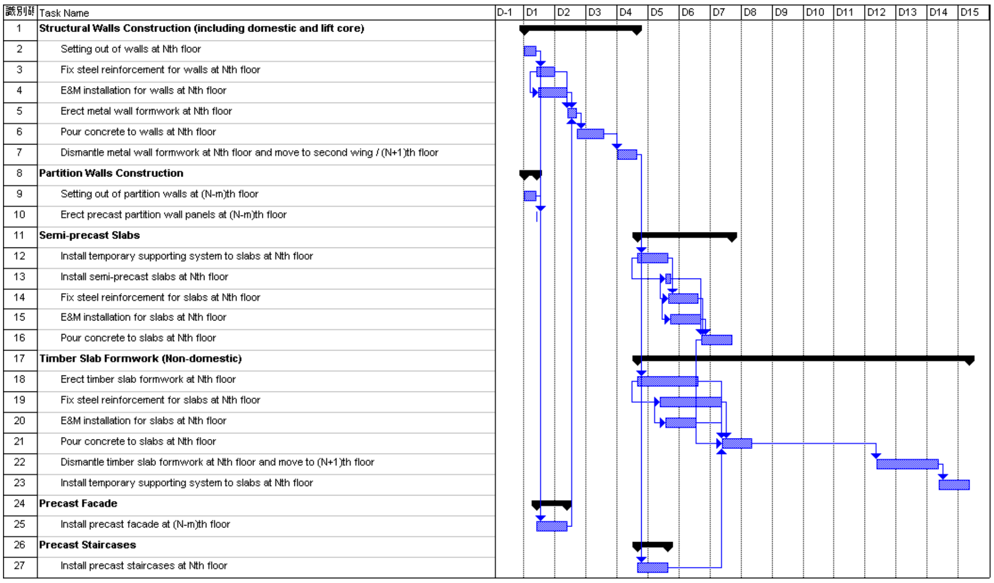


Figure 16 - Sequencing for constructing Harmony Block with "Alternative 12" (8-Day Construction Cycle)

Alternative 12 (4-Day Construction Cycle)

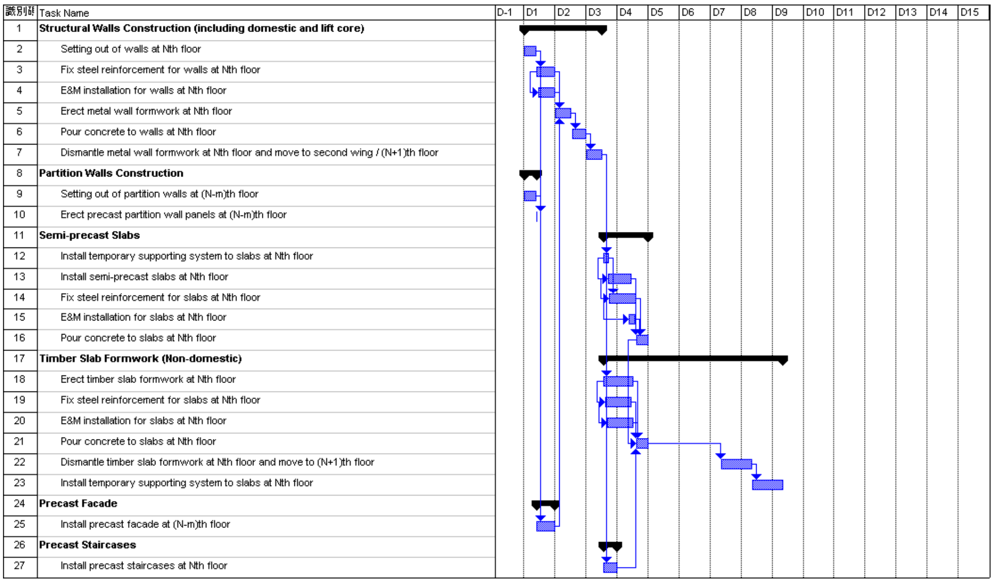


Figure 17 - Sequencing for constructing Harmony Block with "Alternative 12" (4-Day Construction Cycle)

RATIONALES FOR DIFFERENT ACTIVITIES SEQUENCING

Various combinations of different building techniques and input of resources for the construction of Harmony Blocks result in different sequences of construction activities with different construction cycles. The difference in activities sequencing and construction cycles (as illustrated from Figure 14 to Figure 17) are mainly attributable to the following factors: -

Construction Methods

Depending on the specific requirements on time, cost and quality for the construction of housing blocks, different construction techniques will be deployed for the construction of major building components. Generally speaking, mechanization which adopts mechanised construction methods such as large panel formwork and tower cranes, and, prefabrication which transfers the construction of complicated components from site to factory have effected in substantial savings in skilled on-site labour, expedition of the construction and better quality products rather than that of tradition timber construction.

As illustrated in Figure 14 and Figure 15, the difference in construction cycles is mainly attributable to the construction of staircases and façades. Using precast staircases and façades, instead of timber formwork for construction, will expedite the construction by reducing the works on site and putting these activities as non-critical. For the construction of domestic slabs, metal slab formwork allows shorter construction duration than that of timber slab formwork because the time spent in assembling and striking formwork is much less than that required by the timber slab formwork. Besides, using metal slab formwork which is one of the large panel formwork will eliminate the common deficiency of timber slab formwork like stepped joints, grout leakage, plywood pealing off, bulging of concrete surfaces, etc. (Mak, 1998).

Performance Requirements

The most influential factor affecting the construction cycle is the performance requirements of concrete components, particularly for the in-situ concrete construction. For the formwork construction, there are statutory requirements on the minimum period, which must elapse before formwork may be removed (Building (Construction) Regulations, 1997). These ensure the final concrete structure shall support safely the combined effects of all loads and within the limits of acceptable dimensional tolerances. Taking structural walls construction and slab formwork construction as examples, they shall not be dismantled until 12 hours and 4 days were elapsed upon concreting respectively as illustrated in Figure 16.

To shorten the minimum period before striking formwork, higher strength of concrete than that required by the statutory (Building (Construction) Regulations, 1997) can be deployed for better durability and high early strength. In Figure 17, Grade 35/20 concrete was used for the construction of slabs to achieve a minimum of 10MPa and 20 MPa cube strength for 1-day and 3-day age respectively as compared with Grade 30/20 concrete normally used for domestic building.

Machinery

Not until 1981 (Construction & Contract News, 1983) did the Housing Department stimulate the use of semi-mechanised and fully-mechanised systems for housing construction in the Housing Authority projects, then the local building contractors recognised the benefits of using more advanced techniques in building projects, with particular reference to the improvement in the quality of works and stringent demand on skilled labours. Since then, the labour-intensive works such as using timber formwork, propping, material hoist, scaffolding, trolleys for concreting were largely replaced by the large panel formwork, tower cranes, concrete batching plant, concrete pumps and gondola. Nowadays, contractors are mandatorily required to deploy tower cranes, large panel formwork and concrete batching plant in the construction of typical housing blocks.

In Figure 16, concrete topping to the semi-precast slabs is delivered by tower crane and skip whereas, in Figure 17, concrete is delivered by concrete pump. In this way, no only the time spent in delivering concrete is shortened, but also the craneage is substantially reduced. In fact, the use of concrete pumps reduces the demand on the tower crane by approximately 40 percentage of craneage (Chan and Lee, 1998).

Input of Resources

The use of large panel formwork and prefabrication obviously requires the use of tower crane for the vertical and horizontal transportation of concrete, reinforcement, formwork and precast components. As a result, the tower crane becomes a critical mechanical plant governing the duration of construction works. For ease of site layout planning and economic reasons, one tower crane will normally be erected for the construction of a typical housing block. However, in order to reduce the average craneage and accelerate the relevant construction works, more tower cranes (e.g. three housing blocks with four tower cranes) are inevitable.

Harmony blocks comprise three to four wings and each wing has its own construction cycle. Combining these construction cycles will form the floor cycle for the particular housing block. In the example of Figure 17, one wing set of typical large panel formwork was employed and could be transferred from one wing to another for the construction of structural walls. Roughly speaking, it achieves a 4-day construction cycle with a 11½ -day floor cycle for a typical Harmony 1 housing block. The floor cycle can be expedited to 6½ days and 4 days by employing one or three more wing sets of large panel formwork. However, it may be uneconomy to employ more than one wing set of large panel formwork for the "cyclical" construction of structural walls because the overall construction duration of a typical housing block is only accelerated by 5 days and 11½ days when one or three more wing sets of large panel formwork are used.

Therefore, the common practice of accelerating the construction cycle is to increase the driving resources such as additional formworkers and steel benders, which can shorten the duration of construction works.

CONCLUSIONS

The shift of housing policy from quantitative emergency relief and squatter clearance to a more quality oriented approach since 1972/73 urged for a shorter development period for housing block without scarifying the quality of work. The situation is more obvious due to the increasing supply of housing units over the next decade as pledged by the Hong Kong Special Administrative Region (HK SAR) Government (HK SAR Government, 1997 and Tung, 1997). To fulfil these requirements, an obvious solution seems to be the addition of physical resources such as additional tower cranes, concrete pumps and slab formwork. However, not all of the resources are driving resources. Besides, adding resources will reduce the contractor's profit margin and even adversely affect the construction sequences, especially for those on congested sites. For example, an additional tower crane may, to a certain extent, accelerate the vertical transportation of materials but it may restrict the scope of horizontal transportation of materials in a restricted site, let alone lead to a reduction of the useable working area.

It is for this reason that an in-depth study of the existing construction methods for housing construction has been made, with particular emphasis on the repetitive construction activities such as timber formwork for slab construction. By combining different construction techniques in various degrees and scheduling their activities sequencing at the planning stage, an optimal construction cycle and floor cycle can be easily achieved for the project while meeting specific requirements on time, cost and quality.

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Project Feasibility Studies- Their Role in Promoting Better Practice: A UK and Malaysia Comparison

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Abstract

The paper investigates the project feasibility study (FS) in the context of its being a project management tool. It is hypothesised that the project FS process can contribute to improvement of the construction process. The paper also refers to *Soft System Management Techniques* (SSMTs) in the context of their achieving performance improvement. Postal questionnaire surveys were conducted amongst the construction industries of Malaysia and the UK to compare FS processes. Findings reveal that FSs are vitally important to: the *design process*; *contract strategy*; *performance of time, cost* and *quality*; and *contractor health* and *safety performance.* It is concluded that FSs should be given greater attention than at present. This will include use of SSMTs such as *value management*, *risk management* and *partnering* approaches. Integration of these management tools in the FS process will provide a more practical and holistic solution to construction problems, particularly, in terms of inadequate financial, technical resources and managerial expertise, and specifically for developing countries for the new millennium.

Keywords: *Project Briefing, Project Feasibility Study, Soft System Management Techniques.*

INTRODUCTION

The essence of a traditional FS is to appraise a proposed scheme in the context of its overall viability. Very often the initial aspects of FS will investigate: *Why* build? *What* are the costs and profit? *When* shall work begin and be completed? *Who* and *How* to build? (Stone, 1988). The CIOB (1996) defined FS in two distinct phases. First, site acquisition, planning permissions, financial viability appraisal, pre-letting, identifying sources of funding, grants and taxation provision may be considered. Second, the more practical aspects of executing the project, contract strategy, design and planning, construction and commissioning are investigated.

The Royal Institute of British Architects (RIBA, 1994) Plan of Work outlines four major stages of construction. These are; *Briefing; Sketch Plans; Working Drawings;* and *Site Operation. Briefing* is developed first and represents an essential process of the project FS process. During briefing, attention should be given to the client's requirements and project's objectives, to determine; the most appropriate way of procuring the project; ensure that the project is feasible; will functionally achieve the required quality standards; will technically achieve buildability during construction; and is financially viable.

At the outset of a project a comprehensive FS is essential. Design requirements, contract strategy, financial viability, risk appraisal and many other aspects need to be considered. FS is a continuous process and reappraisal of those factors pertinent to the success of a project must be constantly reviewed. Therefore, the FS process represents a holistic approach to identify, reappraise and overcome potential problems.

Therefore, in this paper the issues of FS are perceived to have implication to a totally modern management approach. These new management techniques (*i.e.* SSMTs) include *Value Management*, *Value Engineering, Partnering,* and *Risk Management*. The paper analyses the importance and the development of a project FS. It also studies how the FS process can impact performance by the integration of SSMTs. It is contended that these SSMTs represent a new way of thinking, providing a framework of activities that accommodate an insight into the study problems of the construction industry. The main objectives of the paper are:

1. an overview of the FS process in project management;
2. an overview and conceptual study of FS practices with respect to SSMTs; and
3. investigation of current FS practices in Malaysia and the UK via questionnaire surveys.

What is FS and what benefits does it offer?

The increased use of FS in construction is a result of: increasing size and complexity of projects; a need for tighter financial control; and shorter construction periods. Project FS should determine specific objectives to achieve best value for money for the client. FS should also improve the performance of the construction process. There are many reasons why a project can fail to achieve the client's objectives:

- failure to appreciate the complexity, logistics and sheer difficulty of executing the work (Potts, 1995);
- improper procurement route or contract strategy;
- inadequate provision of time and resources to the FS process;
- unforeseen circumstances such as design changes due to safety requirements, technology advancements, and external influences (e.g. shortage of labour, inflation, interest charges, and environmental issues (Sykes, 1986)).

In the past few decades many major construction works have had a failure history e.g. non-completion, delay or cost overruns. Projects such as the Channel Tunnel, the Thames Barrier Project, the Sydney Opera House, and the Malaysia North-South Expressway and have well exceed budget. Some projects have taken a lot more time to complete than was estimated (Potts, 1995; Morris and Hough, 1990; MPA, 1994). Common problems in the industry are also caused by: failure to adequately evaluate project viability; unclear project objectives; and vague time objectives. These demonstrate the hazardousness of a client who takes risk from not having adequate FS knowledge.

The role of SSMTs in project FS process

McGeorge and Palmer (1997) found that construction has changed little over the recent decades and is relatively slow to adopt new technology and modern management techniques. They recommend that SSMTs have profound effect upon overall construction process performance. An appreciation of new management concepts (*i.e.* SSMTs in project FS) and some understanding of each technique are vital to the success of a project. It is contended that use of new management techniques in the FS process can create mutual understanding, proper guidance for implementation and the commitment in the initial stage (i.e. briefing) of the construction process. Indeed, all SSMTs could equally be applied to all construction management. As Morris (1996) contends, value management and value engineering activities should take place in a partnering arrangement from the outset. Alternatively, it is also possible that partnering could result from the commitment of value management and value engineering in the FS process. Thus, a conflict does not exist among the new management systems and their application to FS. Figure 1 illustrates how cost saving opportunities can be achieved in project FS process with the implementation of SSMTs. Figure 2 explains how the majority of potential benefits are available long before a project is put out to tender, or after construction activities have begun.

FS process in construction project management

Since the 1940s UK construction has been the subject of many reports and has been urged to adopt new management techniques. There have been many influences from the USA in this respect. These include wide usage of non-traditional procurement methods (Masterman, 1992). A host of reports and inquiries (e.g. Simon Committee, 1944; Emmerson Report, 1962; Banwell Report, 1964; and Latham Report, 1994) have also increased pressure for change in the UK construction industry. Banwell (1964) highlighted the failure of the industry and professions to think and act together or to reform new approach to the organisation of construction projects. Latham (1994) defined that the client is the core of the construction process. However, in reality a very common conundrum for the construction industry is that the client and project sponsor do not often understand their potential influence upon a project. Very often clients do not get what they asked for! These reports have inevitably promoted the increased use of new management approaches in construction.

The primary duties of project management in the FS process are to prepare and establish a preliminary study for the project. Barnes and Wearne (1993) define that the most fundamental component here is to first establish and define the project objectives *clearly* and in *some detail*. In the UK, the CIOB (1996) outlines that project management should start by gaining an understanding of the client's objectives through the FS. At this stage, the client and project manager should meet and agree*:* the basis for the feasibility study and strategy to be used; an outline master programme and cost plan; and the terms and timing for the project. Thus, the primary duties of project management in project FS is to prepare for: selection *of procurement route*; overview *project risks*; offer *various alternatives* (e.g. use of *value management* or *value engineering*); and a viable *outline programme* which covers brief, design, construction and handover.

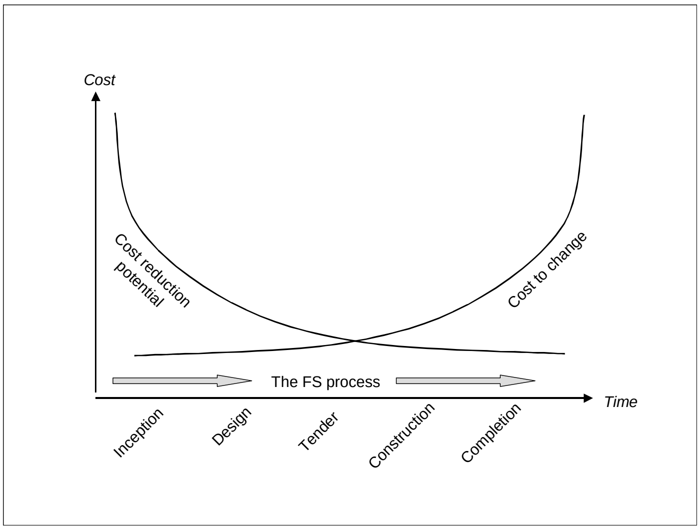

Figure 1: The cost saving opportunities of the SSMTs approaches

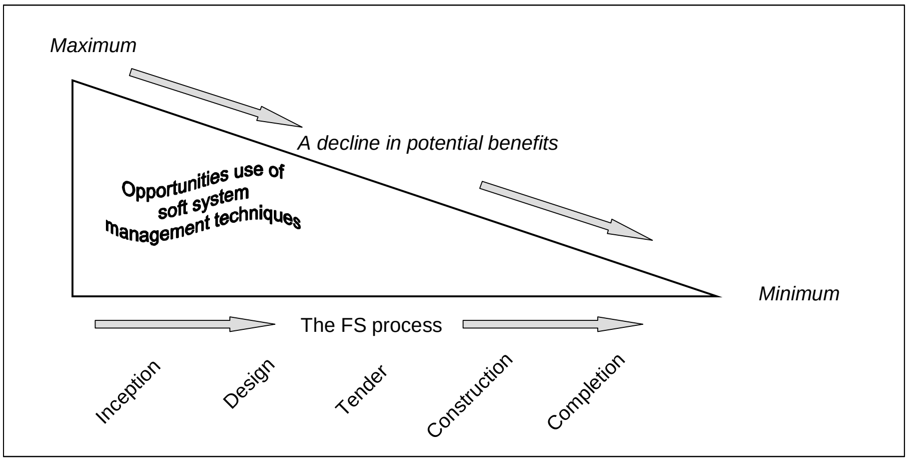

Figure 2: The relationship between the use of soft system management techniques and potential benefits in project FS process.

FS PRACTICE IN THE MALAYSIA CONSTRUCTION INDUSTRY

Construction has played a vital role in the development of Malaysia. It has created the basis for, and benefits from, rapid economic growth (Rashid, 1996). The impressive growth shown in 1995 has reflected the strong momentum seen in construction activities (Anon.,1996a; 1996b; 1996c). This phenomenon has resulted in increasing demand for variants of procurement systems (Hashim, 1996). In 1994, the Malaysian privatisation programmes were launched (Hensley and White, 1993) when the government decided to employ turnkey procurement (e.g. design and build, build-operate-transfer (BOT)) as they found that this is an effective remedy to improve construction performance (Kaming *et al.*, 1994). Privatisation has inevitably stimulated the transformation and led to rapid development of infrastructure and economy.

Nevertheless, the Malaysian construction industry has not been exempted from problems on basic performance. Like many developing countries (DCs) Malaysian construction has faced problems of project time and cost overrun (Ofori, 1993; Kaming *et al.*, 1994). These inter-related problems have in part been attributed to the use of traditional procurement routes and contractual frameworks (*i.e.* traditional *British-based* procurement). According to Edmonds and Miles (1983) these traditional *British-based* procurement options have been adopted with little modification are often inadequate to attend problems faced by DCs. In the early 1990s Malaysian construction performance was frequently influenced by shortage of construction materials, technology, plant and equipment, skilled construction personnel. Indeed, apart from these, it is no exaggeration to state that a majority of Malaysian construction management and organisational processes relied on traditional based construction personnel (*i.e.* architect or engineer).

According to Hashim (1996), traditional procurement is still the most commonly used in Malaysia. This causes fragmentation of project participants. Clearly, the responsibility for the design process is completely divorced from the responsibility for production. Very often in the case of project FS process, traditional construction personnel are appointed by the client to carry out the construction process. Moreover, the attentions of works are (i.e. time, cost and human resources) more emphasised in the construction stage rather than the FS process. This has discouraged professional practices such as the use of SSMTs in construction project management.

QUESTIONNAIRE SURVEY

Methodology

The questionnaire focused on two main aspects of FS. First, it investigated clients' project performance satisfaction (*i.e.* time, cost and quality) in retrospect to the strength and extent of FS performed for previously completed projects. Second, it surveyed participants' opinions and common understanding of FS in relation to its potential benefits with regard to the SSMTs. A 3-*point ordinal measure* (1 for '*poor* or *no impact*', to 3 for '*outstanding* or *significant impact*') and *binary decision* (YES/NO) were employed in most of questions. This allowed respondents to easily rate their perceptions. The data were analysed using percentages to determine perceived level and strength of opinion. 110 questionnaires were send to *property developers*, *architects* and *engineering consultants*, *design* and *build contractors*, *main contractors* and *clients' representatives* in both Malaysia and the UK. There were 26 (24%) and 36 (33%) of questionnaires returned completed from both Malaysia and UK respectively.

Result of Questionnaire Survey

Number, Size and Performance of the Completed Projects

There were 13 and 8 numbers of completed projects from Malaysia and UK reported respectively. Of these, 7 projects worth above £10 million Sterling; 3 projects between £5 million to £10 million Sterling and 3 projects below £5 million Sterling from the Malaysia (all figures reported in July 1997, before Asian monetary crisis). These results were in contrast with the UK, where all the completed projects were less than £5 million Sterling. The findings also indicated that the overall performance of the completed projects in the UK was better than in Malaysia. In the UK, there were 7(87%) projects completed on time, 6(75%) projects within cost and 6(75%) projects achieved desired quality. However, there were only 4(31%), 7(54%) and 6(46%) respectively from Malaysia. Figure 3 shows a number of projects reported by the respondents and the levels of satisfaction perceived.

According to the survey, the UK respondents have better FS development compared to Malaysia. 75% of respondents in the UK perceived project briefing as vitally important and therefore held it 'most of the time' and on 'a regular' basis, whereas only 46% from Malaysia did so. However, the size and complexity of completed projects was different from both countries (more than 75% of the completed projects in Malaysia were worth above £5 million Sterling). Thus, under these conditions, comparisons of achieved project performances are not conclusive.

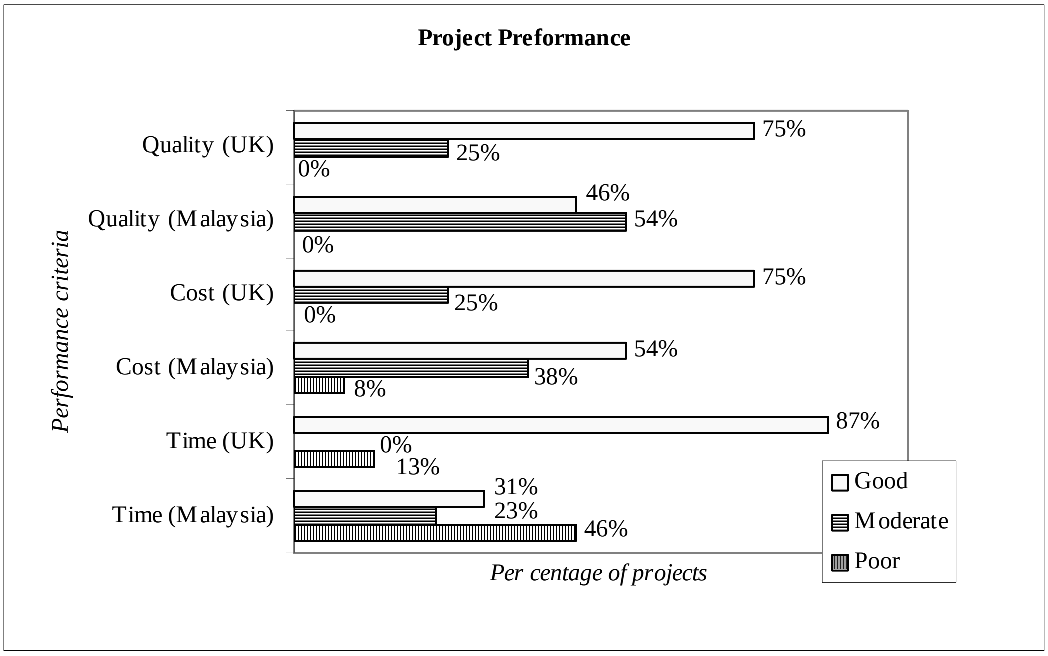

Figure 3: Project performance reported by the respondents

The Brief leader during Project FS in Completed Projects

Findings also indicated that the vast majority of completed project briefing processes in Malaysia were prepared the by architect and / or engineer followed by client's representative (e.g. project manager), client, design consultants and contractor (in design and build schemes). There were 39%, 30%, 19%, 6% and 6% respectively. There were 20%, 20%, 18%, 18%, 14%, and 10% respectively from UK. It was indicated architects and engineers remain predominant during project briefing in Malaysian construction process. However, respondents from the UK have different perception. Some respondents also indicated that combined efforts of the client, client's representative and architect during briefing were indispensable during project briefing. Perhaps this also indicated that the need for a separate function of management role played by this additional project team. The responsibility of brief-leadership is divorced from any design work and purely deals with the project management and organisational task, in the FS process as well as when construction takes place.

Impact of FS to Project Performance of the Completed Projects

74% of the total respondents reported that comprehensive and detailed FS process is of vital importance. Among these, there were 94% and 64% of respondents from UK and Malaysia respectively. This indicated that the majority of UK respondents have a common consensus that an inadequate FS process will affect construction performance. These include completion *in time*, *within budget*, *good quality*, *complexity*, *buildability*, *risk assessment* and *avoidance*, and *dispute resolution* (Figure 4).

Impact of FS to Choice of Contract Strategy and Improvement to Design Process

UK respondents perceived that the FS process may have an impact on the choice of contract strategy. They agreed that it does impact: *the construction programme; appointment of consultants / contractor, design strategy;* and *contracting risk*. However, results from Malaysian respondents were slightly different (Figure 5). A detailed investigation into the impact of project FS upon design strategy revealed that both Malaysia and UK respondents have a general consensus that project FS could improve the design process, i.e. *reduce unnecessary repetitive design, unnecessary specification changes* and *shorten the time of design processes* (Figure 6).

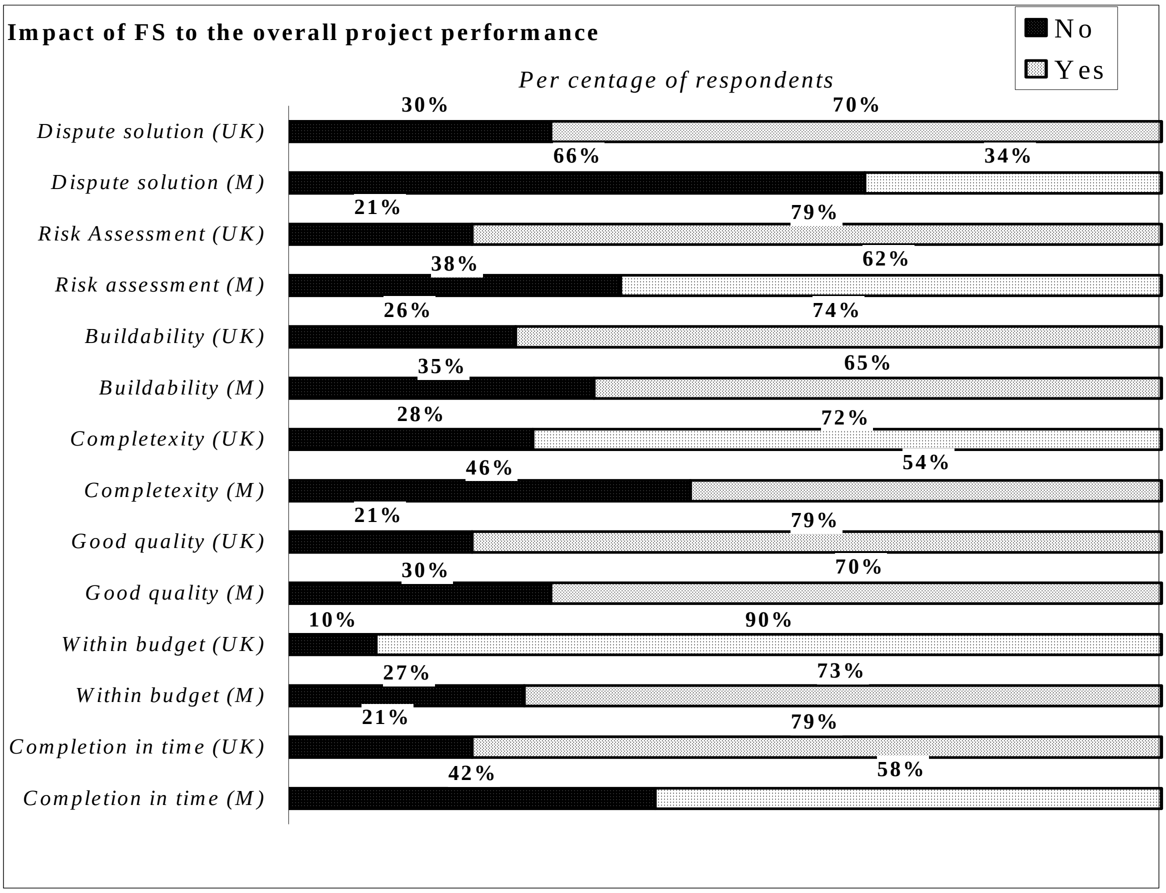

Figure 4: Impact of FS to project performance to the completed projects

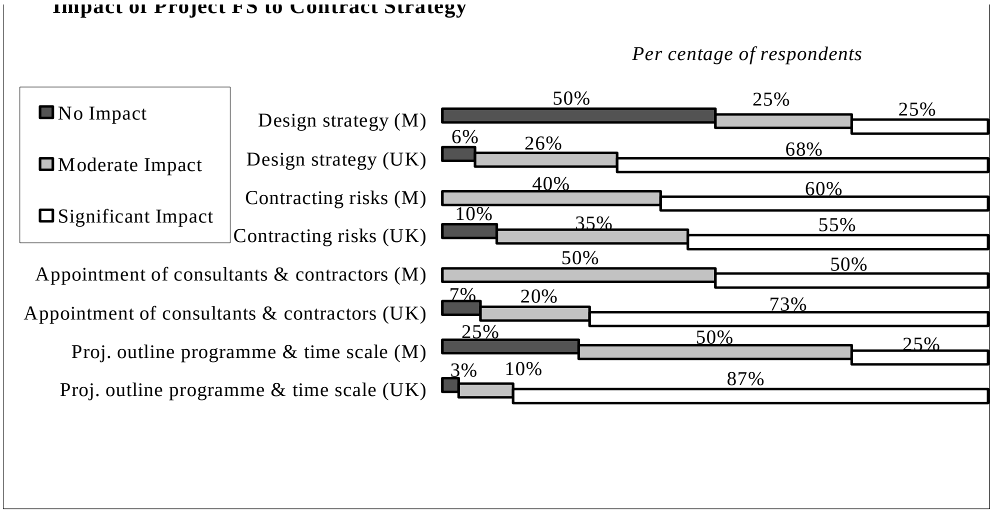

Figure 5: Impact of FS to contract strategy of the completed projects

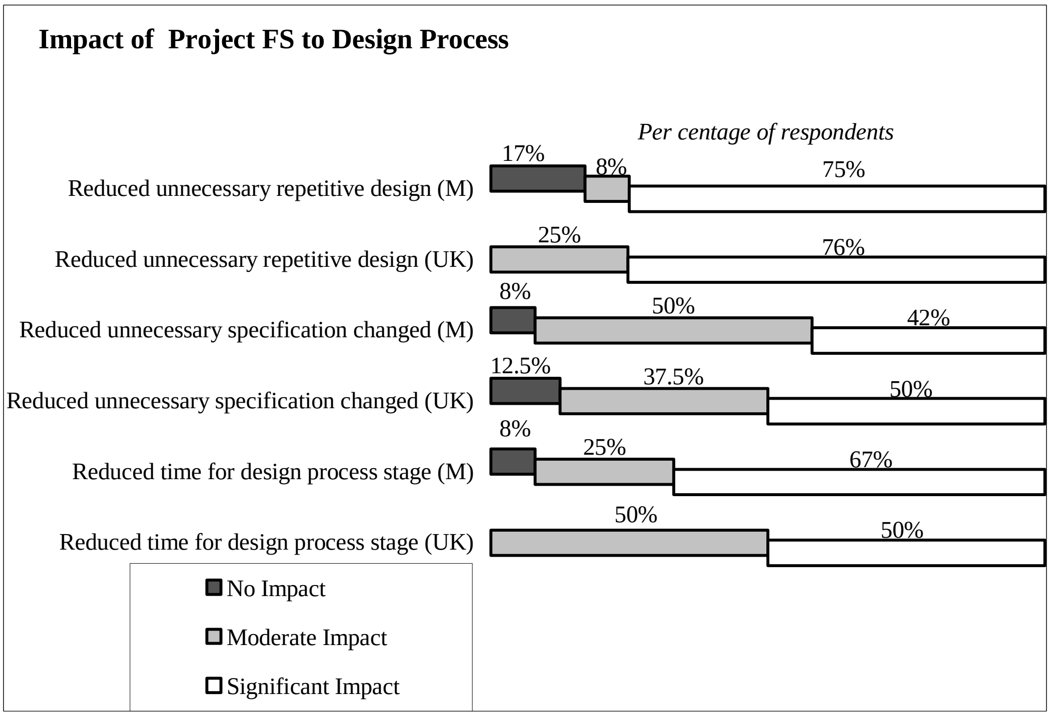

Figure 6: Impact of project FS to design process

<u>Impact of FS to Health & Safety Performance of Completed Projects</u>

Regarding health and safety, 53% of the UK and 42% of Malaysian respondents agreed the impact of FS to health and safety performance in the construction stage. The expected results slightly contrast to early findings. Perhaps many of the respondents less emphasise health and safety issues during project FS. Indeed, involvement of the *Planning Supervisor* (*i.e.* safety officer) in UK construction (*i.e.* the implementation of Construction (Design and Management) Regulations 1994, UK) during FS is of vital importance.

<u>Project FS: Individual's Opinions Findings</u>

According to the Malaysian respondents, there is often lack of understanding on the part of clients about the FS process. Most respondents thought FS is mainly for investment and marketing guidance. Findings from UK respondents show that the client is the core of the construction process. The main barriers to effective FS process include vagueness in terms of client requirements, inadequate guidance and experience with respect to so many different procurement methods available, and lack of communication among construction teams.

Comments on Findings

Overall, it appears that the majority of respondents in Malaysian construction companies are inconsistent with the results obtained from UK respondents. Particularly, in the area of contractual arrangements and individuals' background. Comparison between the two countries has been difficult to draw because of the variable techniques and a variety of procurement methods used during the construction process. However, indications are clear that the undertaking of FS is of vital importance for the overall performance of the construction process.

The findings also showed that most of the respondents believed some SSMTs should be integrated into the FS process. *buildability, value management or value engineering,* and *partnering* should be considered and adopted into the FS stage. Similar findings have also identified in the latest UK construction performance survey by the Construction Industry Board (CIB), where they found that clients' satisfaction with contractors' performance in time, cost, quality, resolution of defects and trust / confidence have increased for the period 1995 to 1999. CIB attributed these improvements to wider adoption of management techniques, such as *partnering* (Building, 1999).

The findings highlighted differences between Malaysia and UK FS practices as follows:

1. FSs undertaken in the Malaysian construction industry are still in a 'traditional' development process, particularly in *project management* and SSMTs approaches. Unlike in the UK, the professional bodies such as the Royal Institution of Architects, Chartered Institute of Building, Royal Institution of Charted Surveyors and many other professional bodies have being positively promoting the effective way of undertaking project FS in construction process.
2. FS process in DCs like Malaysia tends to concentrate on economic justification, commercial appraisal and takes a short-term view, whilst FS process in the UK consist of a comprehensive study and includes all the fundamental criteria.

Implications of the research

Two major sets of understanding are achieved from these findings. Firstly, FS should be afforded full participation and understanding from clients in order to translate their needs into reality. Second, FS are able to improve the overall performance (*i.e.* contract strategy, project management and control, health and safety). In other words, to get the project completed with in specified time, cost and to satisfactory quality.

There are intrinsic difficulties in defining the FS performance on the UK and Malaysian construction industries; particularly, the differences in professional background of who dominates basic performance and administrations of construction activities. In Malaysia many of the important construction roles are still dominated by architect / engineer, whereas, in the UK construction industry these conditions could be quite flexible. Another differential between the two countries is the project nature. In general, a majority of construction works in Malaysia are commercial, civil engineering works, infrastructure construction and housing projects, whereas almost half of UK construction output is occupied by repair and maintenance (DERT, 1999). Furthermore, the UK construction industry has many kinds of procurement systems in which clients are able to choose the most suitable system to reflect their needs.

The most favoured key person for conducting FS process was also indicated in the findings. The respondents reveal some interesting trends that the whole FS would benefit with the appointment of project manager. Such indication was also stated in the RIBA (1994), CIOB (1996) and RICS (1992). The responsibilities and commitments to briefing during project FS process are paramount importance. Project managers' preliminary duty is to prepare and establish a preliminary study for the project. However, on many occasions it does not exist the in Malaysian construction industry particularly in the traditional procurement system, where the architect or engineer still dominates in taking the role of design as well as contract administration responsibilities.

From the contractor's point of view, the findings also discovered that demand for early involvement and preliminary advice during the FS is necessary. Contractors claimed that their early involvement in the FS is desirable during the design process; allowing them to raise 'early warnings' such as for buildability, selection of construction method and materials to suit the specified quality and safe practices. These factors eventually may increase the cost effectiveness and bring added value to the client.

CONCLUSION

In general, the construction industry is still perceived as considerably fragmented, highly complex in nature involving many disciplines, trade and interrelated industries and institutions. It is essential to unify these teams as a whole into the construction process, in the most effective manner and procurement process. Unless the whole processes are strengthened in every aspect and at every level, these is no way the industry can avoid failure. This paper has attempted to bring a new paradigm of project FS themes; a new way of looking at project management. It is believed that implementation of an effective and proper project FS is more likely to cope with construction industry problems. Project FS is a new management process based on modern management principles, it brings construction participants and professions together; improves the traditional adversarial relationships and takes advantage of resources and contributions from all construction team members.

The implication of the study has also warned that there is a need for construction clients to adopt a comprehensive and well-defined FS. Particularly in the case of DCs, where the initiation of demand for implementing of infrastructure projects is by a perception and quantification of need, and always constrained by lack of managerial / technical expertise and limited budget. Cost is also a major concern inhibiting effective planning and implementation of construction projects and always subjects to public accountability in most public construction. A well-developed project FS therefore, may serve as a useful input to these scenarios.

RECOMMENDATIONS

A greater insight into project FS investigation is crucial. At this stage, the study has offered unexplored opportunity to be discovered. It is likely that future investigation may able to extend into the following areas:

- Research on the Malaysian industry government agency and the industry professional bodies such as Construction Industry Development Board (CIDB), *Persatuan Akitek Malaysia* (PAM, Malaysian Institution of Architects), Institution of Surveyors Malaysia (ISM) and Institution of Engineers Malaysia (IEM) into how they are promoting FS in construction project management.
- Research on the most appropriate, effective and good practice with regard to SSMTs for a FS framework in DCs construction industry.

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The Impact of Organisational Structure on Project Performance

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Abstract

Construction projects possess high complexity and diversity and the volume of work in a project fluctuates as the period of contract progresses. These are patterns of growth and decline of activities which the construction management team would have to oversee. To assist in this work, the team organizes itself to perform well. The organizational structure is the management framework adopted to oversee the various activities of construction work to their efficient and effective conclusions.

This paper examines how the features of organizational structure are affected by the characteristics of the project. Its findings would guide team structuring so that construction projects could be managed to attain higher performance.

Keywords: O*rganisation; structure, features, project; characteristic.*

INTRODUCTION

The level of competition in the construction industry has risen in the past decade and it will be more intense in the new millenium. This is due to the opening of markets for international competition and the use of new technology by the competitors. As a project-driven industry, survival in the construction industry is through project success. To achieve project success, a project management team is required to attain high performance in order to overcome the fluid construction market environment and the different peculiarities of different projects which are diverse and complex.

The site organizational structure is the management framework adopted to oversee the various activities of construction work. A suitable site organizational structure assists the project management team to achieve high performance in the project through gains in efficiency and effectiveness.

OBJECTIVE

The objectives of this paper are:

(a) to determine the basis of using certain organization structures in construction projects by using prevalent theories of structures to test their validity;
(b) to examine the relationships between the characteristics of a construction project and the features of its site organisational structure; and
(c) to provide a guide for the project manager to establish and fine-tune a site organization structure to fit the requirements of different project characteristics.

PAST WORK

Theories of Structures

Theories on organisational structures started with the identification of organizing as a distinct managerial function. They took formal shapes upon results from studies on organizational structures which covered many widely different industries. They included studies on the manufacturing industry (Lawrence and Lorsch, 1967), administrative organization (Blau and Schoenherr, 1980**),** investment banks (Eccles and Crane, 1988) and multi-national organization (Ghoshal and Nohoria, 1989). With the emergence of the systems and contingency theories, the importance of the organizational structure as a critical component of a formal organization had finally gained position in research.

Basic research on organisational structures that are relevant to the objectives of this paper are those of Lawrence and Lorsch (1967), Drazin and Van de Ven (1985) and Mintzberg (1989). In a research on the organization structures in six enterprises, Lawrence and Lorsch (1967) summarized the features of the organization structure to be the span of control, number of levels to a shared superior, time span of review of departmental performance, specificity of review of departmental performance and importance of formal rules. Drazin and Van de Ven (1985) defined the organizational structure in terms of specification, standardization, discretion and personnel expertise. They agreed with Lawrence and Lorsh on the feature of specialization. Mintzberg (1989) studied seven types of organizations, namely, entrepreneurial, machine, professional, diversified, innovative, missionary and political. He found them to be based on key parts of the organization, type of decentralization and their co-ordinating mechanism. All these authors identified the structure of organisation as characterized by not only specialised parts but also their horizontal and vertical relationships.

Applied research on organisational structures in construction companies developed further when many researchers applied basic research results on organizational theory in other fields. Lansley (1994) indicated that strong linkage existed among different organizational models and advocated using them for the reconciliation of conflicts. Mukalula (1996) studied three aspects of a construction firm's structure: namely, organizational complexity, formalization, centralization and decentralization of authority**.** Sunkuk (1997) adopted five among the seven types of organizations presented by Mintzberg (1989) to examine which managerial environment will best reflect that of the construction industry. Applied research extended the study of organisations beyond organizational features to relationships with the operating environment.

Among the basic and applied research studies, there is agreement on the following:

(a) The structure of an organization is important to the performance of the organisation. This would mean that the project management team's structure would certainly affect its performance.
(b) Two basic features of a structure of an organisation are its width as indicated by spans of control, and its height as indicated by the levels of decentralisation.

Models of Structures

From the above observations, researchers theorize that the change in the organizational structure, through its shape in terms of width and height, would affect organizational performance, and even vice versa.

Theoretically, researchers and theorists presented two extremes for possible models of structures. They are the organic structure and mechanistic structure. The model of an organic structure would be a flat and cross-functional team, with low formalization, possessing comprehensive information and relying on participative decision making. The model of mechanistic structure would be the opposite and would be characterized by extensive departmentalisation, high formalisation, limited information and centralisation. (Robbins, 1996). Thus the organic model of structure would have the maximum width (span) but the minimum height (level), while the mechanistic model or structure would have the reverse, minimum width and maximum height. These are illustrated in Figure 1.

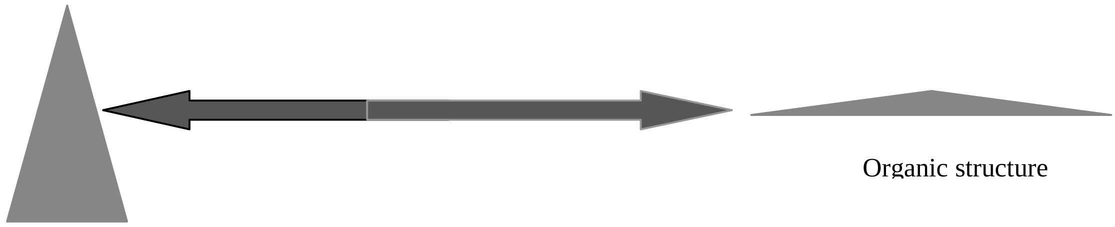


Figure 1: Models of Structures

Although applied research on organisational structures has continued in the construction industry, the main barrier is attributed to the highly diverse characteristics of construction projects and high uncertainties inherent in construction processes. These factors made it very difficult to establish a persuasive model which will reflect all diversities and uncertainties. As a result, the site organization, in particular, did not gain much attention from researchers.

Two items can be considered as basic characteristics of a construction project. They are the Contract Amount, and Project Duration. Seen three dimensionally, the contract amount would indicate the two dimensions of size and complexity of the project while the project duration would express the third dimension of time though which changes in the project take place.

HYPOTHESES

This paper examines the relationship of a construction organization’s structure with its environment. The structure under study is the site team structure. The immediate environment would be the construction project. In this paper, features of the structure studied would focus on the span and level while the characteristics of the project would be limited to amount and duration.

Even though prevailing structural and contingency theories on organizations indicated that there is no ideal rigid structure suitable for all situations, i.e. projects, this paper would attempt to examine which structure would be more appropriate for which project. Prima facie, the large contract amount and the long construction period of large projects will require wide span of control to cope with the volume of activities and small number of levels to deal with the complexities. Large projects seem to require organic structures. The main hypothesis to be tested would be that the structure will tend to be more organic for large projects whereas the mechanistic structure would be more appropriate for small projects.

METHODOLOGY

A sample of forty cases was studied for this paper. The sample was randomly selected. All the projects studied are building projects and structures studied are those of site teams of main contractors. Eight measures were taken, three items for characteristics of the project and five for features of structure. For project characteristics, they are Contract Amount, Project Duration and Completed Amount Per Day. For structural features, they are Total Number of Supervisors, Number of Divisions/Departments, Maximum Number of Span of Control, Maximum Number of Supervision Levels and Shape.

The completed amount per day was added because production strongly affects the structure. The larger the amount completed per day means more management effort was required and this surely would impact on the structure. The number of supervisors and departments were added as the number of supervisors is an indicator of organisation size and the number of divisions reflects the extent of work differentiation or specialisation. The measure of Shape is calculated as Division divided by Level.

The above measures are coded as follows in the tables and figures.

Amount	Contract Amount for Each Project
Duration	Construction Duration
Pday	Completed Amount per day = Amount/Duration
Supno	Total Number of Supervisors in the Site Team
Division	The Number of Divisions in the Site Team
Maxlevel	The Maximum Number of Total Level in the Site Team
Shape	The Shape of organisation = Division/Max level
Socmax	The Maximum Number of Span of Control in the Site Team

ANALYSIS

Table 1 shows the composition of the sample of 40 cases taken randomly among building projects of main contractors. Table 2 shows the correlations found among the characteristics of the projects, with features for structure.

Project Characteristics and Team Structures

The correlations listed in Table 2 strongly indicate that Contract Amount (Amount) is a very important characteristic of the project for it affects nearly all the features of the site team structure. All the structural features listed, except the shape, have significant correlation with the contract amount at 0.01 level (2-tailed).

Table 1: Composition of Sample

	Unit	***N***	***Minimum***	***Maximum***	***Mean***	***Std. Deviation***
Amount	S$(in million	40	2.80	1500.00	99.86	250.37
Duration	Days	25	300.00	2970.00	716.40	506.56
Pday	S$/per day	25	5555.56	370370.37	74081.68	70350.91
Supno	No.	40	3.00	93.00	21.30	20.06
Socmax	No.	40	2.00	9.00	4.40	1.52
Maxlevel	No.	40	3.00	10.00	5.13	1.95
Division	No.	40	1.00	9.00	3.50	1.75
Shape		40	0.60	4.00	1.79	0.91

The significant correlation between Amount and Socmax (0.549 at 0.000 level) is also revealing as it shows that in a large project there would be a wide span of control. This supported the hypothesis that large projects will have organic structures.

On the other hand, if size is reflected by construction duration (Duration), it was found that this characteristic does not influence the structure. None of the features of structure has significant correlation with duration, even at 0.05 level. It is understandable as large projects would require long construction periods because of the large quantity of work, but small projects may also take a longer time due to poor supervision and low productivity. The characteristic of large project that would cause its structure to be more organic is contract amount rather than construction duration.

Projects Irrespective of Size

Figure 1 shows a strong relationship between Supno and Pday. The completed amount per day (Pday) is another important project characteristic studied. Pday indicates the rate of production. It combines the influences of amount and duration. Pday displays an amazingly strong correlation with the number of supervisors in the site team (Supno) with a value of 0.894. This supports the argument for increasing the number of supervisors for production level increases. Pday also correlates with the maximum number of levels in the site team (Maxlevel) at 0.006 level with a value of 0.531. This indicates a limit whereby changes in the number of levels of the structure would have little impact on productivity on the project.

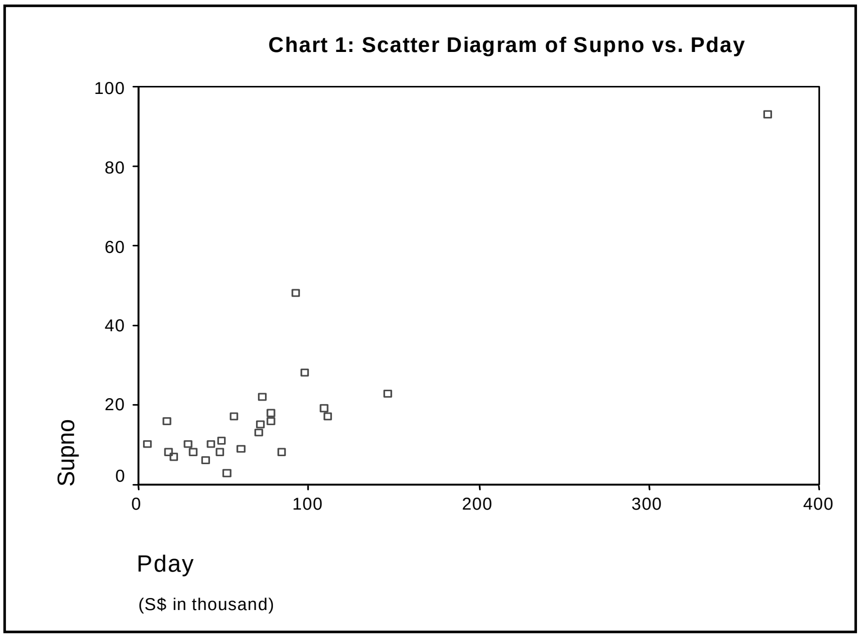
Table 2: Correlation of Project Characteristics and Structural Features

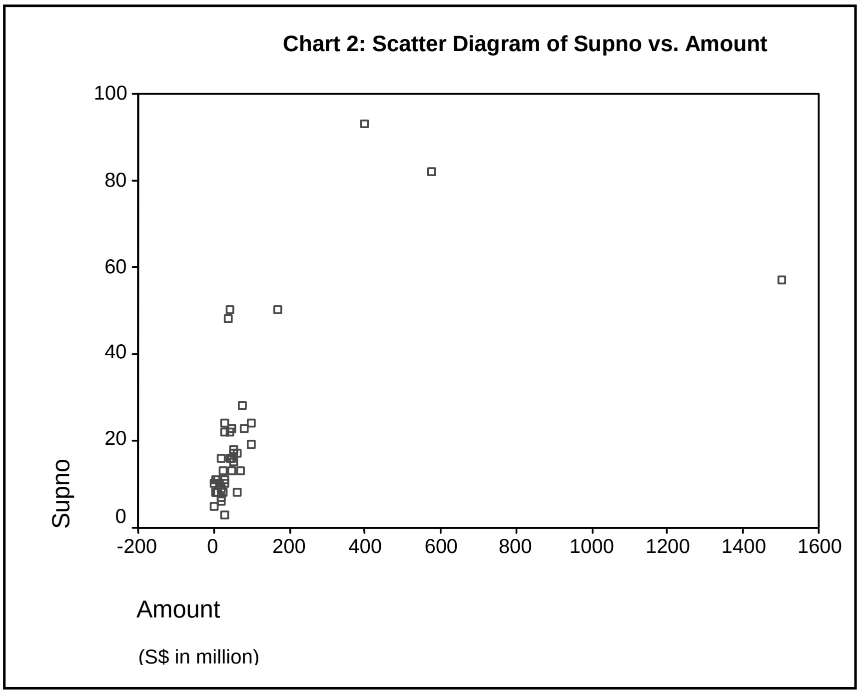
		Amount	*Duration*	*Pday*	*Supno*	*Socmax*	*Maxlevel*	*Division*	*Shape*
Amount	Correlation	1.000	.225	.958**	.605**	.549**	.487**	.509**	-.094
	Sig. (2-tailed)	.	0.280	0.000	0.000	0.000	0.001	0.001	0.562
	N	40	25	25	40	40	40	40	40
Duration	Correlation	.225	1.000	.038	.152	-.075	.162	.149	-.168
	Sig. (2-tailed)	0.280	.	0.858	0.469	0.723	0.440	0.476	0.422
	N	25	25	25	25	25	25	25	25
Pday	Correlation	.958**	.038	1.000	.894**	.374	.531**	.422*	-.235
	Sig. (2-tailed)	0.000	0.858	.	0.000	0.065	0.006	0.036	0.258
	N	25	25	25	25	25	25	25	25
Supno	Correlation	.605**	.152	.894**	1.000	.529**	.763**	.466**	-.035
	Sig. (2-tailed)	0.000	0.469	0.000	.	0.000	0.000	0.002	0.830
	N	40	25	25	40	40	40	40	40
Socmax	Correlation	.549**	-.075	.374	.529**	1.000	.494**	.752**	-.371*
	Sig. (2-tailed)	0.000	0.723	0.065	0.000	.	0.001	0.000	0.018
	N	40	25	25	40	40	40	40	40
Maxlevel	Correlation	.487**	.162	.531**	.763**	.494**	1.000	.498**	.050
	Sig. (2-tailed)	0.001	0.440	0.006	0.000	0.001		0.001	0.758
	N	40	25	25	40	40	40	40	40
Division	Correlation	.509**	.149	.422*	.466**	.752**	.498**	1.000	-.733**
	Sig. (2-tailed)	0.001	0.476	0.036	0.002	0.000	0.001		0.000
	N	40	25	25	40	40	40	40	40
Shape	Correlation	-.094	-.168	-.235	-.035	-.371*	.050	-.733**	1.000
	Sig. (2-tailed)	0.562	0.422	0.258	0.83	0.018	0.758	0.000	.
	N	40	25	25	40	40	40	40	40

Notes:**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

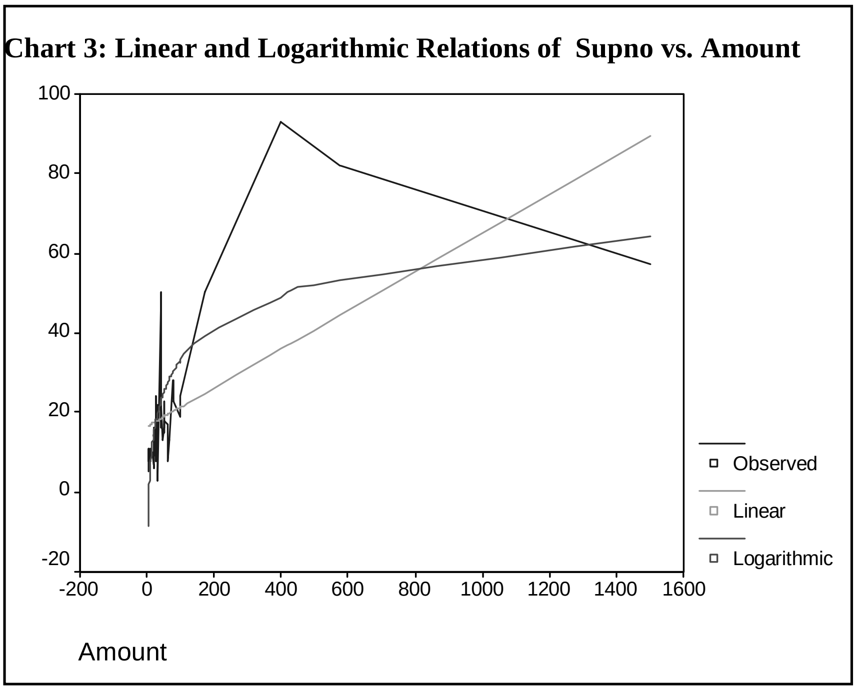
Figure 2 is a scatter diagram of contract amount (Amount) and number of supervisors (Supno). It shows a bunching of projects in a range of amount of $20mil. to $90mil. The bunching based on contract amount distinguishes common size from large size projects. Similarly, the bunching based on the number of supervisors ranging between 4 to 18 shows the effective team size for common size projects.

Figure 3 shows that a logarithmic curve (R square=0.534) fits better than a linear relation (R square=0.367). The logarithmic curve shows an ascending slope, much steeper at the earlier stage before a turning point is reached, and a much gentler descending slope after passing this point. This point shows that although the increase in the contract amount would normally require more supervisors, there would come a size where an increse in the poject amount would not necessarily demand more supervisors. Such a size as $400mil. would allow radical structural and managerial measures which would render the increase of supervisors unnecessary.



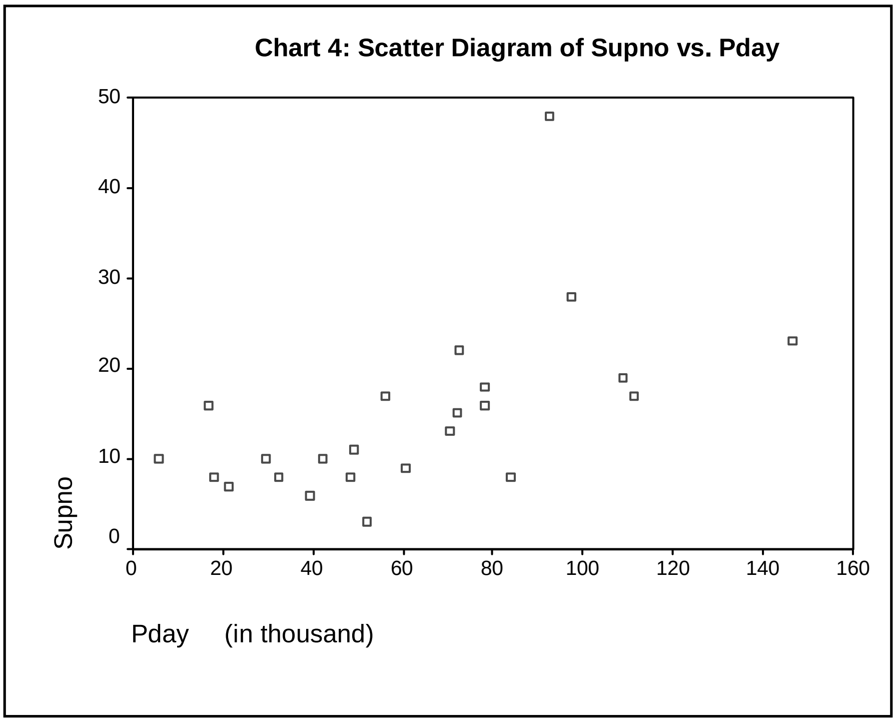


Together, Figures 2 and 3 suggest that there is a limit to the effective number of supervisors required in a site team. This means that the team size need not be endlessly enlarged as the size of contract amount increases.



Projects of Common Size

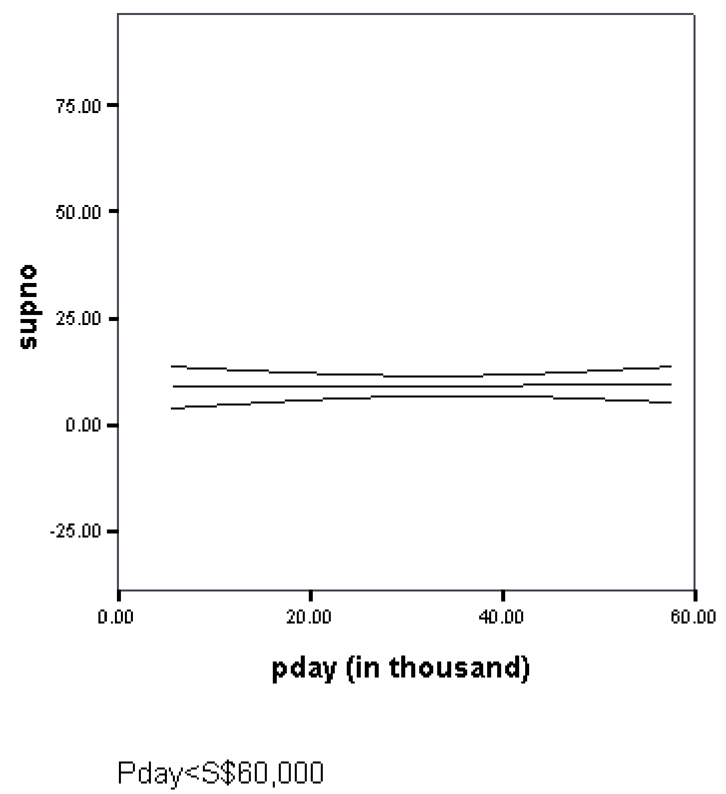
Further analysis was carried on projects with contract amount less than S$90mil. to detail the correlation between Pday and Supno for common size projects. The $90million line was based on the earlier scatter diagrams where the limiting line could be drawn.



In Chart 4, the scatter diagram shows that the number of supervisors (Supno) to stay relatively constant at 10 persons for the completed amount per day (Pday) of less than $60,000. In Chart 5, the predicted linear regression with 95% mean prediction interval within this range is: Supno= 8.73 + 0.01 x Pday with correlation value of 0.00.

The relatively flat slope (0.01) proves the consistency of the number of supervisors when the completed amount per day (Pday) is less than $60,000. Meanwhile, the intercept (b0) = 8.73 (approximately 9 persons) presented the basic number of members in the site team. Relative low correlation (0.00) indicates that the relation is very weak between Pday and Supno in this range

CHART 5: Linear Regression of Supno vs. Pday



As the completed amount per day exceeds $60,000, the number of supervisors (Supno) increases rapidly as the amount completed per day (Pday) increases. Further details are shown in Chart 6. The predicted linear regression within this range becomes: Supno = 7.17 + 0.14 x Pday with correlation value of 0.10.

The relatively high slope (0.14) indicates that the number of supervisors will increase significantly as the completed amount per day (Pday) exceeded 60 thousand, although the correlation is relatively low because of small number of samples.

It could also be noticed that, as this linear relation was summarized from practice, it indicates that most general contractors prefer a relatively fixed number of site team members for a relatively small completed amount (when less than $60,000 per day), a characteristic of mechanistic structure. As the completed amount increases, the number of supervisors becomes relatively flexible and this leads to a tendency towards an organic structure. Based on these observations, it could be concluded that the rate of productivity would dramatically affect the site team structure.

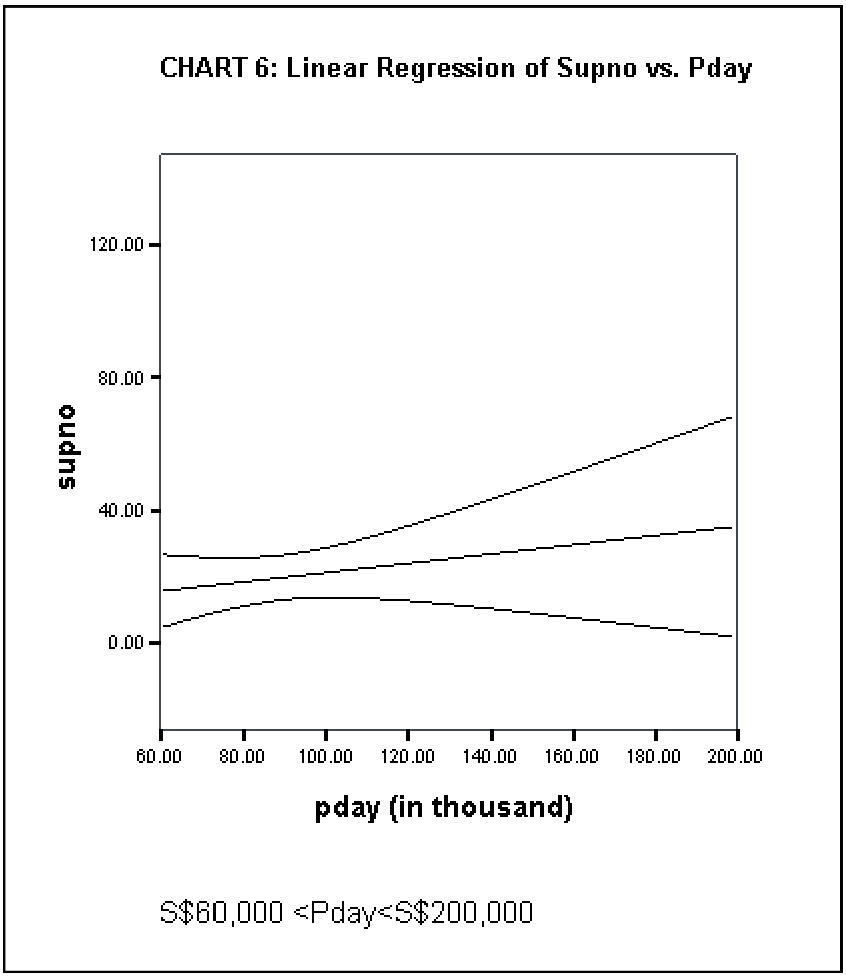


CHART 6: Linear Regression of Supno vs. Pday

CONCLUSION

This paper has shown that the structure of the site team will tend to be more organic as projects increase in size in terms of contract amount and not in terms of project duration. It also shows that the site team needs to increase in size in terms of number of supervisors as the production rate in terms of contract amount per day increases. However, a limit would be reached whereby any further increase in the production does not necessarily demand an enlargement of the site team. At this stage, neither would changes in the levels of the team structure have an impact on productivity.

This paper determined the distinction between common and large size projects to be at $90mil. Up to this limit, team size ranges up to 18 with a mean of 10 members. This indicates the span required of the team leader. Beyond the size of $90mil., project characteristics display little effect on structural features. It is also found that the team size is more stable below than above the production rate of $60,000 per day.

Overall, the paper observes that all of the structural features are closely intercorrelated with each other as well. A variation in one structural feature will cause the changes in the others. The only exception is the shape, which possesses strong correlation with only two features of structure. As the shape has a strong correlation with the maximum of span of control, shallow shapes strongly correlate with larger span of control, consistent with the characteristics of the organic model.

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A Total Quality Management Approach to Competitive Bidding

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Abstract

The objective of the paper is to present a tender evaluation method based on TQM philosophy. The proposed method combines the Multi-attribute Utility Theory and Social Judgment Theory. With this method, the successful bidder will be selected by a combined score rather than one score consisting of the price. With this expansion of considerations, the evaluation of bids takes the total approach to ensure better performance in contracts. This multivariate approach would significantly improve the project procurement process and result in a successful construction product.

Key words: Total Quality Management; bidding evaluation; multi-attribute utility theory; social judgment theory.

INTRODUCTION

Total Quality Management (TQM) intends to improve both the process and its product. It achieves improvement in quality by enhancing working relationships. The concept and application of TQM have been successfully applied in the manufacturing and service industries worldwide. Recent reports indicate that more organizations are applying TQM today.

However this proven method, TQM, has not been as widespread in the construction industry. There are still many questions raised about the implementation of TQM in construction. Anon (1993) showed the results of a survey conducted among 300 architectural, engineering and contracting firms. The firms surveyed ranged from under $20 million to well above $500 million in annual revenues. The results revealed that most of the top managers of these firms do not understand or accept TQM. The survey concluded that most employees and sub-contractors neither considered quality nor are empowered to make such improvements. In another study, Shammas-Toma (1996) found that the quality achieved generally fell below the required standards, despite the fact that all contractors involved had some quality control procedures in operation.

One major difficulty preventing wider implementation and acceptance of TQM in the construction industry is the barrier caused by traditional or conventional practice. One glaring example is the traditional way in evaluating bids by placing most importance on the product price. It is widely known that the client usually selects the contractor based mainly on the lowest price with less considerations for past experience, current workload, and reputation for quality. Similarly, subcontractors are chosen on the same basis, mainly on price. As a result of the conventional fixation on one factor – price, it is difficult for all other factors to be considered with equal importance.

OBJECTIVE

The objective of this paper is to examine a method for evaluating bids that will be based on TQM. This paper proposes to combine the Multi Attribute Utility Theory (MAUT) and the Social Judgment Theory

(SJT) for the purpose. Through them, the successful bid will be selected by a combined score, instead of one score based on cost. This will help to select the better bid and hopefully, the better contractor.

Past Work

Research performed by Russell and Skibniewski (1988) identified several evaluation strategies in use. They comprise dimensional weighting, two-step pre-qualification, dimension-wide strategy and pre-qualification formulae, in addition to subjective judgment. Ellis and Herbman (1991) suggested using time as a means of evaluating bids of highway construction contractors. By this method, bidders enter a bid price together with a time to finish the contract; the bid combined these two factors in cost terms. Larry and Donn (1995) proposed a qualification evaluation which utilized a collective assessment of project value, a measure of disagreement, and an expected recurrence relationship in order to identify unreasonably low bids. The unreasonable bids could then be subject to verification, investigation, or rejection based upon the preference of the client. A means of using the Program Evaluation and Review Technique (PERT) methodology to incorporate uncertainty or imprecision associated with the assessment of contractors' data in terms of the ultimate project goals of time, cost and quality had also been proposed by Hatush and Skitmore (1997).

Methodology

This paper uses a methodology that is a hybrid derived from a combination of Multi-attribute Utility Theory (MAUT) and Social Judgment Theory (SJT). The inclusion of the latter in particular, is because TQM is a management philosophy that effectively determines the needs of the customer and provides the framework, environment and culture to meet those needs. The customer's satisfaction is one of the fundamental goals of TQM. This combination is a realistic and effective methodology which lends itself to TQM application.

The totality quest in the methodology is therefore to determine all the relevant factors which have to be considered in the tender evaluation. Factors such as cost, time, quality, technology, experience, personnel and others can be chosen to determine the contractor's ability to complete the project well. The number of factors considered will depend on the client's requirements. This feature will ensure that the evaluation fully meets the client's goals.

Modelling

Both MAUT and SJT share a common focus which supports their combined use. It is the focus of MAUT to avoid the problem of direct assessment of multi-attribute utility, of say $u(x_1,\ldots,x_n)$. This is also true with the SJT procedure in general. One method of dealing with the problem is to decompose a multi-attribute utility assessment into a series of single attribute assessments. The proposed model could take this form:

$$u(x_1,x_2,\ldots,x_n) = \lambda_1 u_1(x_1) + \ldots\ldots + \lambda_i u_i(x_i) + \ldots\ldots + \lambda_n u_n(x_n) \qquad (1)$$

x_i is a measure of the extent to which a given alternative possesses the $_i$th attribution. In the evaluation model, x_i represents the factors that are chosen by the client. $\lambda_i u_i(x_i)$ is the uni-dimensional utility function of the $_i$th attribute (i.e. value measured for each objective in relation to each and every alternative). A numerical scale of 1 to 10 is used, where 10 represents "perfect" while 1 represents "a relative disaster". λ_i represents relative weights of importance, indicating how much of one attribute the decision maker is willing to sacrifice in order to gain a particular amount of another attribute: $\lambda_1+\lambda_2+\ldots\ldots+\lambda_i=1.0$

This proposed model utilizes a hybrid method of SJT and MAUT. Direct interrogation will be used to establish $U_i(x_i)$, and regression analysis (SJT version) to obtain λ_i. In the regression-based SJT, weights are estimated by analyzing the decision maker's past choice and behavior.

Establishing λ_i Using SJT

In introducing one particular utility transformation of individual attribute variables, namely, $u_i(x_i) = x_i$, the decision maker's judgment policy obtained would be:

$$J = u(x_1,x_2,\ldots,x_n) = \lambda_1 x_1 + \ldots\ldots + \lambda_n x_n \quad (2)$$

Equation 2 is a basic regression type utility-decomposition model, in which it is simply assumed that all individual attribute utility functions are linear. By setting $U_i(x_i) = x_i$, arbitrarily for all attributes, it would avoid the need for the often tedious and elaborate assessment of component utility functions. Only the assessment of weights or scaling constants (λ_I) remains.

The main purpose of applying SJT is to obtain an explicit, quantitative description of the decision maker's cognitive system, by which information is integrated into an expression of preference. In the regression-based SJT, weights are estimated by analyzing the decision maker's past choice and behavior or , if such data are not available, the decision maker's evaluations of a battery of experimentally generated alternative scenarios or combination of objects. This procedure amounts to an indirect interrogation of the subject.

The preferences of individual policy makers will, of course, differ. Thus, for example, one policy maker could be characterized by policy J_1 ($_i$ =1,2,3). Then one by policy J1will be: $J_1 = 0.7x_1 + 0.2x_2 + 0.1x_3$. Another by policy J2 will be: $J_2 = 0.6x_1 + 0.1x_2 + 0.3x_3$, and so on.

Once constructed, if such cognitive models truly represents a policy, then they permit prediction of the policy maker's preference judgments in response to variations.

The steps to derive the quantitative forms would be as follows. Firstly, the necessary constraints must be determined. Secondly, a large number of variations (within the established ranges) would be randomly generated. Thirdly, the policy maker then judges each combination. Fourthly, a weighted average regression model is fitted through the observations and the weights λ_i are calculated. Lastly, the final λ_i's for the model are formed by taking the weighted average of all J_i's.

As an example for the purpose of illustration, the SJI model to this problem could be in this form:

$$u(x_1,x_2,x_3) = 0.65x_1 + 0.15x_2 + 0.2x_3 \quad (3)$$

Establishing $u_i(x_i)$ Using MAUT

The calculated values of λ_i in Equation 3 represent the decision maker's feelings (weights) towards the importance of each objective. At this stage, the values of u_i (i=1,2,3) have not yet been determined. Earlier, it was set that $u_i(x_i) = x_i$ arbitrarily for all attributes in order to facilitate the procedure to establish the values of λ_i. Now, it is possible to establish the values of $u_i(x_i)$ and the following steps are proposed.

(a) Each decision maker is to answer $u_1(x_1)$ (Utility value of 1 to 10) with respect to each A_i
He will then go on to $u_2(x_2)$ with respect to each A_i
And still go on to $u_3(x_3)$ with respect to each A_i

(b) Gather all the decision makers' responses of $u_1(x_1)$ with respect to all Ai, and take the average values.
Do the same for $u_2(x_2)$ and $u_3(x_3)$ with respect to all A_i
These values will be put into Eq.2 to form the complete model.

Each decision maker will be interrogated beginning from his response to the second alternative in consideration. The successful bidder will be the one with the highest $u(x_1,x_2,x_3)$.

TESTING

The model is tested on bids for a design and build contract of a school building. The successful contractor will be determined by five decision makers. Four contractors are considered in the tender stage (Table 1).

Table 1: Bids for Design and Build Contract of Proposed School Building

	Contractor A	*Contractor B*	*Contractor C*	*Contractor D*
Cost (million)	12	12.5	13	13.2
Time (month)	24	22	20	24

Five relevant factors are chosen in the bidding evaluation. They are cost, time, quality, design experience and project management. In establishing λ_i , SJT is used (Table 2).

Table 2: Establishing λ_i using SJT

	J_1	J_2	J_3	J_4	J_5	*Average*
λ_1 (cost)	0.60	0.55	0.70	0.60	0.75	0.64
λ_2 (time)	0.15	0.20	0.05	0.05	0.10	0.11
λ_3 (quality)	0.10	0.10	0.15	0.10	0.05	0.10
λ_4 (design experience)	0.05	0.10	0.05	0.10	0.05	0.07
λ_5 (project management)	0.10	0.05	0.05	0.15	0.05	0.08

In establishing $u_i(x_i)$ MAUT is used. Since $u_1(x_1)$ (cost) and $u_2(x_2)$ (time) are firm data, the decision makers' scores are put to be the same. For other $u_i(x_i)$ (i = 3,4,5), each decision maker has his own opinion. Table 3 shows their decisions of $u_4(x_4)$ (design experience). Table 4 shows all $u_i(x_i)$ scores and $u(x_{1,......}x_5)$ values.

Table 3: Establishing $u_i(x_i)$ using MAUT

	J_1	J_2	J_3	J_4	J_5	*Average*
Contractor A	7.5	7.0	6.5	7.0	7.0	7.0
Contractor B	8.0	8.5	8.5	9.0	8.0	8.4
Contractor C	9.0	9.5	10.0	10.0	7.5	9.2
Contractor D	10.0	10.0	9.0	8.5	10.0	9.5

Table 4: TQM based Scoring

	$u_1(x_1)$	$u_2(x_2)$	$u_3(x_3)$	$u_4(x_4)$	$u_5(x_5)$	$u(x_{1,......}x_5)$
Contractor A	10.0	8.0	6.2	7.0	6.5	8.91
Contractor B	9.5	9.0	9.5	8.4	9.4	9.36
Contractor C	9.0	10.0	8.8	9.2	8.5	9.06
Contractor D	8.8	8.0	9.8	9.5	9.2	8.89

The successful contractor should be contractor B which has the highest score of 9.36. Although contractor A has the lowest price, it ranks behind contractor B and C due to poor performance in other aspects.

CONCLUSION

The main advantage of this proposed method using MAUT and SJT is in avoiding the need for the tedious and elaborate assessment of component utility functions. Since the objectives of SJT are similar to those of MAUT, the similarity provides a common basis for their joint application. The two theories differ only in the way the data to be used are obtained. The differences between MAUT and SJT lie in obtaining $u_i(x_i)$ and λ_i. The underlying decomposition forms are often common, and are shared equally.

The standard lottery technique, advocated by Keeney and Raiffa (1977) for estimating $u_i(x_i)$'s and λ_i's in connection with the multiplicative form, is not incorporated into this procedure. It is felt that these methods are quite complicated for the intended users (decision makers on the bidding process for construction projects). For simplicity and practicality, the uni-dimensional utility functions are also assumed to be simply linear.

This paper has proposed a methodology which considers more factors in the evaluation of bids than the conventional practice in the industry based on the factor of price. In so doing, it promotes extending consideration to include as many factors as possible. This is in line with the TQM concept which advocates a 'total' approach.

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Chinese policy on science and technology and technical improvement in the construction industry

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Abstract

Firstly, this paper will depict the current situation with regard to Chinese technology system and polices. Then it gives a brief introduction of present Chinese construction industry, its future development, and the construction market opened to foreign companies. Following that, the development plan for 2010 in relation to the construction industry is introduced. This plan is composed of four parts: to develop new construction technology, to transform and popularize research results, to advance technological improvement in enterprises, and to enhance international cooperation. Finally, some proposals for the development of science and technology in the construction industry are suggested, and some lessons, which can be shared with other developing countries, are drawn.

Keywords: Science and technology policy; construction; technology import; technical improvement; development of science and technology.

INTRODUCTION

In the late 1970s, China began to implement the policies of economic reform and open its door to the outside world. Since then, China has achieved remarkable success in the national economic development. However, as time elapsed, marked changes have taken place in Chinese scientific and technological systems and policies. These changes influenced the development of national industries. This paper attempts to describe the changes and the new development plan for the construction industry under Chinese scientific and technological policies.

Firstly, the major characteristics of Chinese scientific and technological systems and policies are outlined. Second, a brief introduction to the present Chinese construction industry, its future development and the construction market for foreign companies is given. Third, the Chinese government's policy on science and technology and its development plan for 2010 in relation to the construction industry is presented. Finally, some proposals for the development of science and technology in the construction industry are suggested.

THE CURRENT SITUATION WITH REGARD TO CHINESE SCIENCE AND TECHNOLOGICAL SYSTEM AND POLICIES

Before 1979, projects for scientific research and technological development were determined according to compulsory government plans, and were undertaken by designated institutes with government funds. But, since the adoption of reform policies, China's scientific and technological system and policies have changed greatly. Firstly, scientific research and technical development are no longer subject to compulsory government plans alone; instead, they are under a combination of compulsory government plans and guidance. The main difference between the compulsory plan and the guidance plans is that the former is financed mainly from government allocations, but the latter is financed from enterprises, localities or other organisations. In the latter case, the central government supplies few or no funds but does grant them preferential treatment by way of loan priority, low interest loans and special priority for imports. This is because in China, only with the approval of the government can an enterprise obtain a bank loan for its own technical development projects. Most of the compulsory plans are associated with important basic research programs. Each of these programs has identified key areas for development and key research topics. Examples are *the General Outline* 863 (State Science and Technology Commission, 1986), *the National Plan for Major Basic Projects* (State Planning Commission, 1991), and *Key State Projects for Technical Development* (State Planning Commission, 1992). The guidance plans, on the other hand, were set up in order to speed up the process whereby scientific and technical results can be quickly popularized and put to practical use. Examples include the "*Sparks" Plan* (State Science and Technology Commission, 1985), (for promoting advanced and practical technology in the rural areas), the *"Torch" Plan* (State Science and Technology Commission, 1985), (for promoting the commercialization and industrialization of high and new technology), the *State Plan for the Popularization of Scientific and Technical Results* (State Planning Commission, 1990), and the *State Plan for the Popularization of Key Technology* (State Planning Commission, 1991). Besides, the government is also responsible for planning the import of foreign technology.

Secondly, industrial enterprises and non-governmental organizations have began to replace free state research institutes as the mainstay of technical development. While continuing to support public institutes in research and development, the Chinese government also encouraged enterprises to develop their technology independently. For example, enterprises are asked to engage in what is called "technical renovation" aimed at developing new products, raising product quality, saving energy and raw materials and increasing exports (Jia et al. 1994). Besides, enterprises and research institutes are encouraged to integrate their efforts so that research activities can be made to serve the enterprises directly.

Thirdly, the results of scientific research and technical development can now be transferred through a technology market as commodities. Before 1987, the results of scientific research and technical development belonged to the state and could not be bought and sold as commodities. This system failed to provide incentives for research institutes and researchers. In 1987, China enacted the Technical Contract Law, which provided a legal guarantee that scientific and technical results could be put on the market. The figures published by State Statistical Bureau show that the number of technical exchange markets and the volume of transactions on the markets are increasing every year. The establishment of the markets benefits both research institutes and researchers and medium-sized and small enterprises. On the one hand, researchers are encouraged to develop new technology. The commercialization of research results allows them to obtain more funds to develop this new technology. On the other hand, those medium-sized and small enterprises that lack the ability to develop technology can buy applicable technology in the market.

Finally, individual scientists and engineers are encouraged by government policies to do research and transfer their research results to the market. In addition to central government activities, local governments also map out their own plans for scientific and technological development, and special funds are allocated by local financial authorities for scientific research and technological development. The policies adopted by local governments for encouraging scientific research institutes and enterprises to engage in technological development involve the same kind of preferential treatment as the policies adopted by the central government. The influence of local government policies on science and technology is very important to small and medium-sized enterprises and non-government organizations, because these enterprises and organizations are hardly affected by central government's policies. The main reason is that within the framework of government plans and policies, the emphasis of technical development is directed at the renovation of existing enterprises, mainly state enterprises which have been in existence for many years. But the pressure of market competition has given these enterprises, especially the non-governmental ones, a strong motivation for technical improvement and, because of this, they compare favourably with large and medium-sized state enterprises in terms of their ability to engage in technical development.

OVERVIEW OF CHINESE CONSTRUCTION INDUSTRY

In China, the construction industry is one of the pillar industries of the national economy. The construction industry includes civil engineering construction, building, installation of pipelines, other lines and equipment, and decoration engineering. Construction is the third largest sector of the national economy, ranks next to industry and agriculture, but before transport services and commerce. During the Eighth Five-Year Plan, the total fixed assets investment was 6,163.7 billions Yuan RMB. Almost forty percent of the investment (3.926.3 billions Yuan RMB) was provided by the construction industry (Yao, 1997). In 1998, the total fixed assets investment was 2,9850 Yuan RMB. About sixty percent of the investment was provided by construction and decoration enterprises (Zheng, 1999).

Construction and decoration enterprises are classified in four levels according to their experiences on engineering projects, the ability of the enterprise's management, the number of engineers, the amount of fixed assets and circulating capital, mechanical equipment, and the total output each year. There are more than 94,000 registered construction companies in China (Yao, 1997). Among these companies, 2,126 of them are Class One construction enterprises that are qualified to engage in any kind of construction projects in their working fields. Others are Classes Two and Three enterprises. More than thirty million people are engaged in construction work. This number accounts for five percent of the total employment.

The management of the construction industry is undertaken by central and local construction administration departments. The Ministry of Construction, one department of the State Council, is responsible for the comprehensive management of the national construction industry. But the management at central level is focused on macro-regulation. The main objectives are to lay out the development plan of the construction industry, work out industrial policies, make laws (such as the law of construction, the law of tendering and bidding), guide system reform, promote the transformation of business operating systems in enterprises, foster the construction market, formulate rules and regulations on technical progress, quality management, safety, supervise the implementation of these rules and regulations, and manage overseas construction companies' business in China. Because China is such a big country, the central government cannot control all of the work. Therefore, there is a construction department or construction committee in every province. This committee is responsible for the management of the construction industry in the province.

According to the national economic development strategy, the main missions of the construction industry involve four areas. First is the construction of national projects, such as energy, transportation, raw materials, and irrigation projects. Second is housing construction. During the 1990s, the total area of housing constructed was 1.65 billions square meters in cities and 6.5 billions in the countryside. Third is the construction of cities and towns. By the end of 2000, China will construct another 230 cities and 5000 towns (Yao, 1997). To improve the investment environment, there are a lot of reconstruction works in many cities. There is a huge potential market for construction in the countryside. The investment by government in the countryside accounts for more than thirty percent of annual national fixed assets investment. Planning, design, technology services, construction materials and products are urgently needed in the construction market in the countryside.

To promote the development of the construction industry, the Chinese government has encouraged foreign construction companies to enter the Chinese market. Since a Japanese company was selected as the general contractor of Rubuge hydroelectric power station in the early 1980s, many companies from the United States, Japan, France, British, German, Italy, Korea and other countries have come to China as general contractors or subcontractors. More than 1000 joint venture construction companies have been established. Foreign companies are allowed to enter Chinese construction market in the following ways:

(a) Establish joint venture or cooperative engineering construction company, real estate development company, construction supervision company, or construction consult company.
(b) Bid for the projects (be allowed by government) as general contractor, joint general contractor, or subcontractor.
(c) Supervise the projects funded by foreign companies or overseas loans.

(d) Set up representative offices in China.

The policy of opening the construction market to overseas companies is profitable to China. These companies bring technology and capital. Shortage of money is one of the bottlenecks to the development of the construction industry. Chinese construction companies can import advanced technology and management experiences, and develop new managers. While foreign companies enter the Chinese market, Chinese companies also enter the international market. The imported advanced technology and management experiences strengthen Chinese enterprises' competitive ability. Finally, the competition on price, quality and technology can promote the development of the domestic market for construction materials, labour, technology and information, and the development of the market-oriented economic system.

DEVELOPMENT PLAN FOR 2010 IN RELATION TO THE CONSTRUCTION INDUSTRY IN CHINA

According to the national development plan, the Ministry of Construction has set up the following development objectives (Ministry of Construction, 1996):

(a) By the end of 2000, fifty percent of the development of construction industry should come from scientific and technical progress. By the end of 2010, this figure should be sixty percent.

(b) By the end of 2000, fifty percent of scientific research outcomes should be transformed to physical products. By the end of 2010, this figure should be seventy percent.

(c) By the end of 2000, the technical level of construction industry should come up to the advanced countries' level in the early 1990s. By the end of 2010, it should reach world standards.

To achieve these objectives, the Ministry of Construction has worked out four main missions. The first is to develop new construction technologies. These technologies involve city development strategy and modeling; city modernization and sustainable development; construction industrialization and modernization; improvement of the functions and quality of housing; energy-saving technology and the development of energy-saving products; computer and information technology (IT) and their application in the construction industry; new construction mechanisms; development and use of underground space; enhancement of the ability to take precautions against natural calamities; examination, appraisal and reinforcement of old buildings; and basic science and technology research and management skills.

The second mission is to transform and popularize research results. During the period of the Ninth-Five Year Plan, the objectives are the application and dissemination of new technologies of construction energy-saving materials and new wall materials; high quality housing products; high-strength and good performance concrete; the use of underground space and foundation treatment; water supply and water-saving; garbage disposal; chemical building materials; construction mechanisms; utilization of waste materials in a comprehensively way; and CAD, GIS and MIS.

The third mission is to encourage enterprises to advance technical progress. It is enterprises that can transform the results of scientific research into production forces. Therefore, enterprises are encouraged to cooperate with research organizations, technology development institutes and universities. The enterprises are also encouraged to import, digest and absorb advanced technologies from overseas.

The final mission is to strengthen international science and technology cooperation. Chinese organizations are encouraged to cooperate with foreign organizations in the areas of construction energy-saving, house building, city environment protection, city traffic improvement, preventing and fighting natural calamities, and the application of computers and IT in the construction industry. It is hoped that the importation of new technology can accelerate technological innovation at enterprise level.

FUTURE PROPOSALS FOR DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN CONSTRUCTION INDUSTRY

To achieve all of the objectives discussed above, some measures must be taken. The first is to establish an index system to evaluate technical progress in construction. With the help of this system, the administration department could have a complete and clear understanding of the difference between Chinese and foreign construction industries. It will then be possible to know the key technologies that must be tackled, and the technologies that must be popularised.

Second, to deepen the process of enterprise reform. Experience shows that only when enterprises become fully independent economic entities, responsible for their profits and losses, will they be cautious in implementing policies and responsible for the risks and benefits in their operations. These are the basic foundations for success in technological improvement. It can be realized through establishing modern corporations, clarifying property rights, separating ownership from management rights, and nurturing a group of entrepreneurs.

Third, to transform the function of the government. Now governments, at various levels, interferes too much in enterprises' business. Instead of doing that, government should strengthen macro-control, administrative instruments and investment in major technical improvement projects to avoid excessive duplication and the introduction of inappropriately low-level technologies. Duplication has wasted a lot of scarce resources in the past few years and destroyed the balance of supply and demand.

Fourth, to establish an intermediaries market to service technological improvement. Enterprises, especially medium and small-sized enterprises, suffer heavy losses due to inadequate feasibility studies and incorrect information. It is necessary to use more consultation for market surveys, data collection, information analysis and appraisal of technology improvement. In that case, the role of the government can be changed and the role of enterprises can be brought into full play as the real entities in technological improvement.

Finally, the introduction of technology from abroad is an important way to achieve technological improvement. The structure of technology imports should be adjusted to one that favours software technology in the form of licenses, consultation, management etc., and rely less on hardware in the form of equipment imports. There has been too much emphasis on the import of equipment in the international technology trade. This has led to poor assimilation of the technology introduced, and there has been no improvement in China's self-sufficiency rates for key commodities. Although many factors contribute to this, one of the most important has been unclear government policy.

CONCLUSION

Technological improvement is normally achieved through three ways: invention and adoption of new techniques, transactions that diffuse technology among domestic enterprises, and the import of technology from abroad. The Chinese government has set up a development plan for 2010 in relation to the construction industry. But whether these objectives can be achieved depends on many factors. One of the important elements is government policy on science and technology.

For many medium and small-sized construction enterprises, it is not easy to develop new technologies for themselves. An easy way is to import these technologies from domestic or international technological markets. As a developing country, the import of technology, its assimilation and absorption should be integrated parts of a single process. More resources should be used for absorption. Various levels government and enterprises should allocate funds not only for the import of technology, but also for absorption. Chinese enterprises have failed to promote research and development in new technology. They also lack funds for assimilation and absorption of imported technologies. This has inhibited the ability to develop new technologies independently, and promote the technical improvement in the industry.

Another problem of the entrepreneurs should also be emphasized. Since the introduction of the responsibility system in the early 1990s, entrepreneurs have frequently been hired on contract. But managers' terms of office were often too short to encourage them fully solve the assimilation, absorption and development problems.

Some of the problems described here are Chinese characteristics. But other developing countries may also face similar problems. Therefore, the proposals may be valuable. As a developing country, importing technology from advanced countries is an effective way to promote construction industry development. Some lessons from China can be shared with other developing countries. The technology strategy should be consistent with national economic policies. It must be stable and not be guided by political objectives. Second, technology should be imported on the basis of national economic requirements rather than simply chasing after the newest and most advanced items. That is to say, technology transfer should aim toward better planning and integration with emphasis on the appropriateness of the technology and the ability to absorb and use the technology. Thirdly, instead of building new plant, emphasis should be placed on rehabilitating and improving existing factories. The interest should be away from importing technology that is incorporated into equipment and toward the importation of technology know-how, a shift which Chinese commentators have characterized as a move from "hardware" to "software", or from "eggs" to "hens". Finally, the level of transfer should be shifted from assimilation to adaptation and development. This requires recipient firms to possess capabilities for problem identification and solving on their own initiative. These capabilities can be developed through the cumulative effects of technology and teamwork among the firms.

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