Systemic Innovation in the Management of Construction Projects and Processes

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Systemic Innovation in the Management of Construction Projects and Processes

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Preface

In an industry that is dominated by one-of-a-kind projects involving competence sharing between different organisational entities, and thin profit margins, a key challenge in the new global economy is to ensure delivery of projects that are on time, within the cost limits, of high levels of quality, sustainable, and provide value to the customer. All this, while ensuring that contractors remain profitable without raising project costs. This calls for systemic innovation in the management of construction projects and processes that takes into consideration all relevant aspects and stakeholders of the complete product and service lifecycle [1, 2 and 3].

The Project Management Body of Knowledge (PMBOK) [4] provides one perspective to the effective management of projects and processes. Understanding the unique characteristics of the construction industry, a special construction extension to the PMBOK was released [5]. It is primarily based on a set of guidelines for different functional areas for the management of processes within projects. Concerns have however been raised about its completeness and applicability[1]. In fact, Koskela and Howell [6] challenged the validity of the underlying theory of project management. If not more, this at least presents the impetus to explore project management from a different set of perspectives. As an example, one could consider management of processes and projects from the perspective of information flows and contract networks (figure 1) within inter-enterprise project environments such as construction [7]. This simple illustration is an indicator of some of the underlying problems in the management of processes and projects within the construction sector.

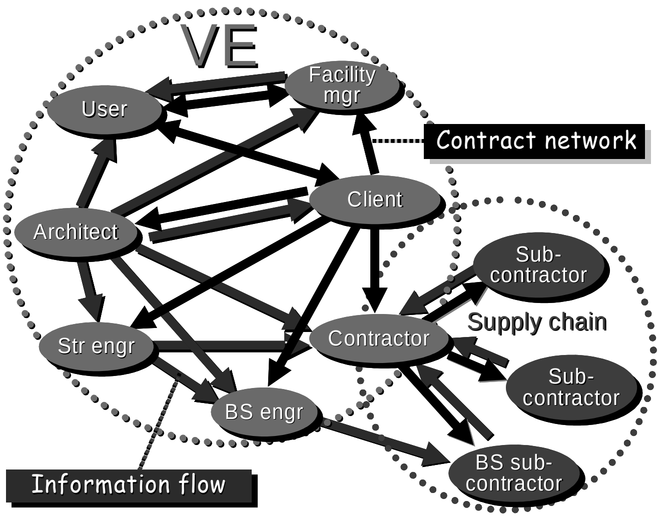

Figure 1: Information flows and contract networks within construction projects

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[1] See the review of [4] by Max Wideman at http://www.maxwideman.com/papers/pmbok3/intro.htm

The challenge of systemic innovation in the management of construction projects and processes has been taken up in this book. Contributions and experiences from Australia, Brazil, China, Croatia, Finland, Norway, Saudi Arabia, Sweden, Taiwan, The Netherlands, United Kingdom, and USA unveil how systemic innovation is being used to manage projects, product processes and control, productivity and performance improvement, product delivery systems and contractual practices, and risk management.

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Section I

Managing Projects – Methods and Practices

Briefing for Arts Construction Projects: Capturing the Needs of Arts Clients

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Abstract

More than £ 1 billion of public funding has been spent by the Arts Council of England (ACE) Lottery Fund on the arts, mainly on building constructions. However, it is evident that many of these projects were completed over the budgeted amount and scheduled time. Among various phases in the procurement, the briefing process has been considered critical to successful construction and yet problematic in its effectiveness. Whilst the briefing process in construction projects has been generally claimed to 'limit' the client in further stages, the briefing process for the Arts is required to translate the spatial needs of the so-called 'artistic vision' into a building. Thus, the briefing process in the Arts project is expected to accommodate the needs and requirements of the Arts clients that may be unique and dynamically change over time. The research aims to elucidate the most appropriate briefing process or processes that delivers a 'better' environment for the Arts. The methodology applied in this investigation is literature synthesis followed by case study. Case historical analyses of six case studies will be performed with one of the cases as a pilot case. In further phases, in-depths interviews to the key persons of the six cases will be conducted to complement the case historical analyses. Findings from the literature synthesis of generic briefing and the proposed research methodology are brought together in this paper and major issues highlighted.

Keywords: Arts projects, briefing, client needs and requirements

1. Introduction

A distinctive characteristic of most of the Arts buildings is the many sources of funds there may be for a single project, acquired from a broad base of funding sources. These sources of funds may affect the phasing of the building programme or incorporation of special facilities [1]. Various sources of funding are available for the Arts. The funding is for promoting the Arts, subsidising Arts productions, supporting Arts projects, as well as capital projects [2]. In addition to one-off grants from local and central government, tourist authority, European Union, Development Corporation, and Regional Arts Boards, there are loans from local governments, banks and financial institutions [1]. However, local governments' funding is typically through providing buildings and revenue support to Arts organisations. Private sector is another source of funding [2]. Government's funding the Arts has been channelled through several non-governmental organizations [1, 2], the largest of which is the Arts Council.

More than £ 1 billion has been spent by the Arts Council of England (ACE) Lottery Fund on the Arts building construction. However, a significant proportion has been considered problematic. The National Audit Office (NAO) reports many of the reviewed projects were experiencing cost overruns and delays [3, 4]. The CIB (1997) [5] has published a set of documents designed to improve the quality, effectiveness and efficiency of construction projects with particular emphasis on the briefing process since the outcome of any project is considered relying on the quality of the briefing. Kelly et al. (1993) [6] recommended a thorough briefing in order to develop a building with better value for money. Whilst the best value for money is considered achieved when quality is maximised for a given cost, cost minimised for a given quality or some optimal compromise between the two [7], it has been generally accepted that quality is defined in term of punctual deliver of the completed facility, functional utility, social and legal acceptability and aesthetics [6]. Hence, the success of the briefing process can be associated with the success of the project deliveries. Despite the fact that the briefing process has been extensively researched, building for the Arts are considered complex and unique due to the strict requirement to meet exacting technical requirements and also necessity to respond to various and sometimes conflicting demands of artists and performers, managerial staff, funding organizations, and the general public [1, 2]. Hence, an alternative approach may be required to apply the generic concept of briefing 'good practices' into the performing of Arts building projects.

In light of this, the research is set to investigate the most appropriate briefing practices to enable a 'better' environment in order to deliver excellent buildings for the performing Arts. This is to be achieved by investigating and analysing selected buildings for the performing Arts (i.e. case studies) that have been briefed, designed and procured in the relatively recent past. The use of case study method allows the research to retain the holistic and meaningful characteristics of real-life events [8]. In-depths interviews to the key persons of the studied cases will be conducted to complement the case historical analysis. The outcome is expected to provide valuable new insights and guidance for the Arts community to engage in a capital project to receive the best value for money in providing spaces for the performing Arts.

2. Construction Briefing

The common understanding of the briefing process in the UK (also known as architectural programming in the USA terminology) is generally about capturing information and ideas from Clients. This process results in the development of the brief and is followed by understanding the captured information and ideas, proposing and explaining to the Client all the alternatives and issues related to their requirements (e.g. risks and constrains), justifying and getting approval of the Client for certain alternative or scheme, followed by the translation to the designers' language to form the base for further stages. Despite this common understanding, various formal definitions of the briefing process exist [5, 9, 10, 11, 12]. Complementing the definitions, researchers have also provided their own explanations in understanding the process. Kamara et al. (1999) [13] defined the briefing process as the process of formulating and developing the brief. Barrett and Stanley (1999) [14] perceived briefing process as a process of innovation in which ideas are created and implemented and continued to inform all the technical work throughout the project. In the field of building design management, Grey *et al*. (1994) [15] regarded the briefing process as providing a clear means for proceeding and communicating the design tasks and objectives across the interfaces between one stage and the next. Hyams (2001) [16] described briefing as a process that is distinct and yet integral to the design process, avoiding wilfulness and giving client they have decided, need and want. From the various definitions and views on briefing discussed, three central themes were observed to enable further discussion, namely the role of the parties in the briefing process, the extent of the briefing process in regards to the construction stages, and the objective of the briefing process.

2.1 The Role of the Parties

The briefing process has been considered as a team effort between the participants from both the client group and the consultant team [17]. Further break down of the parties were provided by various research [16, 18, 19] into four general groups, namely the *Clients*, the *Building Users*, the *Regulatory Agencies* (including public interest parties), and the *Consultants*. However, the term *Client* reflects a singular term often intended to encapsulate a complex consortium of stakeholders whose opinions and factual requirements need to be consolidated into a singular consensus view [20]. Hence, in the subsequent discussion, the term *Client* is considered encompassing both the client organisations and the *Building Users* (i.e. end users).

Various definitions and views of the briefing process prescribed the role of the parties, particularly the Client and the Consultant. BSRIA (1990) [11] regards briefing as a process by which the designer receives all information to form the basis for detailed design involving the extraction of information from clients regarding their requirements and expectations. CIB (1997) [5] explicitly mentioned that the Clients should inform other of their needs, aspiration and desires, either formally or informally implying that the Client is responsible to make clear the requirements to the consulting team. This stand is supported by BRE (1987) [18], describing clearly that the Client is responsible for the briefing process by the means of preparing and providing enough information. Sports Council (1994) [21] prescribed the Client's body to be responsible in determining what is and its local community need or want. The purpose of briefing process is for the Clients to communicate their needs and objectives in initiating the project [22]. Clients must clearly express project objectives in terms of building requirements, costs and time budgets [23]. The findings from a study by Cherns and Bryant (1984) [24] have demonstrated the importance of this Client's role in a briefing process.

In contrast to the views above, British Standards (1995) [25] views the briefing process as a process of identifying and analysing the needs, aims and constraints of the client. RIBA (1967) [9] prescribed that the briefing process is intended to prepare general outlines and plan future action by setting up the Client organisation for briefing and also to provide the Client with an appraisal and recommendations. These views shifted the responsibility from the Client to the Consultant. The Consultant is no longer perceived as a passive party relying on the Client to provide information, but rather as an active party to identify, capture, and analyse the Client's requirements and needs. Several researchers were even promoting further analysis of the Client's business processes in order to improve the briefing process and to understand the way in which any proposed built solution would impact upon these business processes [6, 26, 27].

Various other views present a reconciliation of these two views. Murray (1996) [28] asserted that the Client has direct responsibility for the project development in the briefing process with a 'symbiotic' relationship (i.e. a reciprocal interaction) to achieve more effective briefing. CIRIA (1995) [12] views the briefing process as a collaborative and evolutionary process between the Clients and their advisors. BSRIA (1998) [11] perceived the briefing process as an iterative process involving regular feedback from the Client, advisers design team, and end users. Thus, briefing is a collective process involving both the Client's and the Consultant's contributions. The allocation of responsibility bearing on the briefing process is associated with the experience of the Client. Gameson (1996) [29] asserted that the level of briefing interaction between the Client and the Consultants varies considerably depending on two factors, one of which is the Client's previous experience of building construction. The experience of the Clients has been reported to influence the potential of having changes on the pre-construction and construction periods [30, 31]. The more experienced the Client is, the less necessary for the Consultant to identify, capture, and analyse the Clients' requirements and needs.

2.2 The Extent of the Briefing Process

Kelly et al. (1993) [6] and CIB (1997) [5] recommend two stages of the briefing process, known as the strategic briefing and the project briefing. The strategic briefing comprises a strategic review of the Client's organisational needs and further specified as an independent stage to set up the project strategy for the Client's business needs and objectives prior to any formal design and construction action. The latter is more tactical in nature and is primarily concerned with issues of performance specification. A detailed chart of briefing process has also been provided by CIB (1997) [5]. In this chart, the strategic briefing is subdivided into two key stages (i.e. *Getting Started* and *Defining the Project*). Each stage is defined as a set of necessary activities in order to produce a strategic brief or project execution plan. Gray *et al*. (1994) [15] asserted that the briefing stage should provide a clear means for proceeding and communicating the design tasks and objectives across the interfaces between one stage and the next. These views are inline with the view from RIBA (1967) [9] mentioning that the briefing process encompasses the inception and the feasibility phases of their *Architect's Plan of Works*.

However, RIBA (1973) [10] expanded this view on briefing process later on to include the outline proposal and scheme design phases of the *Architect's Plan of Works* and freeze the content of the brief for the subsequent phases. Whilst accepting many criticisms for freezing the brief after the scheme design phase, this expansion of the briefing process demonstrated a significant shift from viewing the briefing process as a 'one-off' event to the one that encompass other phases in the construction process. The briefing process is now considered to encompass both the strategic and project briefing. This shift of paradigm can be addressed to the limitation of the 'one-off' view which is not allowing options to be kept open to reflect the changing circumstances during the development of the project [32]. Atkin and Flanagan (1995) [26] proposed an eight-stages briefing process which overlaps the briefing process with the design process. Furthermore, CIRIA (1995) [12] considers the briefing process as a process after the feasibility stage that encompass programme for the design and construction work, and control procedure to guide the progress of the project within the time and budget. British Standards (1995) [25] considers a brief as a working document which specifies at any point in time the needs and aims, resources of the Client and user, the context of the project and any appropriate design requirements. Barrett and Stanley (1999) [14] considered briefing process as a process that starts early and continues to inform all the technical work throughout the project.

In the facility management, Preiser (1993) [33] identified the importance of developing a database of previous projects to learn from successes and failures in building performance to future buildings, thus promoting the importance of the Post Occupancy Evaluation (POE). In line with this, the function of briefing is extended further to the post project stage involving a constant feedback loop [5, 32, 34, 35]. Briefing is regarded as a continuous and cyclical process in order to evaluate the project and feedback to new projects (includes the POE process). Nutt (1993) [35] proposes a *total briefing cycle* in the facility management. The focus of this approach is on extending briefing into a cycle feedback information system, in which the brief is regarded as a periodic modification and improvement of facilities for a long-term consideration. The concept of POE is employed into *a total cycle* of the briefing process. Reinforcing the *total cycle* view of the briefing process, Blyth and Worthington (2001) [32] proposed a framework associated with a series of activities to identify various types of briefs that recorded the entire project development. The briefs are then guiding the development of the design process in sequence including POE. The shift from viewing the briefing process as a part of an early stage into an integrated part of the entire construction and management process encompassing the POE has been considered as the current trend [36].

2.3 The Objective of the Briefing Process

Generally, the objective of the briefing process is to develop the brief which encompasses the Client needs and requirements to enable the designer fulfilling those needs and requirements. Several views [37, 38, 39] have stimulated an ethos shift from merely fulfilling the needs and requirements specified in the briefing into pursuing for the Client's satisfaction. Clients are most likely to be satisfied when the final product matches or exceeds their expectations [40]. Research on the construction process has suggested the significant role of briefing in delivering client satisfaction [41] underpinned by the underlying assumption that an improved briefing process can deliver a better product to the Client [42]. Driven by this redefined objective (i.e. to satisfy the Client), further research emerged resulting in various frameworks and interesting findings. The Innovative Manufacturing Initiative/IMI (a joint research council activity funded by Engineering and Physical Sciences Research Council/EPSRC, Economic and Social Research Council/ESRC and Biotechnology and Biological Sciences Research Council/BBSRC) targeted the construction sector with a number of programmes. One of these programmes is the Link IDAC (Integration in Design and Construction) programme, co-funded by the Department of Environment Transport and Regions (DETR). Many of the projects are concerned with briefing and design or general information capture from the Client in construction such as *Managing the brief as a process of innovation* (Link IDAC 88) by the University of Salford, *Design information methodology and tools for the management of detailed building design* (Link IDAC 100) by the Loughborough University, *A client's project definition tool* (Link IDAC 11) by the University of Reading, *Decision making tools for controlled innovation in construction* (Link IDAC 82) by the Cranfield University, *Building a high value construction environment* (Link IDAC 229) by the London School of economics and the Leeds Metropolitan University, *The proposed requirements/conceptual design project* (Link IDAC 5/044) by the Loughborough University and the Strathclyde University, *The proposed IMI Process Protocol* - Level 2 project by the University of Salford and the Loughborough University, and *Learning from Experience: Applying Systematic Feedback to Improve the Briefing Process in Construction (LEAF)* by the University of Sheffield.

Leaman (2002) [43] proposes a detailed matrix (known as 'targeted briefing') method to conduct the briefing service to the Client. This method assumes that the Client's requirement can be identified thoroughly by fulfilling targeted headings of the brief format. Various other researchers prescribed models based on the matrix framework [34, 44, 45, 46]. This matrix framework has been generally considered an advancement of the more traditional checklists as proposed by Salisbury (1998) [47] or Hyams (2001) [16]. Moreover, Kamara *et al*. (2002) [48] proposes the *Client Requirements Processing Model* (CRPM) focusing on a solution-neutral formulation of client requirements. Another research by Fisher *et al* (2000) [49] proposed the *Client Project Definition Tool* (CPDT) with a focus on capturing user requirements for buildings. These models represent the implementation of methods applied in manufacturing industries for reconciling costumer's need and business objectives in the product development into construction briefing process, widely known as the Quality Function Deployment (QFD).

3. Evaluation of Briefing in Arts Construction Projects: the Research Methodology

This research project aims to assess the briefing process in the performing Arts construction projects. The measurable objectives of the research is to investigate and analyse thoroughly how selected buildings for the performing arts have been briefed, designed and procured in the relatively recent past. This is expected to lead to the identification and the development of the successful ‘good practice’ (applicable to all stakeholders) exploiting the particular skills and abilities in the Arts for creating and communicating ideas and 'visions'. This is to be followed by a broad dissemination of the new understanding in ways which are intelligible and engaging, exploiting media familiar to the Arts community in the use of the moving image, performance, narrative and scenario building in addition to more conventional outputs.

In order to achieve the aims and objectives of the research, the generic overview of briefing process in the construction projects has been reviewed. In-line with this, subsequent phase discusses the evaluation of the briefing process in the Arts construction projects. As a starting point, the evaluation of the briefing process in the Arts construction projects can be viewed from three different perspectives explained in the previous section, namely the role of the parties, the extent of the briefing process, and the objective of the briefing process. As highlighted earlier, the study intends to investigate and analyse selected buildings for the performing Arts that have been briefed, designed and procured in the relatively recent past. Hence, the selected strategy is multiple case study and grounded theory methodology in order to ensure an in-depth interaction between the researchers and the participants of the briefing process and formulation of an interpretation of the encounters. The richness of descriptions will be organized to develop a new understanding of briefing for the arts buildings.

Grounded theory is a general methodology to develop theory that is grounded in systematically gathered and analysed data aiming to develop theory through continuous interplay between analysis and data collection [50, 51, 52]. Theories emerging from grounded theory methodology are always traceable to their original data source, and are always fluid due to the emphasis on interaction among participants, temporality and process. This faithfulness of theory to the actual data offers usefulness in practice [50]. In acknowledging the multiple perspectives of a diverse range of existing theories, it is considered important to combine the theory emerging from the grounded theory methodology with the existing ones, while keeping the connection with the actual data [14]. Case studies are empirical inquiries investigating phenomena in their natural settings [8]. In a multiple case study strategy, the cases are studied in their real-life contexts with reliance on multiple sources of evidence and with a purpose to generalise to theory, which is emphasized in the research design phase [52]. Case studies are essential for description [53, 54] and therefore useful with grounded theory. The multiple case study aims to identify patterns using replication logic within and among cases, which can be either similar (literal replication) or contrary but for predictable reasons (theoretical replication). Consequently, one of the strategies is replication seeking, in which repeating patterns (either similar or contrary) are presented. The other strategy is pattern matching, in which findings are compared across cases or to a theoretical proposition to reveal patterns [8].

Two techniques of data collection are intended for use in this research, namely interviews and archival research. These two techniques are expected to inform each other at different stages of the study. Interview was set as the primary method of data collection, since individuals are considered the valuable sources of particular information. Interviews allow both parties to explore the meaning of the questions and answers involved. The interviewees were targeted and selected from different stakeholder groups to provide multiple perspectives and in-depth understanding of different issues in the briefing process. Archival research involves locating and assessing primary data or information in archives pertinent to the topic of the study [55]. In this study, the major archives resource is the documentation from the design teams. Another source considered is the building management, such as the management boards' files.

Being the interplay phase between analysis and data collection, coding for analysis is integrated to data collection procedure. One option of establishing coding frames is to follow the sequence of open coding, axial coding and selective coding [56]. Open coding involves organising the data into categories and sub-categories. Axial coding puts the data back together in a new way through establishing the relationships between these categories and sub-categories [57]. Selective coding involves conceptualising the relationships among categories for theory building [52]. Selective coding also includes comparing the potential theoretical frameworks emerging from analysis to the existing theories in the literature [14].

Following the finalisation of the cases and respondents selection, the broad framework for interview questions are prepared based on the literature review and pre-pilot interviews. The pre-pilot interviews are conducted prior to the pilot case with respondents involved in briefing and design processes for a performing arts building other than the cases selected for this case studies and aims is to complement and clarify the topics identified in the literature review. The pilot case is intended to provide guidance in evaluating the interview questions, the types of archives to investigate, and the coding frame at this stage of analysis. The pilot case will be started after clarifying the broad framework for interview questions. Upon completion of interviews and archival research of the pilot case, initial stage (open coding) of the analysis will be carried out. In this phase literature will be revisited to provide important insights in preparing the coding frame. The three perspectives identified (i.e. the role of the parties, the extent of the briefing process, and the objective of the briefing process) are intended to assist in understanding of the briefing processes in the performing Arts construction projects. For the remaining five cases, similar analysis procedure follows. At the cross-case analysis stage (axial coding), the coding frames of each case will be compared. The final theory building will be based on pattern matching among the cases and revisiting the literature to compare the emerging theoretical frameworks to the existing ones in the literature (selective coding). Within the scheme of multiple case study strategy, performing arts buildings are selected to ensure variety (theoretical sampling) and accessibility of the resources (purposive sampling). The variety criteria of the selected cases are based on the type of the client, number of spaces in the project, type of the project (new-build or refurbishment), funding source, budget size, audience type, and program type. The selection of cases also considers the completion (within the last five years) and the accessibility to archives and interviewees. At the present stage, six cases have been identified and targeted in order to fulfil the desired criteria. The selected case studies include two arts centres, three theatres, and one drama studio. The case studies represents both newly-built and refurbishments. The initial budget size of the cases ranges from £ 4.8 millions to £106 million. At the moment of preparing this paper, many of the interviewee targets from the selected cases have been contacted and requested for cooperation.

In order to summarise the research methodology designed to evaluate the briefing process in the performing Arts building projects discussed above, a diagram is provided in the Figure 1.

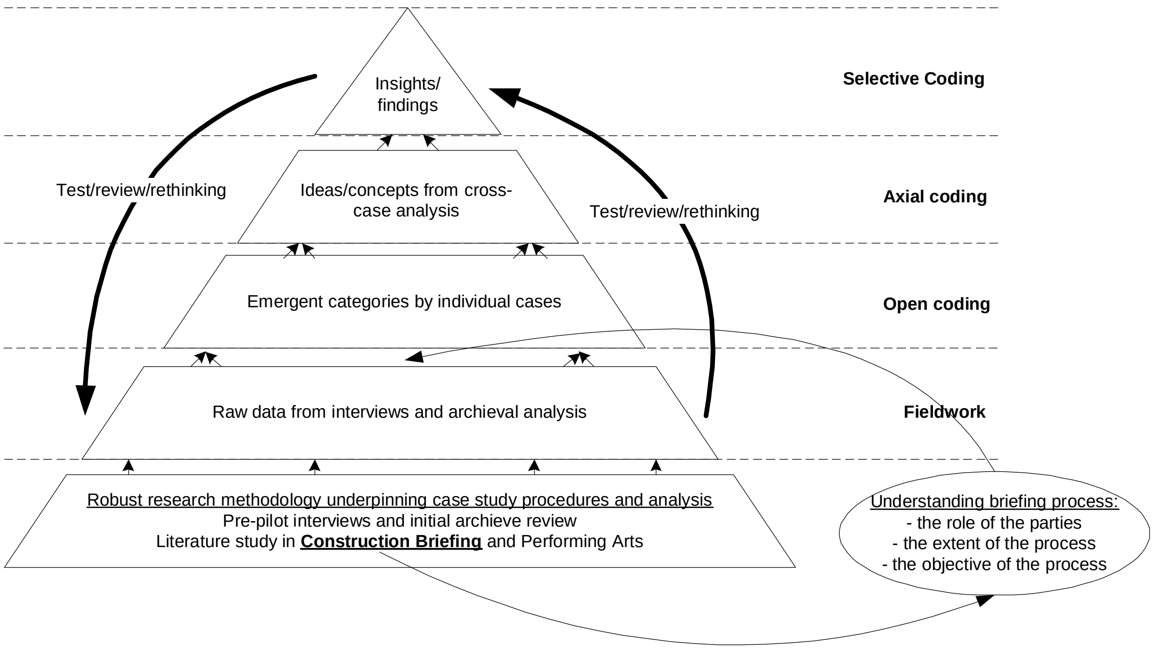

Figure 1. Research methodology to evaluate briefing process in performing Arts construction projects (adapted from Barrett and Stanley (1996) [14]).

4. Conclusion and Further Research

This paper has explained an on-going research project aimed to assess role of the briefing process in providing a ‘better’ environment for the performing Arts projects. The measurable objectives of the research is to investigate and analyse thoroughly how selected buildings for the performing arts have been briefed, designed and procured in the relatively recent past. This is expected to lead to the identification and the development of the successful ‘good practice’ (applicable to all stakeholders) exploiting the particular skills and abilities in the Arts for creating and communicating ideas and 'visions'. This is to be followed by a broad dissemination of the new understanding in ways which are intelligible and engaging, exploiting media familiar to the Arts community in the use of the moving image, performance, narrative and scenario building in addition to more conventional outputs.

The briefing process has been reviewed in detail in this paper. Various views on the briefing process have been presented by providing in-depth discussion on emerging three central themes, namely the role of the parties in briefing process, the extent of the briefing process, and the objective of briefing process. In discussing the role of the parties in briefing process, different opinions on allocating the responsibility of the briefing process became evident. The allocation of responsibility of such a process was then found influenced by the experience of the Clients. The more experience the Clients, the higher their own ability to ensure that the Consultants understand their needs and requirements and the Consultants are then responsible to accommodate the needs and requirements into their design. The discussion on the extent of the briefing process revealed differences on the implementation of the briefing process on the construction stages. Some views consider the briefing process as a 'one-off' event that performed in the pre-project stage, typically prior to the design phase to establish a 'frozen' brief. However, the review of the literature has also revealed the shift from this view into the one that consider the expansion of the briefing process into the whole life cycle of the project. In discussing the objective of the briefing process, the shift of working ethos from merely fulfilling the Clients' needs and requirements into the one that embrace the Client's satisfaction was identified. Various research were attempting to achieve such redefined objective including the implementation of methods applied in manufacturing industries for reconciling costumer's need and business objectives in the product development into construction briefing process.

Furthermore, the research methodology has also been explained in detail. The use of multiple case study strategy enables the study of each building's briefing process in detail. Interviews are expected to enhance the thoroughness of the study by providing access to exploring actual experiences of participants whilst archival review is considered to offer precise and detailed descriptions of conducts among stakeholders during the briefing process. The use of grounded theory methodology has also been considered crucial for identifying successful 'good practice' since the emphasis of the methodology is on the interplay between data and analysis in developing theories. Six cases have been identified and targeted in order to fulfil the set criteria. Further phases involve finalising the interview questions (to be tested with a pre-pilot interview) prior to performing the interviews and data analysis of the selected six case studies.

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Project Diagnostics – Assessing the Condition of Projects and Identifying Poor Health

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Abstract

In many cases, construction projects do not achieve the objectives that the project participants set for them. If participants could better understand how their project is performing overall, at various stages of its delivery, then the opportunities to achieve project success would almost certainly be greater.

This paper documents a method of assessing the status of a project, at a point in its design or construction phase, or after completion. The status is assessed in terms of up to seven (7) key success factors. Any evidence of less than adequate performance in these performance areas is scrutinised to seek out the root causes of why this situation is happening. Using these identified root causes of under performance, general suggestions can then be made as to how to return the project to good health.

A software package that assists in assessing the status of the project has been developed. The package is currently being calibrated before commercial release.

Keywords: Diagnostics, project status, project performance indicators, root causes

1. Project Diagnostics

1.1 The Gestation for Project Diagnostics

Many projects fail to meet predetermined objectives. This failure is a major issue adversely affecting the construction industry, and more generally, the community. From the need to better understand how to judge the prognosis for a particular project (in terms of its likely performance), the idea of developing a "diagnostic kit" arose.

Project Diagnostics is a research initiative of the Australian Cooperative Centre for Construction Innovation (CRC CI). Arup Pty Ltd (Arup) is a founding member of the CRC CI, and lead this research project. This project was undertaken by a team with industry, government, and academic expertise.

1.2 The Human Health Analogy

Humphreys, Mian, Sidwell, (1) identified parallels between construction project health and human physical health, and proposed that in many ways the "health" of a construction project is analogous to human health. Human health can broadly be thought of as the condition of the body. When physical health is poor, performance or quality of life can be compromised. Poor physical health often has associated symptoms that can be used to help pinpoint the cause of ill health quickly and accurately.

Once the cause has been identified, a remedy can be implemented to assist the return to good health. If symptoms are left unchecked, they can develop into critical situations. In many ways the 'health' of a construction project is analogous to human physical health:

- State of health influences performance
- Symptoms can be used as a starting point to quickly assess health
- Symptoms of poor health are not always present or obvious
- State of health can be assessed by measuring key areas and comparing these values to established norms
- Health changes temporarily
- Remedies can often be prescribed to return to good health
- Correct and timely diagnosis can avoid small problems becoming large.

Project health is synonymous with project performance. If a particular project aspect is not performing as expected it would be perceived as unhealthy, or failing. On the other hand, if it is fulfilling expectations, it would be perceived as healthy or successful. The requirement for rapid, accurate diagnosis leads to the concept of an initial broad health checking mechanism, which could guide further more detailed investigations. More detailed appraisals identify the more fundamental factors contributing to poor health.

1.3 Industry Need

Research during the latter part of 2002 indicated that a reasonably comprehensive tool to assist in the assessment of the state of the existing health of construction projects was not generally available. Ready access to such a tool would significantly enhance the opportunity for an under performing project to be appraised - and then corrected, in a focused and systematic way.

Project Diagnostics has developed such an assessment tool to aid understanding of the current condition of a project. The assessment identifies performance against industry benchmarks for the key success factors. Further analysis of any underperforming areas is carried out – enabling the probable root causes of poor performance to be captured. This diagnosis can then provide a prognosis for the success of the project, or otherwise. The diagnostic toolkit can then point the way to remedial actions that could be taken.

These activities are highly relevant to industry. If project participants are able to confidently compare how a project is currently performing against industry norms, then targeted action can be taken to improve performance, as necessary. The diagnostic toolkit can be then applied again at subsequent stages of the project, to continue to monitor the effectiveness of remedial action taken.

2. Methodology

2.1 Project Methodology

The Project Diagnostics methodology is shown in Figure 1. The following steps outline the methodology and should be read in conjunction with this figure.

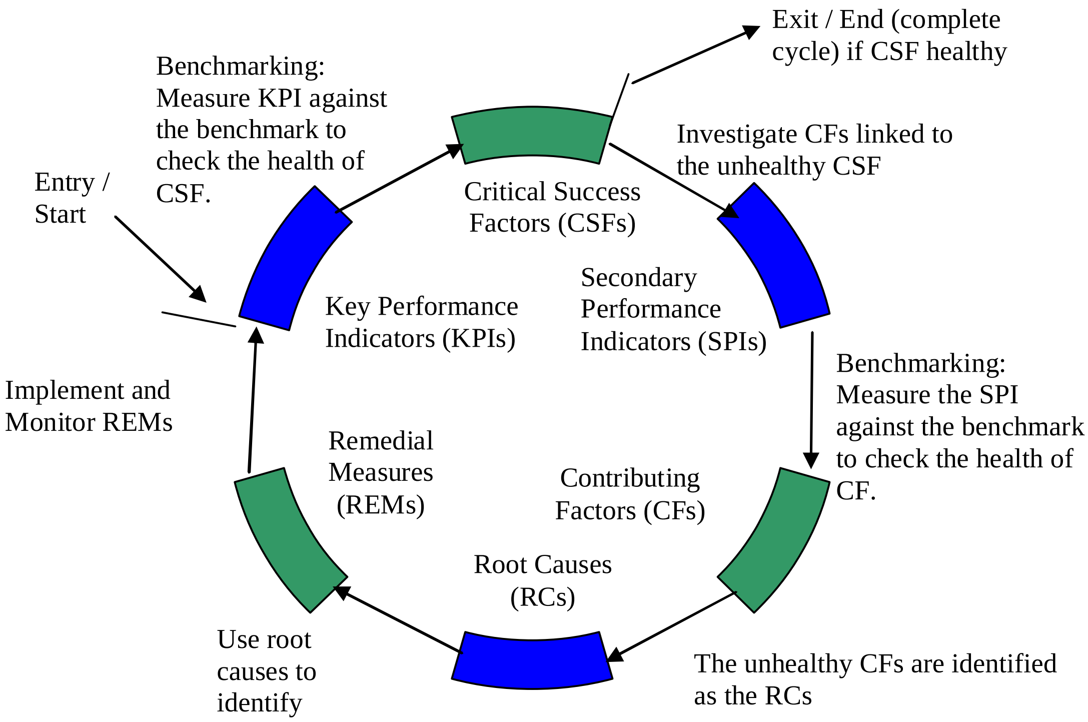

Figure 1: Project diagnostics methodology

2.2 Critical Success Factors (CSFs)

Research carried out in the last decade provides many sources of success and failure measures, totalling more than 120 different relevant measures. The measures have been split among different stages of a project. In order to make these extensive lists more manageable to work with, and to help analyse the interactions, they are represented by seven main measures of success. These are termed Critical Success Factors (CSFs).

The factors used for the assessment of current health of the construction project are:

- Cost
- Time
- Quality
- Relationships
- Safety
- Environment
- Stakeholder value

As is the case with human physical health, these measures are critical areas that can facilitate a broad evaluation of project health; they need to be investigated in order to ascertain project health.

2.3 Key Performance Indicators (KPIs)

The seven CSF themes represent critical areas of construction project health. In order to use these CSFs as indicators, they need to be properly assessed. This task was achieved by developing an associated series of Key Performance Indicators (KPIs) for each CSF.

The KPIs are used to measure the degree of acceptability of CSFs. Their value is compared to benchmarks, to check status. The aggregation of CSF status information provides an indication of the project health. This process involves collecting data from the project under scrutiny, calculating the KPIs, and comparing them with benchmarks.

The use of KPIs to assess the performance of the main CSF themes allows the model to be applicable to most (if not all) of the project stages and a majority of the procurement methods. To facilitate the KPIs application to assess the performance of the CSFs, they were calibrated using benchmarks from Australia (Coles 2003, (2)), UK (CBPP 2003 (3)) and USA (CII 2003 (4)). Calibration makes the model applicable to a project regardless of generally how the performance target was arrived at.

After careful scrutiny, a total of 33 KPIs were chosen. As an example, the KPIs for the “Cost” CSF follow:

Table 1: KPIs for Cost

CSF	Key Perf Indicators	Explanation of Indicator
Cost	CPI (Cost Performance Indicator)	CPI = BCWP / ACWP Where: BCWP = budgeted cost of work actually performed. ACWP = actual cost of work actually performed. CPI ≥ 0.85 indicates a healthy project. CPI < 0.85 indicates an unhealthy project. The benchmark is based on an average value of cost overrun of 15% from survey of 375 general building projects in the Giles Royal Commission (1992) into the productivity of building industry in NSW. This indicator provides a snapshot of the project cost at a particular point in time. The source for gathering ACWP would be the progress claims of the consultant/contractor showing the approved amount at that point of time. This will be compared with the BCWP at that time - can be sourced from the contractor/consultant cost plan. The budgeted cost should include approved variations.
	PJCI (Projected Cost Indicator)	PJCI = BAC / EAC Where: BAC = budgeted cost at completion. EAC = actual cost at completion (i.e. actual cost to date plus updated estimate of work remaining). PJCI ≥ 0.85 indicates a healthy project. PJCI< 0.85 indicates an unhealthy project. The rationale behind the above benchmark is the same as the CPI. This purpose of this indicator is to check the health of a project at completion based on the forecast from the particular point in time chosen for the snapshot for CPI. In order to check the health of a project as far as cost is concerned, the CPI & PJCI are considered together in terms of the following conditions: CPI < 0.85 & PJCI < 0.85 indicates an unhealthy project. CPI < 0.85 & PJCI ≥ 0.85 indicates an unhealthy project. CPI ≥ 0.85 & PJCI < 0.85 indicates a healthy project. CPI ≥ 0.85 & PJCI ≥ 0.85 indicates a healthy project. The CPI and PJCI are applicable to all stages of a project from planning to hand over.

It was necessary to validate the robustness of these KPIs by testing them on actual projects. Table 2 provides an explanation of how the indicator was used in testing.

Table 2: Example Cost Performance Indicator (CPI)

CSF	**Indicator**	**Explanation of Indicator**
Cost	CPI	Definition: CPI = BCWP / ACWP Where: BCWP = budgeted cost of work actually performed ACWP = actual cost of work actually performed Benchmark: CPI ≥ 0.85 indicates a healthy project CPI < 0.85 indicates an unhealthy project This provides a snapshot of cost performance on the day of health check.

For all relevant CSFs (up to seven), the results are then analysed and the overall health of the project is able to be assessed. If the results indicate a healthy project the cycle ends. Otherwise, the use of the toolkit proceeds to the next step.

2.4 Contributing Factors (CFs)

CSFs that were found to indicate project performance as being less than industry benchmark levels were used as the focus of a more detailed investigation. Factors leading to poor levels of performance against benchmarks were assessed; these factors are called the Contributing Factors (CFs). There is a direct relationship between CFs and the root causes of poor project performance.

A list of Contributing Factors associated with each CSF was developed in consultation with industry through pilot studies. Pilot interviews were conducted on projects identified by the industry partners from the research team. These interviews were conducted using a structured questionnaire. The respondents included clients, consultants, contractors and sub contractors. A total of 28 interviews were conducted. The questionnaire was designed to allow identification of CFs and to allow them to be ranked in terms of relative importance using a numeric scale. This list of CFs was augmented with CFs identified from a literature survey.

The CFs were further validated using a Delphi type approach using industry partners as specialists.

The overall ranking of the identified CFs for each unhealthy CSF from the pilot questionnaire was calculated, using a statistical frequency analysis.

Table 3 shows the rank and importance index for CFs for "Cost" as an example. The indexes are ranked in descending order.

Table 3: Rank and Index of Contributing Factors

CSF	Contributing Factors (CFs)	Index	Rank
Cost Overrun	Variations	14.7	1
	Inaccurate cost estimate	6.0	2
	Rework	3.3	3
	Lack of client decision making	2.7	4
	Competitive nature of market	2.3	5
	Poor quality of design and documentation	2.3	5
	Approvals	2.0	7
	Contractor / Sub-contractor work efficiency	2.0	7
	To manage project simultaneously a large component of work was done in another city branch office	2.0	7
	Poor workmanship	1.3	10
	Work sequencing with other trades	1.3	10
	Audit testing	1.0	12
	Change of management	1.0	12
	Emissions and under measures in documentation	1.0	12
	Lack of completeness of contract documents	1.0	12
	Limited resources	1.0	12
	Lack of architect higher management interest	0.7	17
	Productivity of workforce due to traveling involved due to remote location of project	0.7	17
	Relationship workshop	0.7	17
	High quality product required	0.3	20
	Higher management direct involvement	0.3	20
	Programming issues causing pressure on contractors	0.3	20

The importance index and rank for each CSF was found by calculating the average index for the rank 1 to 4 of contributing factors within each CSF. Table 4 shows the index and rank of the overall CSFs.

Table 4: Rank and Index of CSFs

CSFs	**Index**	**Rank**
Cost	6.68	1
Time	3.86	4
Quality of documentation - increase in RFI	3.20	8
Quality of construction - increase in rework	4.65	2
Safety	3.60	5
Relationships	4.15	3
Environment	3.40	7
Stakeholder value	3.43	6

As mainly successful projects were evaluated in pilot studies, the list of CFs was not considered comprehensive. Augmentation with CFs identified from a literature survey occurred. The CFs were further validated using a Delphi type approach using industry partners as specialists. Thes team members added CFs to the list obtained from pilot studies so as to achieve a comprehensive list. A second round of feedback on CFs was instituted with the research team. Finally they were discussed in a workshop attended by the same specialists to get a final list, based on the consensus of these specialists.

2.5 Secondary Performance Indicators (SPIs)

Like CSFs, the CFs needed to be assessed to pinpoint the areas most likely to be causing poor project health. This task was accomplished with a series of Secondary Performance Indicators (SPIs) for each CF. A number of key criteria, similar to those used for selecting KPIs, were also used for choosing SPIs. A sample of “Cost” SPIs follows:

Table 5: Example showing "Cost" SPIs

CSFs	Contributing Factors	Secondary Performance Indicators
Cost Overrun	Inaccurate estimating of cost	To measure the reliability of cost estimates, actual design or construction cost is needed and estimated design or construction cost; and using the formula: Performance Percentage Predictability = (Actual design or construction cost – Estimated design or construction cost) / Estimated design or construction cost and plotting this value on the Predictability - Cost curve indicates the performance level.
	Consultant / contractor lack of appropriate experience	Profile is an indicator - has consultant or contractor successfully completed a similar project in terms of size, locational restrictions, complexity etc. This indicator however needs benchmarking.
	Inflation	Magnitude has direct impact on cost estimates.
	Lack of trust in contractors and consultants by client	The policy adopted by the client may lead to teams' protecting their own position, resulting in loss of focus or reduced productivity.
	Adoption of inappropriate contract type	An inappropriate contract type (eg, Fixed, or Cost Plus, when scope is not well defined), can lead of cost overruns.

Potential SPIs associated with each CF were identified from the literature. As with the KPIs, these SPIs needed to be benchmarked. Benchmarks were identified through a literature review of research material from the UK, the USA and Australia. In addition, results from four projects of the project team members were used to validate the results. The results weer further reviewed in a workshop with industry research partners.

2.6 Root Cause Identification

Knowledge of the particular CFs failing to meet the target (benchmarked) values, provide the necessary insight to confidently identify root causes of poor performance. For example, if the relevant "Cost" CF was the use of an inappropriate contract type (as highlighted by the SPI), then the relevant root cause becomes almost self evident. In some cases, the CF and its root cause are quite similar. In other cases, such as the relevant "Cost" CF being inaccurate cost estimating, then the specific root cause needs further review; is the inaccurate cost estimating due to poor project scoping, or inadequate resources, or lack of skills, or some other basic cause? It is here that the experience of the project participants, and/or external professionals, comes into play.

Once the root causes were acknowledged, remedial measures associated with each of them were able to be identified: based on lessons learnt from the industry partners, through case studies, and from another literature search.

Correct and timely identification of contributing factors along with accurate assessment of SPIs, generally allowed an effective remedy to be prescribed, through insight into root causes of concern. The role of the subsequent remedies is to return the project to good health. Recognising the potential effect early and taking the proactive steps necessary to avoid unwanted consequences, can achieve this.

2.7 Remedial Activity

The practical nature of construction suggests that a suitable approach for development of a suite of remedies for a range of health problems would be based on the experiences of the project participants, but focused on the specific results of the CF/ SPI analyses.

A combination of the Project Diagnostics specifics, and a broad industry understanding is a powerful project improvement tool. In some cases, it may be appropriate to introduce independent industry professionals to assist the project team in this process.

One of the limitations of using lessons learnt is that remedies tend to be dependent on personal experience. This means that remedies for a given contributing factor or identified root cause, may vary from person to person – and potentially in conflicting ways. The approach for this model will be to develop a set of remedies that have proved historically to be workable and can achieve results.

However, it needs to be understood that each project is unique, with its own set of issues and most appropriate ways of restoring it to good health.

For this reason, remedies nominated in Project Diagnostics can be generic remedies only – and should only be seen as such, until and unless the particular project dynamics are clearly understood.

It is possible that single or multiple remedial measures will be associated with each of the contributing factors for the specific unhealthy CSF. The implementation of the measures may require the coordination of multiple project participants or stakeholders. Once implemented, time may be required time to restore the project to good health.

As necessary, the KPIs for relevant CSFs are able to be measured again later, to check if the cause of poor performance has been remedied. The cycle can iterate until the project health is considered to be satisfactory.

3. Software Development

3.1 Toolkit

The aim of Project Diagnostics was to develop a Toolkit that enables the user to:

- Investigate the health of a construction project
- Identify the root causes of poor health
- Give an indication of remedial measures which could be implemented to improve project performance and outcomes.

This toolkit has both the potential to be used as required when clients or other project participants feel that a project is not performing according to their expectations; and at regular intervals as a 'health check' during the delivery of the project.

The toolkit is designed to have integrated benefits that include identifying areas of poor project health, pointing to the probable root causes and suggesting possible remedial measures. It is envisaged that the use of the toolkit will be very cost effective for clients and stakeholders as compared with the costs associated with the adverse impacts of failing projects. These include cost and time overruns, inadequate build quality, poor project relationships, loss of reputation, public clamour and legal disputation.

The software development is well advanced. As at January 2005, commercial arrangements for the finalisation of the software toolkit are being finalised.

3.2 Validation

Further validation of the KPIs, CFs and SPIs, and linkages to case studies are required, before the package is ready for commercial release. To date, four case studies during the later stages of development of the toolkit have been used to validate the model and refine the parameters used. Ten pilot projects were used earlier in the initial development of the approach used in the software.

Comprehensive validation of the software package is intended to be complete by early 2006. The package will then be available for commercial use. Expectations are high for the benefits that Project Diagnostics will bring to the entire industry.

4. Conclusions

Project Diagnostics aims to bring the benefits of industry knowledge and experience, built up over many years, to project participants. By assessing the state of critical success factors for construction projects, at various stages of progress, it is possible to gain a confident view as to the likely prognosis for success of the project.

The software toolkit automates this assessment. The toolkit facilitates the identification of areas of project under performance. Use of the toolkit will assist in setting appropriate remedial measures, to facilitate the restoration of the project to good health.

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Documenting the Real Causes for Delay in Highway Construction Projects

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Abstract

For the past three years, Florida Department of Transportation (FDOT) construction contracts have run approximately 23,000 days over original contract time each year. These extended days comprised 28%, 23%, and 25% of the original contract days, respectively. During the same period, the cost of the projects averaged $124 million per year over the original contract amount. Even though the increase did not result entirely from the extended days, it is reasonable to assume that the project cost increase is related to the time extensions in some way.

The data for this paper were obtained from the FDOT database. FDOT posts "Construction Cost and Time" Quarterly Reports on their website, with available data including project location, duration, cost, contract type, and delay days.

FDOT categorizes delay days as either weather days, time extensions, or supplemental agreement days, depending on the circumstances. The time extension (TE) heading and supplemental agreement days (SA) heading both are broken down into 12 sub-headings of circumstances, which can cause delay. These 12 sub-categories are the same for both SA and TE. The twelve categories of extended days (TE and SA) and weather days are analyzed in this paper as causes for delay in highway construction projects.

The goal of this paper is to analyze the factors that influence contract duration for highway construction. Also of interest is the relationship between delay and cost increases, so a regression model was developed showing that relationship. Using the results of this analysis, a comparison between regions of the state representing urban and rural areas, and a comparison between contract types (unit cost, lump sum, and others) were made so that parameters could be set for estimating more reasonable schedules for future projects depending on project regions and contract types. Finally the most prevalent causes for delay in highway construction projects are identified.

Keywords: Delay, weather days, time extension, supplemental agreement, project cost changes, regression model, lump sum.

1. Introduction

There is a growing need for rehabilitation and reconstruction to sustain the U.S. highway system. However, while desperately needed, the construction causes many problems, such as inconvenience and delays for road users and economic loss for communities. Shorter construction durations usually produce better results in terms of safety for the public and construction workers because the public is exposed to the work zone for shorter periods of time. Other advantages of shorter construction durations are lower road user costs due to minimizing traffic delay and lower overhead costs for both the contractor and public owner (agency).

In reality, however, it is very difficult for a construction project to be constructed both "on time," and "within budget." Delay is one of the most common problems in the construction industry. FDOT had 22,835 delay days in fiscal year 2001/2002 (28.4% of the original contract duration), and, although they decreased to 22,634 days (22.6% of the original contract) in fiscal year 2002/2003, the delay days increased in 2003/2004 to 23,919 days (25.2%).

Over the last three years, FDOT has averaged spending $124 million per year more than initially planned for construction projects. FDOT paid $1,240 million to the contractors in fiscal year 2001/2002, for projects originally contracted at $1,104 million. The amount paid also increased from an original $1,399 million to $1,522 million in fiscal year 2002/2003 and from an original $1,387 million to $1,501 million in fiscal year 2003/2004. By analyzing the factors affecting construction duration for transportation construction projects, reliable parameters can be set up concerning the relationship between delay days and project cost changes, with variability depending on region, contract type, and district characteristics.

The subject of construction delays has been analyzed previously by many researchers, but most of the studies have been conducted using survey results. Very little information was found which described research using delay analysis that included delay days from actual transportation projects.

2. Literature Search

The problem with project delays is not a new one. Contractors are obligated to complete construction projects within a time period specified under the contract, so time is one of the most important aspects of a construction project. However, unexpected delays and problems routinely occur, that affect time and cost. Therefore, many studies related to the influence of delays on construction projects and various statistical analyses have been conducted.

From more than 4,000 projects constructed over twenty-seven years (1959-1986), research showed that surprisingly few projects were actually completed within their budget and on schedule [1]. As far as the impact of delay on project performance, U.S. and international research reveal that many nuclear power plant projects in the U.S. experienced an increase in project cost and duration [2]. Arditi et al. reported that the percentage of projects successfully completed on schedule in Turkey ranged from 8% to 15% [3]. Some extreme examples were reported such as a hospital construction project that was completed after a delay of 6 years, amounting to 233% of the original construction duration.

Many previous studies have discussed causes for delays. In studying large building projects in Saudi Arabia, Assaf et al. outlined 56 causes and grouped them into 9 major categories [4]. As a means of delay factor identification, a survey was used and results of that survey indicated that the delay factors categorized as “financial” were ranked the highest (most delay), whereas those delay factors categorized as “environmental” was ranked the lowest by all three groups of respondents - contractors, A/E, and owners. Baldwin and Manthei stated that the major causes of delays in building projects in the United States were weather, labor supply, and subcontractors [5]. These results were also obtained from a survey given to engineers, architects, and contractors.

Majid and McCaffer classified the main causes of non-excusable delays and then identified the factors contributing to those causes using the Ishikawa, or fish bone, diagram [6]. To determine the ranking of the factors, they used previously published reports. For the first three major factors contributing to causes of non-excusable delay, late delivery, damaged materials, and poor planning are identified.

Some studies have discussed the issues relating to delay analysis. Bubshait and Cunningham compared three delay measurement processes, which are as-planned schedule delay analysis, as-built schedule delay analysis, and modified as-built schedule delay analysis. They then showed that one procedure might be more reliable than others in certain circumstances [7]. Computer-aided construction delay analysis for preparing claims was studied by Alkass et al. [8]. They presented an integrated computer-based system (CDCA) as an improved method of analyzing delays and preparing claims. Shi et al. presented a construction delay computation method at the activity level [9].

Many previous studies have discussed subjects relating to delays. When the studies dealt with causes or reasons, conclusions were mostly based on survey results from the respondents and data that were based on the literature review. As noted earlier, no major study has been done to explain causes for delays in transportation construction projects using actual delay data from construction projects.

3. Data Gathering

Data for this paper were taken from Construction Cost and Time Quarterly Reports of the Florida Department of Transportation (FDOT) for the duration between fiscal year 2001/2002 and fiscal year 2003/2004; however, the report for fiscal year 2001/2002 was posted as an entire year instead of each quarter on the Internet. Therefore, when the data were analyzed to see if there was a trend of factors affecting delay by time, the entire 2001/2002 report was used instead of a quarterly report.

In the Quarterly Reports, data is shown for projects that had been completed through that particular quarter within that particular fiscal year, cumulatively. Table 1 shows the number of completed projects for each district by fiscal year. A total of 1,205 projects completed between fiscal year 2001/2002 and 2003/2004 were used for the analysis. Obtainable data from these 1,205 projects included the district in which each project was performed, original contract days, delay days, original contract amount, final contract amount, and contract type.

Table 1: Number of Projects Completed

District	**Number of projects completed**			
	2001/2002	**2002/2003**	**2003/2004**	**Total**
1	52	46	49	147
2	66	90	68	224
3	54	114	79	247
4	39	46	54	139
5	50	59	52	161
6	24	37	40	101
7	28	60	40	128
8	10	23	25	58
Sum	323	475	407	1205

The term "delay days" means all days over and beyond the original contract days; it does not necessarily mean that projects are behind schedule. The delay days can be divided into three categories according to circumstances surrounding the delay: weather days, TE, and SA days. The TE and SA days are also divided into 12 sub-categories according to the reason for the added time. These 12 sub-categories are the same for SA and TE. For this research, weather days and 12 reasons for extended days were considered as factors causing delays (total of 13 factors). In the Construction Cost and Time Quarterly Reports, these 13 delay factors are expressed in the form of number of delay days based on original contract days.

Interviews were conducted as part of the data verification process after analyzing the data from the quarterly reports. Weather archives were also collected in order to verify whether the weather days granted to the contractors coincided with inclement weather as documented by the weather service.

3.1 Identification of Delay Factors

SA Days are those days that were granted as part of a Supplemental Agreement. A Supplemental Agreement is a legal document that amends a FDOT contract in some way. TE days are simply days granted the contractors by FDOT according to FDOT procedures under circumstances that do not require a SA. Weather Days are days that are granted by letter because weather prevented the contractor from working on critical work items on a specific day. Weather Days do not include any damage to the project caused by weather.

Since days granted for weather are not actually added to the contract, the total TE and SA days are the total number of days added to the contract; therefore, the difference between TE and SA days is just in the mechanism by which extended days are granted.

The twelve reasons (sub-categories) for delays granted by either SA or TE are changed conditions, plans modifications, specification modification, value engineering, partnering, CEI action/inaction, minor changes, defective materials, weather-related damage, claims, utility delays, and invalid reason codes.

“CEI” is the term used for a consulting firm that performs construction engineering and inspection (CEI) services. CEI action/inaction means that contract change was brought about by some action of the CEI. It could have been a decision to change something or a lack of decision where the contractor requested some action.

Weather-related Damage means days granted as either a TE or by SA because some damage was caused by weather where the contractor had to redo some of the work.

4. Data Analysis

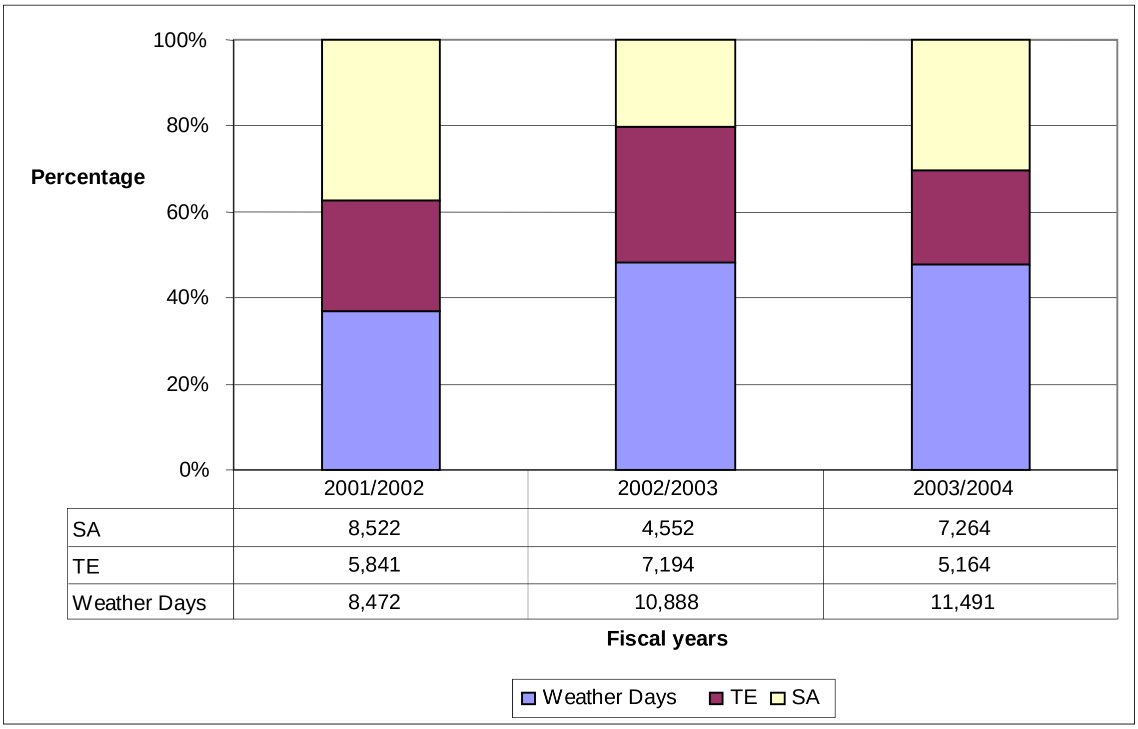
First, factors that influence contract duration were identified as described. The number of delay days that contractors were granted was then obtained and sorted according to which of the 13 factors caused each delay for each quarter from fiscal year 2001/2002 to fiscal year 2003/2004, and the following analyses were done.

1. Factor Distribution
2. Comparison of delays by geographic region, district, demographics, and contract types.
3. Cost vs. Delay Analysis.
4. Regression Analysis of the relationship between delay days and project cost changes.

4.1 Factor Distribution

Delay distribution by fiscal year (representing time) and district (representing location) reveals whether or not a specific type of grant for delay days, such as Weather Days, plays a significant role in the total number of delay days granted.

Figure 1 shows the delay distribution by fiscal year according to grant type. In fiscal year 2001/2002, 63% of all delay days were either SA days or TE, and 37% were Weather Days, whereas in fiscal year 2002/2003, 52% of all delay days were SA or TE and 48% were Weather Days. In fiscal year 2003/2004, delay distribution is also 48% Weather Days and 52% either TE or SA Days. One possible explanation is that according to the weather service there were 12% more rain days in fiscal year 2002/2003 than in 2001/2002 (281 days versus 251 days).



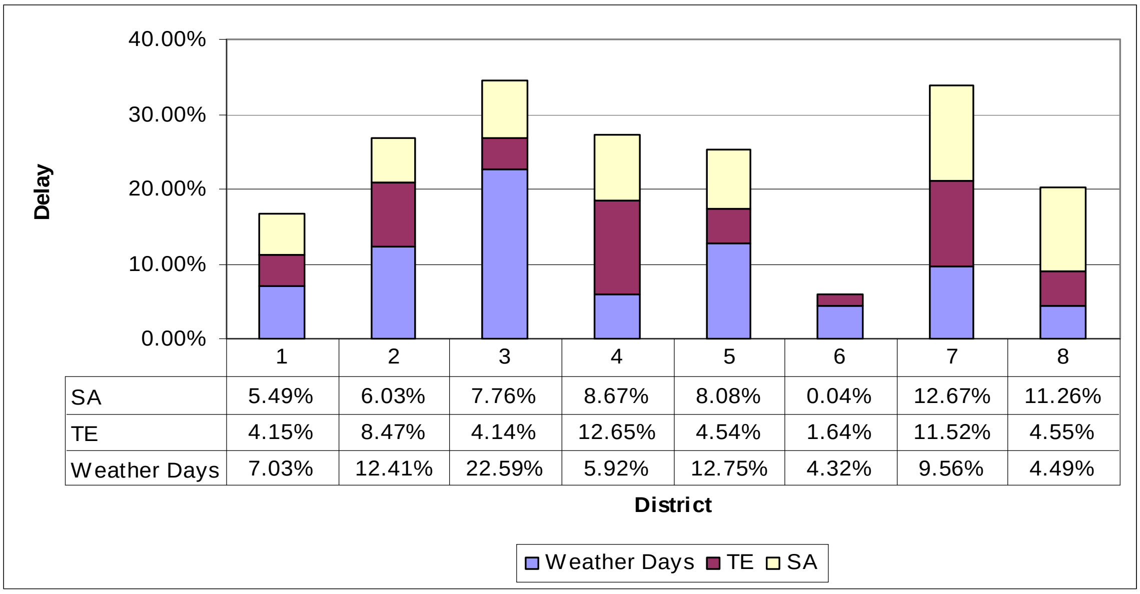
	2001/2002	2002/2003	2003/2004
SA	8,522	4,552	7,264
TE	5,841	7,194	5,164
Weather Days	8,472	10,888	11,491

Figure 1: Statewide Delay Distribution by Each Fiscal Year

The weather archives at the National Climate Data Center under the National Oceanic and Atmospheric Administration (NOAA) classified rain days as either >0.1" rain days, >0.5" rain days, or >1.0" rain days. The research team concluded that >0.5" rain days would generally seriously affect construction projects. To determine the number of rain days in each district, major cities in each district were randomly selected, and the number of rain days in each city was sought. The average rain days among these cities, then, represented the number of rain days in each district, so 281 rain days in fiscal year 2002/2003 means that the sum of each district's average number of rain days from July 2002 to June 2003 is 281days.

According to the delay distribution results during the three years, the proportion of Weather Days and TE/SA Days looks quite consistent.

Delay distribution by district for the three years is presented in Figure 2. District 3 has significantly more Weather Days than any other district in Florida. Weather Days will be discussed later in detail.



District	1	2	3	4	5	6	7	8
SA	5.49%	6.03%	7.76%	8.67%	8.08%	0.04%	12.67%	11.26%
TE	4.15%	8.47%	4.14%	12.65%	4.54%	1.64%	11.52%	4.55%
Weather Days	7.03%	12.41%	22.59%	5.92%	12.75%	4.32%	9.56%	4.49%

Figure 2: Delay Distribution by Districts (2001/2002 – 2003/2004 Total)

Weather days, plans modifications, and changed conditions comprised 44%, 22%, and 20% of the total delay days, respectively. So, these 3 factors comprised approximately 86% of the total delay days while the other 10 factors accounted for only 14% of the delay days. Among the 10 less significant factors, CEI action/inaction and utility delays were responsible for 6% and 4% of the total delay days, respectively. Delay days due to factors such as specification modification, V.E., partnering, defective materials, claims, and invalid reason were very small, with each factor accounting for less than 1% of the total delay days.

4.2 Comparisons

4.2.1 By Region

As noted earlier, District 3 had significantly more weather delay days than any other district. This district is in northwest Florida, and encompasses the "big bend" and "panhandle" areas. The district has a long coastline, so there is a possibility that District 3 had more rain days than other districts. To verify this, weather archives from NOAA were checked. Table 2 shows that District 3 had more rain than the average in other districts in terms of precipitation and more rain days (>0.5"). The difference in precipitation, however, was just 10 inches over 3 years, and the difference in rain days was just 11 days over 3 years. This difference does not explain the wide gap in weather delays.

Conjecture is that perhaps District 3 has a more lenient policy regarding the granting of weather days than other districts, but this cannot be verified by any form of documentation.

Table 2: Weather Comparison (2001/2002 – 2003/2004)

	District 3	**Others (Avg.)**
Precipitation	164.44	153.69
Rain Days (>0.1”)	199	204
Rain Days (>0.5”)	105	94

4.2.2 District Characteristics

Because there were more weather days in District 3 than expected, the research team suspected that granting extended days might be affected by district characteristics. Excepting District 8, which is a turnpike district with no real geographic identity, the research team classified Florida’s districts into three categories. Districts 4, 6, and 7 were categorized as “urban” areas. District 3 was categorized as a rural area, and District 1, District 2, and District 5 were categorized as areas with both characteristics, or “mixed.”

Figure 3 indicates that not only did District 3 (Rural) have more weather days than the other two groups (Urban and Mixed) but delay composition rates also increased gradually from the rural group to the urban group. It is inferred that the more crowded districts are less likely to grant delay days for weather. In addition, even though the difference is not significant, the sum of TE and SA in each group gradually increased from the rural group to the urban group, which is consistent with the general belief that urban projects are more complicated because of their confined working conditions and therefore more susceptible to the 12 areas of potential delays under the TE and SA headings.

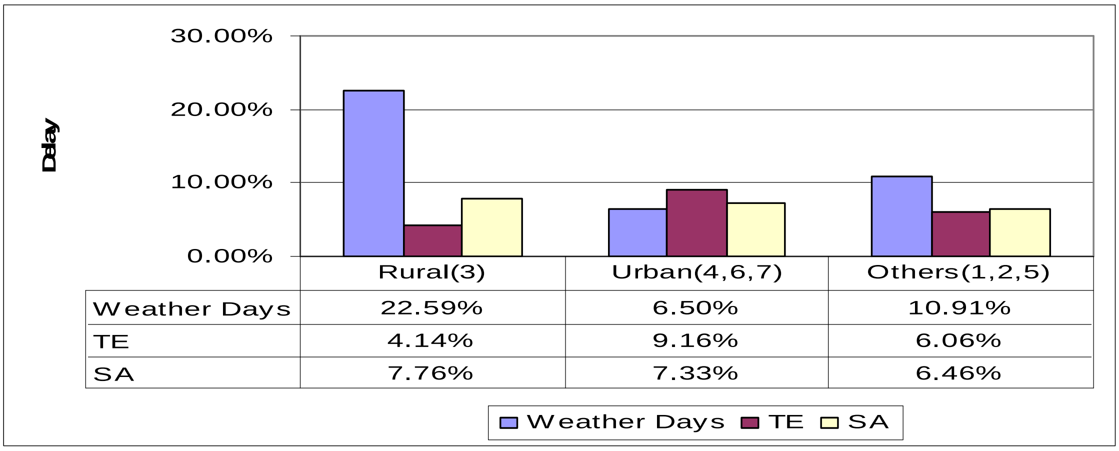


Figure:. Delay by District Characteristics (2001/2002 – 2003/2004 Total)

4.2.3 By Contract Type

The total number of delay days in District 2 was relatively small, and it was learned that a significant number of days were given back to FDOT through SAs. Further analysis was done to determine why District 2 had a negative number under the heading “SA days.”

Among the number of SA days going back to FDOT, which meant time savings, a disproportionate number came from lump sum contracts. District 2 had more lump sum contracts than any other district in Florida in terms of number of contracts and total contracted amount. Most FDOT lump sum contracts in District 2 were completed on schedule. To reveal why lump sum contracts had such good results in terms of the schedule, interviews were held with FDOT personnel in District 2.

It was found that many of the lump sum contracts in District 2 were landscaping projects. Unlike other districts, District 2 has a policy that landscaping work be pulled out of roadway construction projects and given separate contracts.

Conventionally, the contractors are given two growing seasons in a contract that includes landscaping to make sure that plants are well established since production rates for plants can't be determined at the time of planting. Separating the landscaping from the rest of the contract allowed District 2 to eliminate this extra time by having contractors put a warranty on the landscaping plants. Warranty bonds now guarantee that contractors will water the plants after contract time expires, so that time can be given back to FDOT. Burn-in periods for traffic signal contracts are now being handled the same way [10] in this district.

In order to have the best probability for successful lump sum contracts, plans must be better than those of unit price contracts [10]. The fact that there are fewer conflicts concerning quantities begins with the assumption that plans and specifications are clear enough to avoid quantity arguments. If plans and specifications are not good enough, then more conflicts between contractors and the CEI will arise and lead to an adversarial relationship between them, which hinders the success of any project.

As for the process of selecting the contract type, in District 2, resident engineers chose whether they want a lump sum contract or a unit price contract on a specific project. Once it is decided, resident engineers meet with design engineers to formulate a plan that conforms to that particular contract type.

4.3 Relationship between Time and Cost

Intuitively, highway projects that have no, or lower, time extensions have lower overall costs than those with higher time extensions. Figure 4 shows this to be the case. Projects that have higher time extensions are shown to cost, on average, more than projects that have no, or lower, time extensions. In Figure 4, plotted dots represent the number of delay days and the difference between initial cost and final cost for the quarter's projects.

In order to ensure that there was a statistical relationship between extended project duration and project cost, and to further analyze the details of that relationship, statistical analysis was performed, using multiple linear regression.

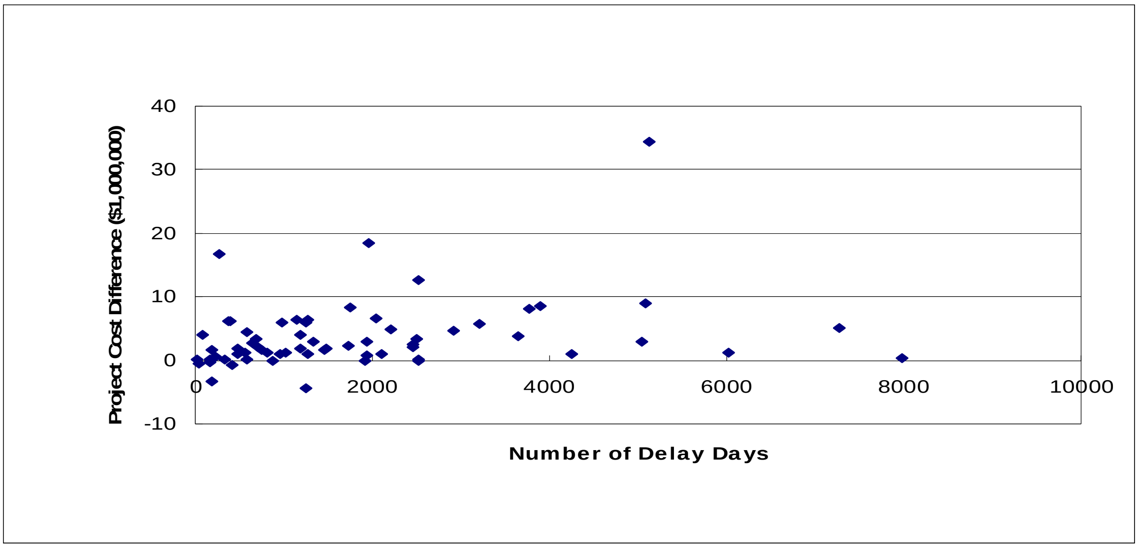


Figure 4: Delay Days vs. Project Cost Changes by Quarter/District

4.3.1 Regression Model

Regression analyses were performed to determine the statistical relationship between a response and the variables. In this analysis, the response was the project cost difference, and the variables were delay factors such as weather days and these factors found under the SA and TE headings such as changed conditions, plans modifications, and specification modification.

Several assumptions are required for the regression model. The regression model is expressed in the form of EQUATION (1).

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_{ip} + \varepsilon_i, \quad i = 1,2,\ldots,n \qquad (1)$$

And, the assumptions of the model are:

- y_i is regarded as the response that corresponds to the levels of the explanatory variables $x1, x2, \ldots, x_p$ at the ith observation.
- $\beta_0, \beta_1, \ldots, \beta_p$ are assumed to be the coefficients in the linear relationship. If there is a single factor (p = 1) for the equation, β_0 will be the intercept, and β_1 will be the slope of the straight line defined.
- $\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_n$ are assumed to be errors which make a scatter pattern around the linear relationship at each of the n observations. These errors are mutually independent, are normally distributed, and have a zero mean and variance, σ^2, under the assumption of the regression model.

The method of least squares was used for both its mathematical simplicity and its ability to provide explicit expressions for estimates of the coefficients in the regression model. The research team assumed that since each variable is a distinct and separate factor in the FDOT system, no interactions between the variables would be considered.

Sixty-four data sets were used, derived from eight quarterly reports, with each report containing eight districts in Florida. From the data sets, all 13 delay factors were chosen for the regression analysis at the first stage; however, a factor (partnering) was removed from the first regression equation because there was no time alteration to any contract over this time period attributed to partnering.

The results for the regression analysis at the first stage revealed that at the 90% confidence level, only two of the 13 factors (plans modifications and minor changes) were statistically significant.

Tables 3 and 4 show the regression and the ANOVA statistics for the final equation. From Table 3, it is interesting to note that when all of the insignificant factors from the first stage were eliminated, only the delay days due to “plans modifications” continued to have a significant relationship with the project cost changes. Even though there were many delays due to weather days, the relationship between weather days and project cost changes was not statistically significant. The weather days might affect the contractor’s cost, but they don’t seem to impact the owner’s cost.

In Table 4, the P-value indicates that the regression as a whole is very significant for a significance level of less than 1%. The coefficient of determination, R^2, indicates that over 60% of the variation in the variables is explained by the regression model, shown in EQUATION (2).

Project Cost Difference ($100k) = 4.23 + 0.204 Plans Modification Delay Days (2)

Table 3: Regression on Delays

Variables	Coefficients	Standard Error Coefficients	t-ratio	P-value
Constant	4.230	5.323	0.79	0.43
Plans Modifications	0.204	0.020	10.30	0.00

Table 4: ANOVA Statistics for Regression on Delays

Source	Degree of Freedom	Sum of Squares	Mean Square	P
Regression	1	123,522	123,522	0.00
Residual Error	62	72,199	1,165	
Total	63	195,721		
R^2	63.1%			
R^2 (adj.)	62.5%			

The adjusted coefficient of determination R2 (adj.) is a rescaling of R2 by degrees of freedom so that it involves a ratio of mean squares rather than sums of squares. This removes the impact of degrees of freedom. Unlike R2, R2 (adj.) need not always increase as variables are added to the model. The value of R2 (adj.) tends to stabilize around some upper limit as variables are added [11].

Figure 5 indicates how the regression equation fits the data. When the values derived from the regression equation are put on the y-axis and the values of actual project cost changes are placed on x-axis, the scattered dots show a linear trend. In this drawing, the ideal estimates will lie on the 1:1 line, which shows that the derived value is exactly equal to the observed value of actual project cost change.

Even though the regression equation proved significant for project cost changes, the assumptions of the regression model should be checked to see if they are satisfied. Homogeneous variances and normal distribution of experimental errors are among the most important assumptions. Residual plots are carried out to provide visual evaluations of the analysis of the constant variance assumptions, which assumes each data point is equally reliable [12].

The residuals e_i measure the discrepancy between the data y_i and the estimated or fitted model $\hat{y}_i$. If the constant variance assumption is satisfied, then residuals will follow a distribution with a zero mean and variance, σ^2. In addition, the residuals should be plotted randomly, having 95% of the residual points within a 2σ horizontal band around zero.

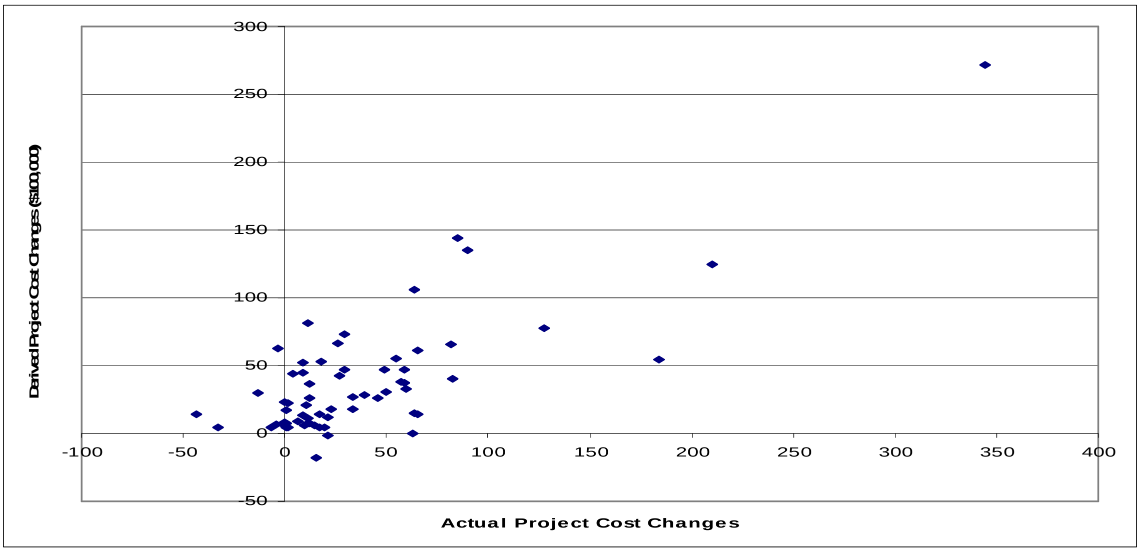


Figure 5: Actual Project Cost Change against Fitted Project Cost Change for Linear Regression Model

In Figure 6, when the residuals from the regression model are plotted against fitted values of the regression equation, any evidence for a nonrandom pattern can be detected. Further, it can be determined from Table 4 that most of the residuals should exist between the ranges of $\pm 2\sqrt{1,165}$, or ± 68.26 since the mean square of the residual error in the ANOVA is an estimator for σ^2, which is 1,165. From Figure 6, it is proved that most of the residuals are between the anticipated ranges; showing approximately two points are located outside this range, or 3% of the total observations. Therefore, it can be concluded that the constant variance assumption is satisfied. One of the purposes of deriving a regression equation in this research was to assist in predicting project cost changes in highway construction projects using actual delay days. With the resulting $R2$ value of 63.1%, it can be said that actual project cost changes can be estimated using the actual delay days under each category.

5. Conclusion

This paper presents an analysis of factors influencing contract duration for highway construction and multiple regression analysis of the causes of delay in transportation projects. Delay distribution was quite consistent, and the composition rates among the grant type of delay days (Weather, TE, and SA) did not change much unless there were noticeable changes in rain days.

The granted weather days were compared to actual weather reports at the National Climate Data Center. Even though both documented precipitation and the number of weather days granted in District 3 were greater than the other districts, the difference in weather days granted was significantly greater than the difference in documented precipitation.

Weather days were the number one reason for delays on highway construction project. Plans modifications and changed conditions were also major reasons for delays.

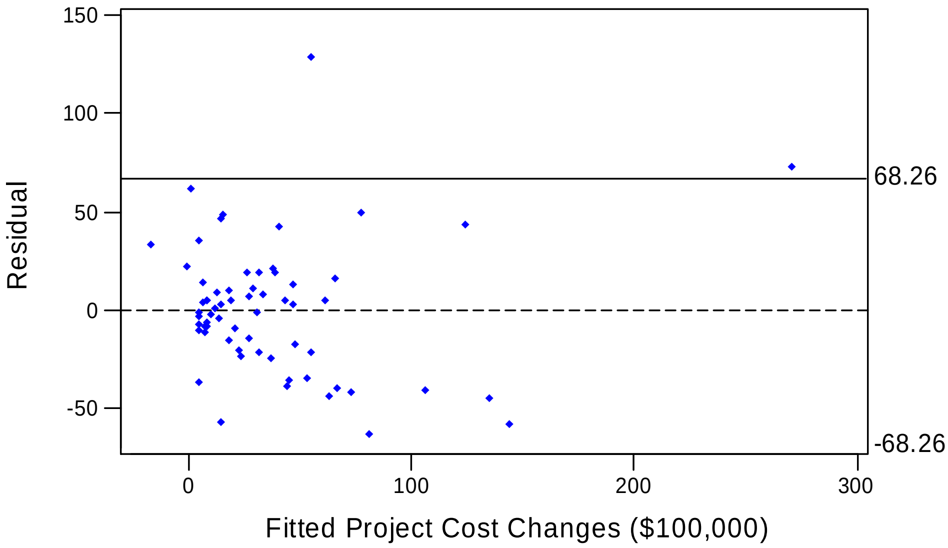


Figure 6: Residual Plot for Linear Regression Model on Project Cost Changes

The composition of the total delay days varied from district to district. The more rural the district, the more weather days were granted on average; and the more urban the district, the more TE and SA days were granted. TE and SA days are made up of changed conditions, plans modifications, specification modification, value engineering, partnering, CEI action/inaction, minor changes, defective materials, weather-related damage, claims, utility delays, and invalid reason codes.

Contract type also had an influence on project duration. In this research, the lump sum contract was noted to have played a positive role in projects having shorter project durations. One reason for lump sum contracts having shorter durations was that landscaping projects were contracted using lump sum contracts with warranty bonds separately from roadway construction projects. With the warranty bond and motivated contractors, the lump sum contract was, then, successful, and FDOT received many days back from contractors through SAs.

Regression analysis was performed, and multiple linear regression determined the statistical relationship between project cost differences and project delay. In this analysis, the regression model for project cost changes has provided a regression equation that satisfies over 60% of the variance. Among the 13 delay factors analyzed as part of the first stage, only delay days due to plans modification had a significant relationship with the project cost changes.

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Benchmarking Project Management in the United Kingdom: Developing the Measuring Instrument

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Abstract

The paper is an output from the research being undertaken by the Task Group in Project Management, which is part the activities of CIB W65. The objective of the research is to benchmark the activities of practising project managers against the Project Management Institute – Body of Knowledge. The methodological approach is a survey of practitioners. This paper reports on the development and piloting of the survey questionnaire that was designed with input from the Task Group in Project Management. The resulting questionnaire is presented and discussed in a UK context. The results show that the questionnaire will form a suitable basis on which to survey current practice. It will allow the assessment of the extent to which practitioners in the UK have the skills to undertake the various project management activities, how much of their time they commit to them, and how valuable they consider their outputs.

Keywords: Body of knowledge, project management, skills, value

1. Introduction

This paper sets out the findings of the development stage of the benchmarking study in project management. It is designed to inform a debate in the CIB W65 Task Group in Project Management on how to proceed with data collection on role of the project manager in the United Kingdom (UK) as the first study in a collection of national studies. The paper sets out a review of project management standards and justifies the choice of the Project Management Institute – Body of Knowledge (PMBOK) as the basic structure for data collection in the benchmarking process. The rationale for the development of a data collection tool is explained and the findings of a pilot of a questionnaire are discussed and reported.

2. Literature Review

The problems and difficulties of the UK construction industry in terms of it delivering satisfactory service levels to its clients have been well documented by various government reports over the years (Simon[1], Emmerson [2], Latham [3] and Egan [4]). In summary, such problems may be classified as not managing project budgets, timescales and/or quality standards. In general, research suggests that the overall track record of British organisations in managing projects leave much to be desired. BS6079 [5] acknowledged such poor levels of performance prevail when it commented “the delivery of projects on time within pre-determined cost and to the requisite standard within set constraints of established safety and quality criteria are less frequent than they should be”.

In essence, these concerns are related to the product of the construction management process. It can be argued that to only focus practice based research on the resolution of such symptoms of construction project management problems is misplaced, as attention also needs to be given to a wider agenda related to the processes (or causes) which produce such symptoms of professional service dissatisfaction. Support for this view can be drawn from the work reported by Hibberd and Djebarni [6]. This study with UK construction industry clients and their consultants ranked for importance the factors that they considered being issues in the delivery of construction projects. This survey revealed that although product or goal related factors such as time (3%), cost (6%) and quality / design faults (16%) were issues that were considered to be problematic there were others. The other factors rated by the respondents to that survey that were more related to the processes used to provide construction project management services such as, change requirements (25%), teamwork (25%), communications (18%), and project team responsibility / roles (5%). The general issues related to the management processes that UK based construction industry consultants use to deliver their services address matters such as what services, how are they structured, when are they delivered and to what quality levels are they provided. For the purposes of this work those concerns have been put into context by addressing matters related to construction project management functions and standards, activities and timescales and quality service level benchmarking. Each are now considered below.

2.1 UK National Project Management Standards and Functions

In the UK, there are two main methodologies, namely, Prince 2 and BS6079 that can be used as the basis of a strategic project plan document. The Prince 2 system can claim to be the *de facto* standard for the UK government and local authority usage. The Prince 2 and the PMBOK cover many of the same topics and both represent best practice. Waterman [7] identified the main sections of the Prince2 system as being, project start-up or initiation, planning, directing or executing, controlling and closeout.

The establishment and revision of the BS6079 [5] standard also aimed to help management address the issues highlighted above. The standard has been developed from a perceived need of central UK government and as a document it is divided into five sections, namely, (i) general matters, (ii) corporate aspects of project management, (iii) project and company organisational structures, (iv) project management processes, (v) project life cycles. Coe [8] has already undertaken small-scale quantitative research studies into the usefulness of BS6079 in practice. In the study it was found that only 40% of respondents were even aware of the existence of BS6079 in its original form. Similarly, concluded that BS 6079 does not yet appear to be taken seriously by the UK construction industry.

2.2 International Project Management Standards

Formal planning and management programmes have developed greatly since the 1950s when the US defence industry introduced the PERT network. From such early developments there has been a continual drive to develop project management standards and certification on a world-wide basis. Many countries and many sectors of industry either have or are attempting to produce their own individual standards so as to formalise their project management techniques. The internet based PMforum hosts a world wide listing of regional, national and international professional project management organisations. It lists on its web pages a total of 35 separate national project management associations from across Europe, Asia, and the Americas - see www.pmforum.org. This proliferation of standards and approaches is presently being addressed by the Global Standards working party and its brief is to establish a global standard that can be used to establish professional competence. Some of the most widely known and used international project management standards are now set out for consideration,

The Project Management Institute (PMI) set out in their Body of Knowledge (PMBOK) what they claim is the necessary guidance on the processes and knowledge required by practitioners involved in managing single projects. Its main sections cover the management of risk, management of people, and the management of time. This standard is seen as being the industry standard that can be applied on a global basis to promote the project management profession. However, as indicated above other standards available include the following,

The Engineering Advancement Association of Japan (ENAA) has produced its own Project Management Body of Knowledge. The Japanese have looked to see how project management can help innovation and improve business value. The standard was initiated by the Japanese Project management Forum (JPMF). The project management book of knowledge concentrates on the management of projects rather than the management of differing systems that make up individual projects. The four main sections of the ENAA BoK are objectives, strategy, value, management and finance. It is interesting to note that this BoK places emphasis on the management of finances and it also covers the management of programmes which is an area that the PMBOK has been criticised for overlooking. This Japanese standard has been heavily influenced by the government and it has been tailored to its needs.

In Germany, there are the DIN standards and the PM-Kanon standards that are most used in relation to project management standards. The DIN standards that are applicable are DIN 69900, 69903 and 69905. These standards relate specifically to the definition of terms and processes used in project management. The standards also give local and national compliance requirements that are similar to the UK British Standards. These standards are essentially national in application and are not seen as having any influence or relevance outside Germany.

The Cost/Schedule Performance Management Schedule was developed in Canada. This standard was developed specifically for major crown and other government projects. In the guidance note it is made clear that this standard is not intended for use on projects which are related to the production of commercial services. Canada is further developing a separate project performance management standard. This is being produced by a joint industry / government working group and its aim is to produce a more straight forward document / standard. The working group have taken on board the development of other standards such as those operating in Australia and the US Department of Defence. In time this will give this revised standard a wider than just national relevance to Canada

There are two main standards in Australia which relate to project management. One standard, AS4360, refers to managing risk in Australian public service. This standard is the one used by the Australian National Audit office to audit projects and programmes undertaken on behalf of the Australian government. The second is the Australian National Competency Standard for Project Management. This is a national standard sponsored by Australian Institute of Project Management. This standard was developed with the aim of promoting the profession and being used as the basis for the certification of professional standards. The PM BoK was used as the initial baseline for the standard and as a result the standard is good in the assessment of an individual's competence but it is limited in its use to the Australian context. Indeed, Turner et al [9] commented that in keeping with other standards "this standard does not prescribe how project management competence should be developed".

The Association of Project Managers Body of Knowledge was developed in 1986 primarily to address all aspects of education and training of project managers in the UK. It is not seen as a standard to be used for the implementation of project management services. Rather it is seen as a mechanism to structure certificated training. The APM and other nationally based standards are based on the PMI body of knowledge that is becoming accepted as the global standard. The standards and guides indicated above detail the functions or the 'what' that constitutes the potential range of services that construction project management needs to address. The next issue to consider in order to begin to establish common approaches to construction project management are the process by which such services are delivered.

2.3 Project Management Activities

During the construction project lifecycle it is self evident that project management activity should be centred on ensuring that the project achieves its recognised success factors. Previous work by Morris and Hough [10], Nicholas [11], Keeling [12] have between them all developed comprehensive lists of issues that construction project managers need to address in order to ensure their management activities are best directed towards the achievement of project success. In summary the principal features advanced in the literature revolve around the conventional issues of project management activity being focused on the management of time, cost and quality during the construction or implementation stage of the project delivery lifecycle. However, Winch [13] notes that such a focus on conventional project success criteria provides a narrow view of what project lifecycle activities actually need to be addressed. Winch [13] suggests that such a view is limited in that it takes as given solutions to the problems during briefing and design and it ignores the differing interests of all project stakeholders. Winch suggests that project management services that focus on such narrow conventional criteria is an approach that is product or goal orientated rather than one that takes cognisance of the processes by which such goals can be achieved.

Burke [14] suggests that project management activities that focus on the processes by which the project life cycle is fully implemented need to address issues that can be grouped under the following headings, namely, the concept and initiation phase, the design and development phase, the implementation and construction phase, and the commissioning and hand-over stage. Given this wider perspective it follows that the time project managers allocate to the differing phases of project delivery should be distributed across the project lifecycle and not exclusively focused on the project's construction or implementation phase.

2.4 Benchmarking

Benchmarking is the term applied to the method of comparing best practices amongst peers or competitor organisations to identify, and adopt best practices that can help a particular organisation to improve the level of its services to its clients. Keeling [12] identifies the concept of benchmarking to be an established mechanism used by project management organisations to ensure that they learn from the experience of themselves and similar business organisations. However, work by Somerville and Stocks [15] indicated that the prevailing 'blame culture' together with the fragmented nature of the UK construction industry may well combine to frustrate the same characteristic of competitive benchmarking to become as established in the UK construction industry.

3. The Project Management Process

3.1 The PMI Body of Knowledge

The Project Management Institute established its first Project Management Body of Knowledge in 1976 on the premise that there were many management practices that were common to all projects and that codification of this "Body of Knowledge" would be helpful not just to practising project management staff but to teachers and certifiers of project management professionalism. It was not until 1981, however, that PMI's Ethics, Standards and Accreditation Committee submitted its recommendations for a BoK to the PMI Board of Directors. These were published in the August 1983 issue of the Project Management Quarterly, and this subsequently formed the basis for PMI's initial accreditation and certification programmes. A revised document was published in the August 1986 issue of the Project Management Journal and approved by the PMI board in August 1987 as the "Project Management Body of Knowledge". Further work by PMI's

Standards Committee resulted in a revised document titled "A Guide to the Project Management Body of Knowledge". This was done to emphasise that even though the document defines the PMBOK as all those topics, subject areas, and intellectual processes which are involved in the application of sound management principles to projects – a claim which this paper will question – it will never be able to contain the entire PMBOK which is out there in the universe of project management. A further revised and updated version was published in 1996. Trademarking of the term PMBOK was recently sought by PMI. Currently, the structure of the PMI's PMBOK™ document consists of "generally accepted project management practices" represented by 37 component processes. It also includes a description of what the PMI defines as the "project management framework": definitions of key terms, a description of pertinent general management skills, and an introduction to the concept of a project management process model (Morris, [16])

3.2 The Construction Extension to the PMI Body of Knowledge

In 2000, PMI issued its Construction Extension to the PMBOK. In the introduction to the extension, the PMI states that the extension "supplements, modifies, reinforces and expands the profession's *de facto* global standard in an easy-to-use format for practitioners in the construction industry" (PMI, [17]). The extension introduces four additional activity areas – project safety management, project environmental management, project financial management, and project claims management. The activity areas of the PMBOK and the Construction Extension are shown in fig. 1.

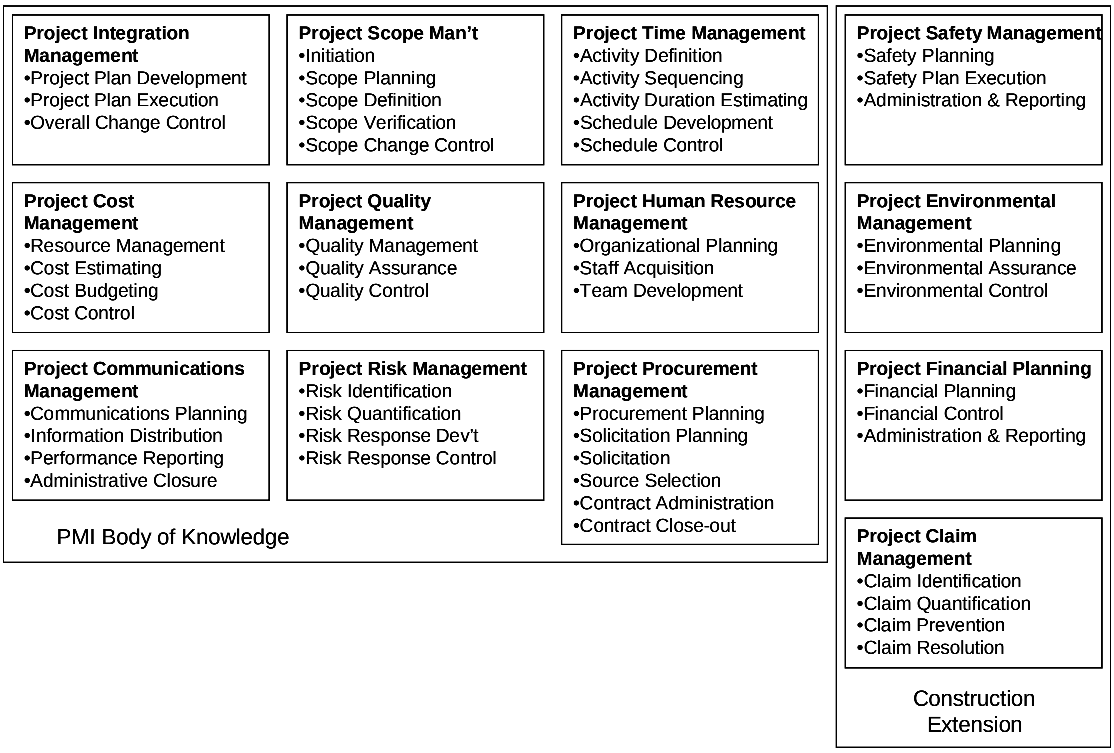

Figure 1 The PMBOK activity areas and the construction extension

4. The Benchmarking Process

4.1 The Task Group in Project Management

The Task Group in Project Management was set up under the CIB W65 Organisation and Management of Construction in 2002. The objectives for the task group include an international benchmarking exercise on the role of project management. The argument for this was articulated in the proposal:

> The globalisation of construction, particularly for large infrastructure projects, creates situations where companies from across the world come together in a unique partnership to solve a particular problem, often working under the direction of a single, project management consultant. Those postgraduate programmes for project management that recruit in a global market are recruiting well and from counties all over the world. There is little or no evidence to suggest that the elevation of the importance and significance of the project manager is confined to the United Kingdom, it is a global phenomenon.

This benchmarking study has two components:

1. A quantitative study designed to examine the role of project managers in construction projects in different countries. This part will attempt to gather data as widely as possible.
2. A qualitative investigation into the factors affecting the differences between countries.

This paper presents the findings of the development of a measuring instrument for part 1 of the study.

4.2 Developing the Measurement Instrument

The measuring instrument has been developed following workshops held alongside CIB symposia in Singapore and Toronto. The PMBOK provides the structure for the benchmarking process. It gives a total of 13 activity areas that are sub-divided into 43 sub-activities (see fig 1).

The starting point is what is meant by role? A dictionary definition would be: ‘the actions and activities assigned to or required or expected of a person or group’. This is an important issue in this context and goes to the heart of the investigation. Role descriptors are usually ascribed to individuals or groups of individuals and any examination of ‘role’ must, therefore, focus on the individual within the process. For this study, the focus is on the role of the project manager in the management of construction projects.

It must be recognised that the term project manager is generic and that the function of the project manager may be undertaken by a separate consultant with the title of project manager, or by any other actor engaged in the construction process, or indeed a combination of these. If it is the role of project manager that is to be benchmarked, rather than the named persons duties, it is important that data is collected on who is performing the duties of project manager?

The next issue is about the investment made by the project manager in discharging their obligations. Here data can be collected on the relative use of manager's effort, in the form of time, across the activities in the PMBOK. This follows on from the study reported by Fortune and Lees [18]. Data also needs to be collected on the perception of value added by each of the activities. This will allow for the alignment between effort and value to be assessed.

Finally, it is important to capture data about the respondents, to establish whether there are trends that affect their execution of the role. Here it is proposed to examine the level of experience, appropriateness of formal education and training and discipline background of the respondent.

The framework for the measuring instrument is summarised in figure 2.

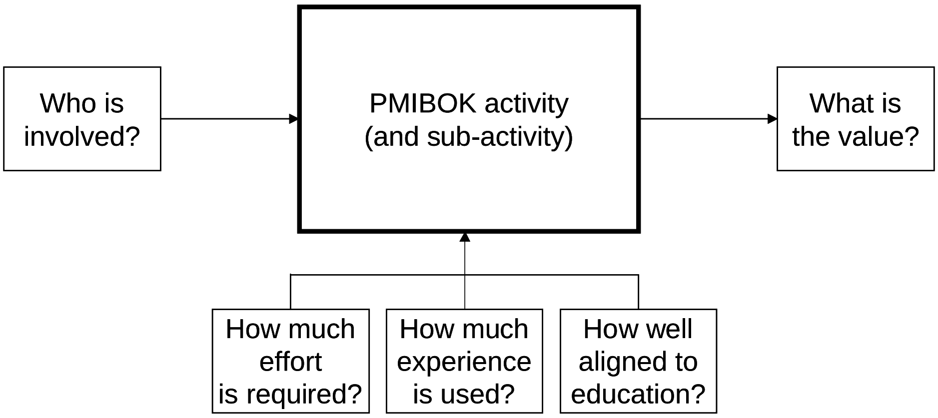

Figure 2 – Rationale for the development of the measuring instrument

4.3 Validating the Questionnaire

For the purposes of this development process a paper questionnaire was prepared in accordance with the principles established in fig 2. The questionnaire in its first form runs to several pages and there is insufficient space here to reproduce the whole questionnaire. However, fig 3 shows the typical arrangement of the questionnaire and also shows an example of how it was completed.

In the pilot study, the questionnaire was given to five practitioners to complete along with a supplementary set of questions that asked questions about their experiences of filling it in. These questions covered ease of understanding, time taken to complete and appropriateness of questions.

The respondents found the questionnaire relatively easy to understand, although there was some confusion over how to respond to the question on the proportion of their time spent on different activities. The main problem here was a lack of certainty over what constituted 100% of their effort. Was it the amount of time spent as a consultant or was it only the amount of time spent as a project manager? Confusion on this matter led to a lack of clarity in the data collected.

The time taken to complete the questionnaire was considered to be too long and likely to have a detrimental affect on the response rate. This matter will need to be discussed by the Task Group before a final decision on how to proceed can be taken. The options would appear to be either to make the sample of respondents a smaller, solicited sample that only includes those who have agreed to respond, or to improve the efficiency of the data collection by making the questionnaire a web-based data entry form. The latter has certain attractions as it would remove the confines of A4 paper sheets and allow a greater level of instruction on how to complete the form.

The general view of the respondents was that they felt the questions were appropriate, but they did not feel qualified to comment on this as they were not fully aware of the purpose of the research.

7. Project Cost Management	What proportion of your time as project manager is given to this activity?	How do you rate the [see below] (where 0 = low and 5 = high) – circle as appropriate: The value-added by your engagement with this process	Your value of your experience to this process	The value of your education to this process	Which of the following ***actors*** has **primary responsibility** for the process? You as project manager	Client	Architect	Engineer	Constructors	Specialist constructors	Others please specify	*Quantity Surveyor*
7.1 Resource Planning - determining what resources (people, equipment, materials) and what quantities of each should be used to perform project activities.	5%	0 1 (2) 3 4 5	0 1 2 (3) 4 5	0 (1) 2 3 4 5	☐	☐	☐	☑	☐	☐	☐	☐
7.2 Cost Estimating - developing an approximation (estimate) of the costs of the resources needed to complete the project activities.	5%	0 1 2 3 (4) 5	0 1 2 (3) 4 5	0 1 2 3 4 (5)	☐	☐	☐	☐	☐	☐	☐	☑
7.3 Cost Budgeting – allocating the overall cost estimate to individual work activities.	2%	0 1 2 3 (4) 5	0 1 (2) 3 4 5	0 1 2 (3) 4 5	☐	☐	☐	☐	☐	☐	☐	☑
7.4 Cost Control – controlling changes to the project budget.	10%	0 1 2 3 4 (5)	0 1 2 3 (4) 5	0 1 2 3 4 (5)	☑	☐	☐	☐	☐	☐	☐	☐

Figure 3 – Example a completed part of the questionnaire

Overall, the pilot demonstrated that the questionnaire design is a reasonably robust and reliable basis on which to develop the measuring instrument. Further work is required in refining the tool before it used to collect data in the UK as the first part of the benchmarking process. A workshop is to be held in Helsinki to move the development to the next stage.

5. Conclusions

The main finding of this part of the study is that the basis on which the measuring instrument is designed is reasonable and robust. However, further refinement is required before the data collection can be undertaken in a full study. This refinement needs to be informed by the debate in the next workshop meeting of the Task Group, which is to take place in Helsinki in June 2005.

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Process Oriented Integrated Management System - Development and Implementation

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Abstract

The management system of Skanska Talonrakennus Oy is an integrated system, which addresses the following aspects: quality, environment, occupational health and industrial safety. The system describes the best practices applied to planning, implementation and improvement of activities as well as the responsibilities of different individuals. The indicators of the management system are intended to support continuous improvement of operations.

Upgrading of the management system was started because the previous functional management system had some significant inherent shortcomings. The old system was not sufficiently customer-oriented, did not support cooperation between the various units and functions, and did not help conceptualize the whole. In addition, the system, maintained in hard copy folders was onerous to update, and reporting of indicators required much work and was not illustrative.

The goals set for the new process-based system were not so much standard-oriented as business-oriented and their purpose was to support the strategic goals of the company. The method chosen was tightly scheduled teamwork led by the process owners and supervised through the different phases by an external expert, Mr. Kai Laamanen. Definition of customer-oriented goals proved to be a good way to help understand customers' expectations and challenge the existing management practices that were the result of the functional system.

The digital management system has proved to be a good concept at the construction sites and offices of Skanska Talonrakennus. The extensive material is logically organized in the system, and documents of the reference material are easy to find. At the same time, the digital system has significantly accelerated the development of the entire management system of Skanska Talonrakennus. Reporting and analyzing of indicators has reached an entirely new level thanks to the software. The reports are illustrative, they are produced on real time and decision-making concerning needed actions on their basis has become more dynamic.

Implementation of the process concept throughout the organization is not yet completed. In 2005, resources will be dedicated especially to training, reference material of the system, and reporting on safety findings. Judged on the basis of the positive first experiences, the reform of the management system has been a significant step in the right direction. In the future, the new system will be a good support for achieving the strategic goals of Skanska Talonrakennus.

Keywords: Management system, process, implementation, improvement

1. Need for Development of the Management System

1.1 Role of Skanska Talonrakennus Oy's Management System

The management system of Skanska Talonrakennus is an integrated system which addresses the following angles: quality, environment, occupational health and industrial safety. The system is certified in respect of all of the above-mentioned areas.

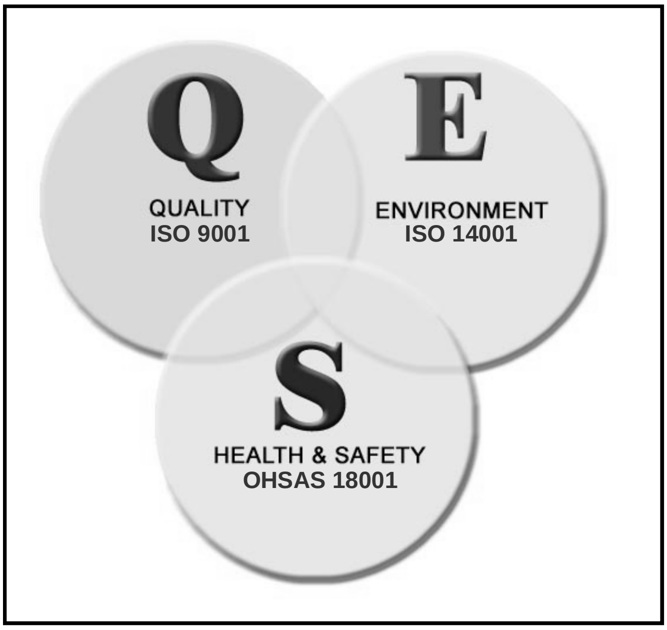

Figure 1. The three components of the integrated management system: quality, environment and health & safety.

The management system plays a significant role in the daily work of all Skanska employees both at the construction sites and offices of the company. The system describes the best practices of the company for planning, implementation and improvement of activities as well as the responsibilities of different individuals. Every Skanska employee has the duty to follow the management system in his/her individual duties.

The indicators of the management system support continuous improvement of operations. Financial, qualitative, environmental and safety performance capacities are measured by several different indicators. Further actions and development projects are determined on the basis of the measuring results.

This article describes the project for reforming the management system, its premises, goals and implementation as well as the characteristics of the new system.

1.2 Problems Associated with the Functional System

Until 2002, the structure of the management system was functional. The management practices were described as entities consisting of different functions. For example planning supervision, bidding calculation and production were such functions. The function procedures were described by means of written procedure descriptions and internal functional process charts. The system also included a large amount of reference materials, such as model plans, forms checklists and model documents. The system was quite viable and was generally considered to have no other defects except its heaviness and the extensive volume of its material.

However, this functional structure had several shortcomings. Firstly, the system contained no description of the customers' activities. The matters described in the system were based on Skanska's internal needs, not on the customer's expectations and requirements. It was impossible to understand the customer's role by means of the system, and customers' expectations were not very significant in the system improvement process.

The functional way of describing the system did not support cooperation between the different corporate units and functions; instead cooperation depended on the active commitment and skills of individuals. In addition, transmission of information between different functions was given relatively little attention.

A third significant question was the conceptualization of the whole. In the functional system, each function had its set goals which could, however, be conflicting with the goals of other functions, the goals of the entire company and those of customers. Employees also had difficulties in conceptualizing the operation of the entire company and their own role in it.

1.3 Problems with the Paper-based System

Previously the functional system was recorded in hard copy folders. About 1,500 Skanska employees in Finland had their individual system folders. Implementation of improvements was difficult, because even the smallest change required duplication of at least 1,500 hard copies of the document and their distribution to different parts of Finland. For this reason, the system was updated only once or twice a year. Small instant improvements were not carried out.

In the manual system, compilation and reporting of the measuring results was tedious work. It required an estimated work contribution of 20 people every six months to collect data on the qualitative, environmental and safety indicators. In addition to hard work, the reporting thus also lagged behind the real situation, and the clarity of the reports was only passable, and it was not easy to identify problems and improvement targets.

2. Goals Set for the Reform of the Management System

2.1 Goals of the New Management System

The management of Skanska Talonrakennus considered the success of the project for reform of the management system as critically important due to the dominant role of the system. The goals defined for the new system were not so much standards-oriented as supportive of the strategic goals of the company. Another goal was to create a system that would serve as the framework for planning of all activities and development in Skanska. Process approach provides a good basis for 3D modeling and standardization of construction projects where Skanska has allocated significant resources in recent years.

An important aspect is that the true objective of the system reform was to achieve the benefits offered by the process approach. The reform turned out to be a large project where the operations of the company were described in an entirely new way. The change of processes required by the new standards could have been achieved by a much easier updating of the system by just calling the existing functions processes and the persons responsible for the functions process owners. But such a flimsy reform would not have generated any new benefits, and the activities and their evaluation would have continued largely unchanged.

The goals defined for the new management system were:

- Our customers are more satisfied.
- We manage the risks.
- Our implementation costs are reduced and our productivity improves.
- The quality of our operations and products improves.
- We deliver the projects on schedule with zero defects.
- Control of our environmental and safety matters improves.
- Our cooperation network together with us does its best to achieve the above-mentioned goals.

2.2 Goals of the Reform Project

A challenging target schedule was set for the reform of the management system. The work was started in April 2002 and the system was to be ready for use and for training of personnel in April 2003. External audits in accordance with changed standards ISO 9001:2000 and OHSAS 18001 were performed in June 2003. In this connection, the environmental standard (ISO 14001 remained unchanged. In addition, the working method of the reform project was to utilize the best skills and knowledge of personnel and support widespread commitment to the goals.

3. Project for Reform of the Management System Step by Step

3.1 Theory Applied

Skanska Talonrakennus had no previous experience from a process modeling and development work of the type of this project. There was, however, ongoing cooperation with Kai Laamanen, a leading Finnish process expert, for instance connected with self-assessments. He was a natural choice as our cooperation partner for this development project, because he was already familiar with Skanska's operations and his process expertise was widely recognized.

It was agreed with Laamanen that he would train Skanska personnel in process management, and would then serve as instructor in the project, supervising and commenting on the different work phases. The three project phases presented in this chapter follow the model for building of process system, presented in Laamanen's book ”Manage your business as a network of processes”. The terminology used is from Laamanen's book ” Terms and concepts in business process management”. [1], [2]

The basic theory of process approach is that there is a certain chain of processes used by the organization to generate value to the customer. This generation of value must be managed in the organization and the operative result of the organization is generated in this process. [1]

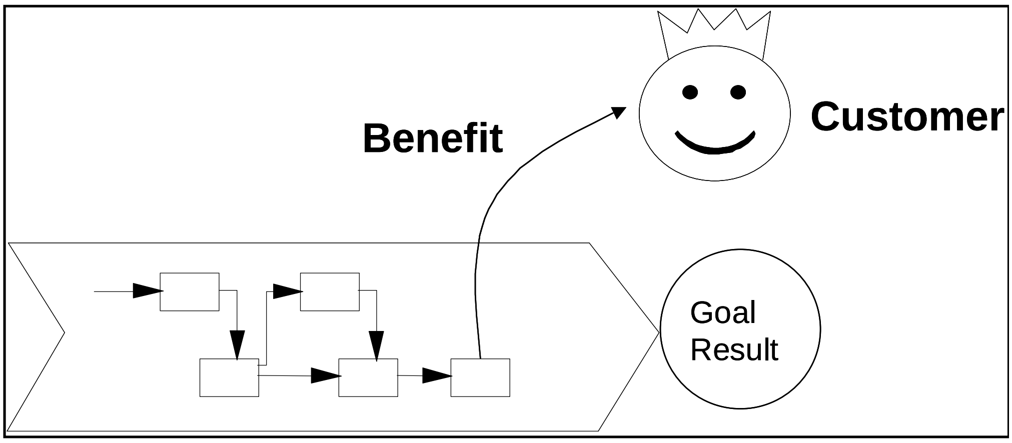

Figure 2. Value generation and target-setting.

3.2 Work Method

In March 2002, a schedule with intermediate goals was created for the project for reform of the management system. The working method came to be such that all persons who participated in the reform project held a joint meeting of a day or half a day at the beginning of all the project phases described in the following chapters. The status of the work and the guidelines for the following phase were reviewed under Laamanen's guidance. Small teams established for each process continued working between the meetings. Each small team had a chairman, and the chairmen were later also appointed as process owners.

APRIL – MAY 2002
Process training to process owners and quality managers
JUNE – AUGUST 2002
Definition of customer's operations
SEPTEMBER 2002
Definition of the inputs, phases and products of all processes
OCTOBER – NOVEMBER 2002
Appointment of process owners. Writing of process descriptions
DECEMBER 2002 – MARCH 2003
Modeling of processes; linking of reference material by means of QPR ProcessGuide
APRIL 2003
Training of Skanska personnel
MAY 2003
First meetings of process development teams
JUNE 2003
External audits

Process owners, key persons and quality managers did the work (50 persons)

Figure 3 .Schedule of the project for reform of the management system.

3.3 Training of Key Persons

Knowledge and skills were seen as key success factors for the project. Training events were organized in April and May for about 35 Skanska employees. Basics of process approach and measuring of indicators were the training themes. The persons who participated in the training were mostly members of senior management and quality managers. These persons and 15 other Skanska experts subsequently participated in every phase of the reform project described in this document.

3.4 Definition of Customer's Operations

Definition of the customer's operations consisted the first phase in the creation of the new process-based management system. Families who buy houses, clients who want to build residential projects, companies investing in commercial and office premises (e.g. insurance companies) and users of commercial premises are customers of Skanska Talonrakennus.

The customer's operations were initially described on a summary level. Six main phases of the customer's operations which illustrate the operations of all the above-mentioned customers in relation to Skanska were described on this level,. The customer's operations were defined during June – August.

3.5 Identification of Processes

The core processes of Skanska Talonrakennus were identified in August 2002 on the basis of the customer's main processes. The role of these core processes is to supply the best possible service to the main phases of the customer's operations efficiently and profitably. The number of these identified processes was five.

Also the most important support processes were identified. Support processes are internal processes of the company that create the preconditions for the function and results of the core processes. The number of these identified support processes was eight.

The above-mentioned core and support processes are Skanska Talonrakennus Oy's key processes and they play a major role in achieving the performance targets of the company. This is why their adequate description and continuous improvement are important. Several support functions whose development in this connection was not considered critically important were excluded from the management system. The customer's operations and Skanska's key processes are presented in the process chart on the highest level of the management system.

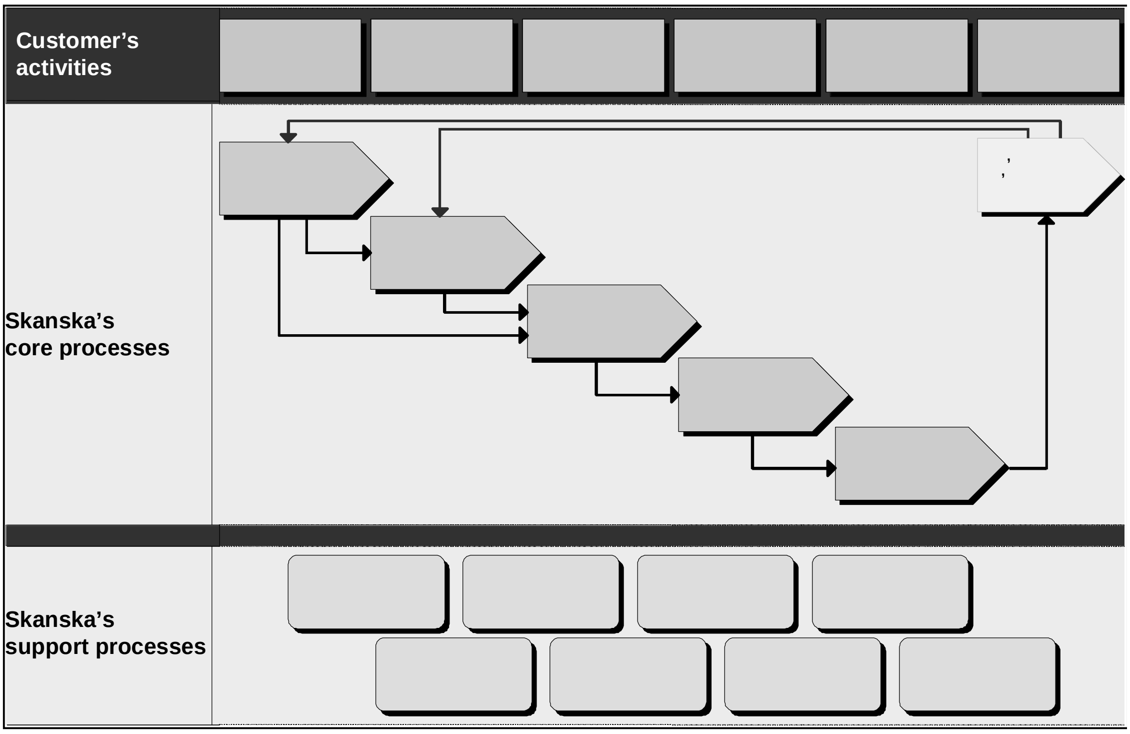

Figure 4. Structure of Skanska Talonrakennus Oy's process chart.

3.6 Setting of Process Boundaries

The boundaries of all processes in the management system were defined in September 2002. This was done by defining the inputs, phases and products of each process and also what happens before and after each process. These boundaries helped get a picture of the process contents and especially of the integrity of the core process, ensuring that the products of the previous core process are inputs of the next one. This also ensures that the processes really go from customer to customer and begin with planning (anticipation) and end in evaluation (learning).

3.7 Appointment of Process Owners and Writing of Process Descriptions

At the beginning of October 2002, an owner was appointed for each process. The owners are typically members of senior management who are in a prominent and influential position. Their first duty was to form a development team for the process, representing extensively all the units and the best know-how within Skanska. The first task of the process development team was to write a verbal four-page description of the process. To facilitate this writing work, all members of the team were given standard headings and questions that should be answered. The process description includes among other things:

- Purpose of the process
- Critical success factors of the process
- Main process phases
- Process indicators
- Process improvement
- Central roles functioning in the process.

In other words, the process chart is part of the process description. The process description is necessary to understand the operations and the critical factors that impact them (e.g. importance of cooperation). This supports operations, management and improvement. The purpose of management is to help people understand their own roles and the critical factors in the functioning of the organization.

3.8 Creation of Process Charts and Linking of Reference Material

The period from December 2002 to March 2002 was used to prepare the process charts by means of the QPR software, and to link the reference material to these charts. Certain basic rules were applied to the preparation work, e.g.

- The maximum permitted number of boxes (= functions in a chart) is 20, in other words only matters critical for success are described
- The charts start from the customer and end to the customer
- The customer is on the top line
- The following lines include Skanska’s different roles, or task definitions
- The functional text must describe activities and be a sentence

- The charts describe who performs the tasks in reality, not only who is ultimately responsible for the matters. [4]

Drawing of the process charts led to extremely fruitful discussions in the process development teams. The straight-forward way of presentation forced the teams to put the processes of the company and the relating functions in an accurate order of priority. Sometimes the description progressed easily in a spirit of good cooperation, while at times there were lengthy discussions about the priorities of doing things and who should do them.

The reference material: instructions used in daily operations, forms, checklists, etc., were linked to the process charts. As a result, more detailed relating material can be accessed from each function box of the process to make implementation easier.

3.9 Training of Personnel and Introduction of the System

The training events organized for all staff in April 2003 were quite straightforward. The first hour of the events was used to review the ideas and goals of process management as well as the changes in the structure of the management system. During the second hour, the participants practiced the use of the management system software in a computer class. After one hour of practice and final test everybody could use at least the basic functions of the system, such as roaming between process charts and retrieval of data. In connection with the training events, the hard copy system folders were collected from personnel and the fully digital system was taken into use.

The quick introduction of the system was supported by the following aspects:

- The basics of the process approach are accurate and straight-forward and aim at efficiency, and are therefore meaningful for business
- The goal of the system was simplicity of content and user interface
- Only the basics were taught during the first training round to ensure that the big organization did not need to absorb too many things at once
- General improvement of computer skills to ensure that users did not find the digital system as frightening or difficult to conceptualize
- Strong role of the management and other key persons in implementation and marketing; in other words, there was no uncertainty about the importance of the matter.

3.10 First Meetings of the Process Development Teams

The first meetings of the process development teams were held in May 2003. At that time, people had one month of experience in the use of the system. After this, the development teams have convened regularly and decided on improvements on the system.

3.11 External Audits

SFS performed the external certification audit of the system in June 2003. In the audit, the new process model was found to be good, and the auditor made very few comments about it.

3.12 Improvement of Measuring Indicators; Further Development

Continuous improvement of the system has continued energetically even after its introduction. Improvement of the measuring indicators has been a special priority during 2003 – 2004. The content of the indicators has been reviewed and improved from the angle of process efficiency and strategies. Reporting and analyzing have taken a significant leap forward following the introduction of the measuring software.

4. Digital Management System

4.1 Requirements

The environment where the management system and its computer applications are used is challenging. Skanska Talonrakennus has about 200 construction sites in different parts of Finland. The sites may be in tightly inhabited population centers and in city centers, or in very sparsely populated areas. The system must function right from the beginning of the site with the available telecommunication connections which can be of a varying quality.

The system must be easy to use, modern and attractive. Both process modeling and the use of the material of the management system must be simple and logical.

Since the management system is continuously used in 200 projects and many support processes, the system must be reliable. We cannot afford interruptions in its use.

4.2 Piloting

On the basis of a brief comparison, the process and score card software supplied by QPR Software Oy seemed to be the most attractive alternative. As the matter concerned the development of a system covering the entire personnel, we wanted to make sure before the investment decision that the characteristics of the software that would be purchased should meet the requirements of usability and information technology.

To ensure suitability, the software was pilot tested before acquisition. We agreed with the software vendor about a pilot project in which all parties participated to supervise fulfillment of their specific requirements. The software was tested at some sites and Skanska offices in different parts of Finland. Skanska's data administration unit tested its suitability for the existing IT environment, and the management evaluated the benefits of the software in its meeting.

Piloting confirmed the suitability of QPR, and there have been no surprises in this respect during the two years of use.

4.3 Use of the Digital Management System; Benefits in Production

The digital management system has proved to be a good concept at the construction sites and offices of Skanska Talonrakennus. The extensive material is logically organized in the system, and the documents of the reference material are easy to find. A basic user needs to know only a few functions, which makes the use of the system more meaningful and efficient. Another benefit for the users is that now the definitely most up-to-date and currently valid system material can be found in one single place on Skanska Intranet.

The digital system has significantly accelerated the development of Skanska Talonrakennus Oy's management system. Small improvements to the reference material are a virtually continuous process, because it takes very little effort to immediately make the updates available to the entire organization.

A new level has been reached in the handling of the measuring indicators thanks to the software. Reporting on quality, environmental and safety indicators used to be tedious, outdated and non-conceptual. Today, after the indicator system has been created, data can be entered in the system on real time, and the most recent information about the performance ability of the company is continuously available by means of the selected indicators.

The way of presenting the measured results is also illustrative and invites discussion. Green light indicates a performance that meets or exceeds targets, yellow is passable, and red is poor. Analysis of process indicators and decisions concerning further steps have become a natural element of management and all significant meetings in Skanska Talonrakennus.

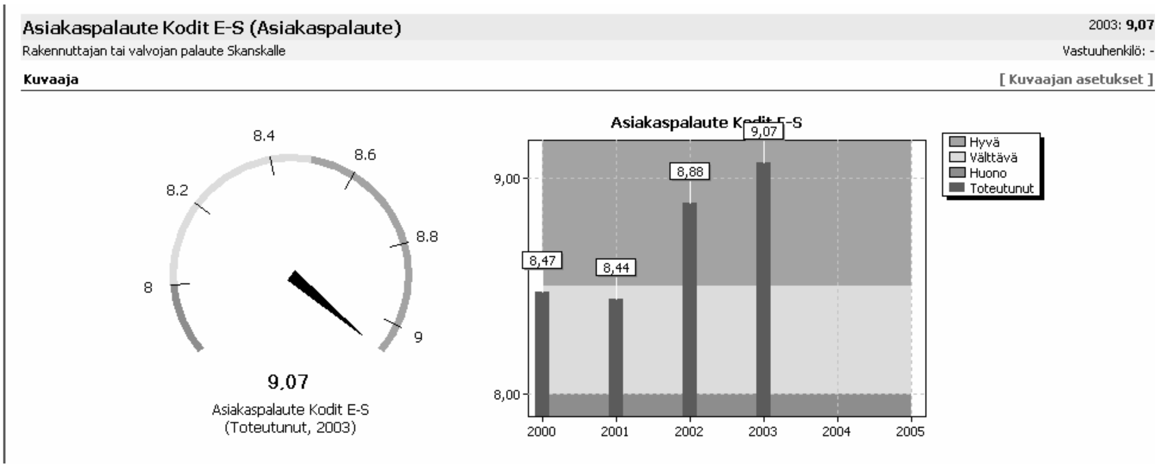

Figure 5. View of the indicators.

5. Critical Factors for the Reform of the Management System

Reform of the management system of Skanska Talonrakennus was an interesting project where many critical aspects and goals were implemented successfully. On the other hand, there is also still room for learning and improvement.

Since we had to deal with a matter new to the organization and even theoretically challenging, there was a risk that the work of fifteen process development teams would lose miss their guiding principles, and the result would be heterogeneous. The implementation of the selected phase-based process theory was, however, quite disciplined, and the result was a logical system.

Customer-oriented definition of processes proved to be a good way to learn understanding the customer's expectations and call to question the conventional practices of the company, which were the result of the functional system. Reception among customers has naturally been very good for an management system of this type.

Appointments of people were successful. Process owners remained active throughout the project. Another essential factor were the intermediate goals set for the project at intervals of roughly two months, and the owners complied with these goals. Their enthusiasm about the process approach and their good position in the organization facilitated the introduction of the system significantly. The duty of the process owners also in the future is to improve the system to ensure that it generates value to customers as efficiently as possible. As the implementers also managed to create a relatively simple, modern system that makes work more efficient, its use was also preferred compared to the old system.

Measuring indicators were extremely successful in improving the quality of reporting. However, their content still requires a lot of improvement. Most of the indicators measure more the outcome than the true efficiency of the process. There are also some indicators in the measuring system whose real useful exploitation has not yet been confirmed.

Although the entire personnel was trained to adopt the process approach and the new management system, training has not yet been sufficient. Training on process contents needs to be increased. Also basic system training must be continued even to other employees, not only newly recruited personnel, because the using skills differ between the regional units. The level of skills is better in units where personnel has had the possibility to practice on their own the basic characteristics of the system in computer classes than in units where training was given in the form of lectures.

6. Conclusions

According to the experiences of Skanska Talonrakennus, process approach is a good way to model, manage and improve project-oriented construction operations. Provided that the process model is kept sufficiently simple, it supports prioritization of activities and development of critical success factors. The process-based management system helps understand the ensemble of all operations.

In the initiation phase of the project it was estimated that taking the process approach through an organization of this size would require five years of work. Now we are about halfway through that time, and a lot still remains to be done. For instance continuous improvement of processes has only begun, and the heritage of functional approach still shows even in planning of operations.

In 2005, resources will be allocated particularly to training events and reference material of the system. Some of the reference material is relatively heterogeneous and outdated, copied from the previous system. Improvement of the usability of reference documents is going on.

This year we will also introduce a new system tool for collecting and analyzing of safety findings. All findings relating to industrial safety at the sites of Skanska Talonrakennus will be recorded in the system. The idea is to have a good system that will activate the entire personnel into improving industrial safety.

Extension of the system to strategic planning, definition of individual user profiles and integration to other Skanska systems are some of the potential development targets.

The quality of the new management system can for the time being be evaluated mainly on the basis of employees' comments and changed management practices. On the basis of their positive nature we have reason to believe that the reform of the management system has been a significant step in the right direction, and that the new system will from now on provide good support to Skanska Talonrakennus in achieving its strategic goals.

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Project Management as a Synergic Competence for a Construction Corporation

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Abstract

Corporate synergy and construction project management (CPM) as a synergic competence are discussed as the two challenges in the context of managing a multi-service corporation in construction. First, a main contractor (as an internal client) and a sub-contractor are trying to meet their own project goals separately. In turn, the goals of two units are seen as the common one in the eyes of corporate management. Herein, the latter can enhance profitable synergy through both (a) hard values such as the scale of economies in procurement contracts and (b) soft values such as shared client relationships, joint development teams, and shared know-how. Ultimately, corporate management gives the guidelines for solving this internal partnering dilemma, i.e. ensuring the competitive price/cost and high productivity in each project. Second, CPM is herein perceived as one of the synergic core competences of a construction corporation. Thus, corporate management guides the advancement of CPM skills, common language and sense of responsibility among key personnel across all the related businesses and units.

Keywords: Construction, cooperation, internal partnering, project management, synergy

1. Introduction

Herein, **the management of a construction corporation** is approached, in particular, in terms of solving the two internal problems that are typical in corporate settings. **The two-fold aim** of this paper is to address (a) the first problem involving conflicts between achieving the real corporate synergy and attaining the project-specific objectives of the two units at the same time, and (b) the second problem which is inherent in enhancing construction project management (CPM) skills as a synergic core competence through all the related businesses and units.

The paper is structured as follows. First, a dilemma of synergic corporate management versus project management responsibility is dealt in light of some relevant literature. Second, the importance of CPM as one of a construction corporation’s synergic competences is highlighted. Third, the dual problem is elaborated with reporting on the initial results of one case study. The case firm is one of the largest corporations in Finland, YIT Corporation. In particular, the actual efforts to solve the synergy problem and the CPM competence problem are discussed. Finally, some promising ways for solving the two problems as part of effective corporate management are emphasized.

2. Project Responsibility versus Corporation Synergy

2.1 Converging Goals of Primary Project Stakeholders

In principle, clients (owners) may set very individual goals for their construction projects. However, it is herein assumed that **(profitable) project stakeholders** have many converging goals such as the finishing of the project on schedule and within budget as well as a project is performed without quality deviations and violations against safety regulations. Owners set various goals for their building projects concerning the effectiveness of the procurement process and the performance and the quality of the built spaces and systems. When strategic thinking in real estate evolves, attention will increasingly be paid to creating value-added services for users. The new sources of revenues and the solutions that improve the overall profitability will be sought instead of only minimizing the acquisition costs. At the same time, the scope of a contractor's duties is expanding as well as long-term partnering and cooperation models are gaining ground. Operational models where both the risks for the investment object in question and the rewards of its successful implementation are shared spur the parties to closer cooperation and innovativeness. Incentive contracts are, after all, designed to line up a contractor's goals with those of a client by making a contractor's benefits partly dependent on the results that are important for a client. In this way, a client's goals become the leading idea driving the implementation of an entire project. [1]

In construction corporations, there are several businesses and units that together create an extensive construction service provider. When one of a corporation's main contracting units is selecting a subcontractor, a natural choice would be the use of in-house services and supplies. In this internal case, both an external client and corporate management expect flexible and profitable cooperation between a corporation's units that are engaged in an external client's project. Typically, an external client and an internal client are both expecting to get high quality and functionality at the targeted (minimum) cost (Figure 1).

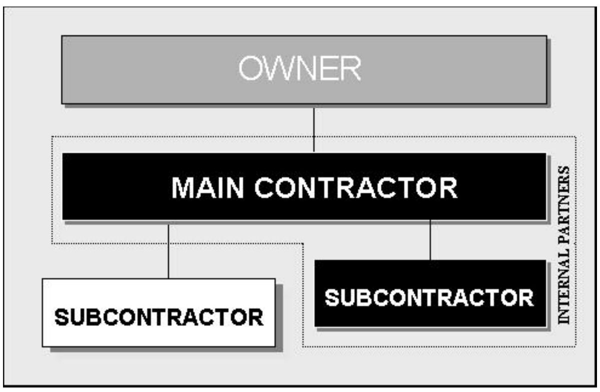

Figure 1: Converging project goals of the external and internal clients of an internal subcontractor (in the case of a construction corporation).

2.2 Procurement Dilemma

In many EU countries, the most common competitive bidding methods (related contracts that eliminate flexibility) and payment rules do still prevent from attaining any higher or broader goals beyond the project-level ones. This practice is coupled with one key task of a project manager, i.e. to finish his/her project within budget and, preferably, to maximize profits. Even in the focal corporate setting, a project manager is usually authorized to procure freely in order to attain the project goals and, thus, a corporate profit is beyond his/her direct concern. A cost-focused project manager drifts to select subcontractors and suppliers through a traditional competitive bidding, which means that an internal unit has to compete with external competitors. In addition, an internal unit is struggling both to fulfill the contract(ed wishes) of its client(s) and to meet its own financial goals, typically, by optimizing the resource uses and implementing everything within the necessities only. Thus, it seems that traditional project management and procurement behavior are together one of the root causes for a procurement dilemma, i.e. diverging project goals and contractual disagreements occur frequently also inside construction corporations.

2.3 Appropriate Internal Procurement

Appropriate procurement is dealt with **in the case of an internal client** as follows. It is assumed that an external client will first select one unit of the focal construction corporation as the main contractor. In turn, this main contractor faces a dilemma of using one or several “sister” units according to the corporation’s procurement policy. How is this internal client to choose the unit that is appropriate, competent, and trustworthy? Herein, only a few of Winch’s principles of resource-base selection are briefly applied to appropriate internal procurement. Typically, service contracts assigned in the early phases of a project, principally associated with design, face higher uncertainty than those assigned later, principally associated with execution on site. It is argued that also internal clients can consider **the four ways of procuring construction services** as follows [2] (Figure 2):

- An internal capability is maintained. This option involves a traditional choice of make or buy. In construction corporations, a true in-house service is regarded as a cost centre only.
- An internal subcontractor or supplier is appointed. In conditions where there is not enough information to allow the preparation of tender documents, the appointment of the internal party based on a list of references for having previously completed similar projects is a viable option. Appointment may also be used when the requirement to mobilize the resources for execution on site is urgent. Internal partnering may become very similar to appointment.
- Concours like procurement can be considered, in particular, concerning design services. The essence of a concours is that competition is based around the quality of a solution offered to a client’s problem, rather than its price.

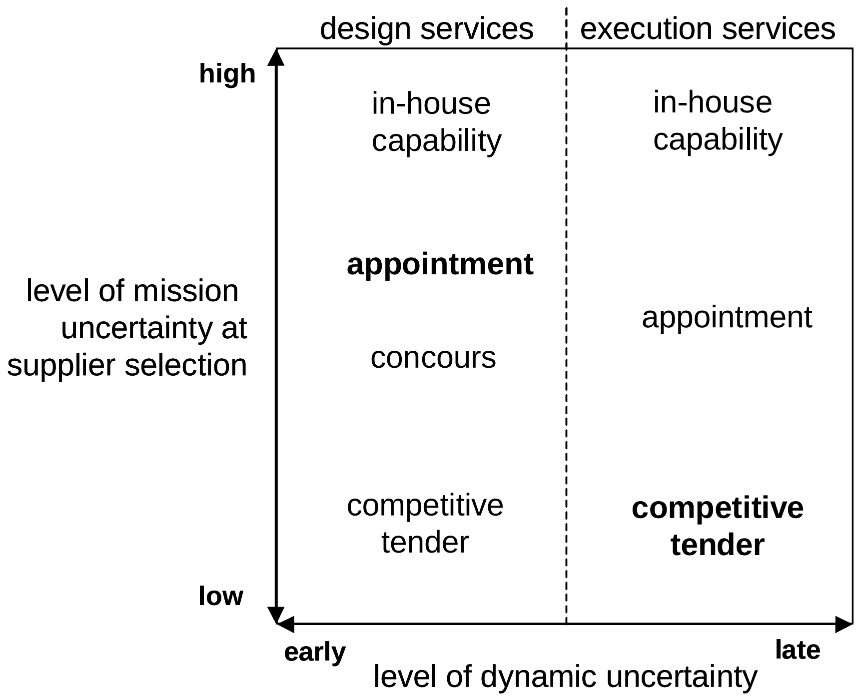

Figure 2: Alternative supplier selection methods (methods in bold are the most common per phase) [2 p. 102]

- Competitive tendering is a plausible basic option for selecting internal subcontractors or suppliers in corporate settings. It is distinguished by the formalization of both the selection process and the criteria upon which the final decision is made. However, competitive tendering often colludes with the idea of corporate synergy.

In broad terms, **the appropriate form** of resource base selection is a function of the level of uncertainty in the specification of the resources required at the time of selection. In particular, the level of mission uncertainty and the phase in the project life cycle are taken into account. [2] In addition, corporate management deals with an economic trend (high, boom – low, depression). During the low economy, it is more in the overall interest of a corporation that internal client-ship works. During the times of boom, it is evident that many possibilities exist to gain higher profits by procuring from supply and service markets.

2.4 Transfer Pricing

In a large construction corporation, management cannot monitor and control all the operation parameters of every unit. For this reason, corporations are organized as a set of divisions. Corporate management aims at coordinating divisions in ways that maximize the total profit. However, each division is still fairly autonomous and its head may have a freedom to take all the actions perceived necessary. Therefore, corporate management meets **a difficulty in evaluating and comparing division-specific performance**. In order to evaluate the performance of each division, several methods may be used for trying to measure the contribution of each division to the total profit of the corporation. One common way is to set transfer prices for internal services, goods, and outputs which are transferred from one division to another. The alternative **transfer pricing methods** are as follows. [3]

The market price is used as a transfer price, if there is a market for an intermediate service price. Often a transfer price is the market price minus the selling expenses. In **a dual price method**, the price that the selling division receives is not equal to the price that the buying division pays - and is usually higher. This mechanism generates a deficit, which corporate management sets off by an optimal transfer price and, hence, the optimal transaction volume, which in turn yields higher performance than other methods. Indeed, this method requires corporate management to be involved in a complex process of price-setting. **Negotiated transfer price** is reached between the relevant division managers. The advantage is that it preserves the divisions' autonomy. Its problem is the sensitivity of the outcome to the managers' negotiation skills. **Resale price** is used when a corporation purchases goods from internal units and resells them to external parties without any value additions being made. The arm's length price is calculated by deducting the gross profit from the resale price on the goods sold.

The cost plus method can be employed when there is a transfer of semi-finished goods between internal units, joint facilities are arranged, or services are provided. A cost base for both a comparable company and the one under review must be carefully analysed to ensure that the costs to be marked up are consistently defined.

Under **the profit split method,** the combined profits, which are the total profits from the controlled transactions, will be apportioned between the internal units based upon the relative value of the functions performed by each of the parties in the controlled transactions. Where two or more transactions are interrelated, it may not be possible to evaluate them on a separate basis. This method seeks to eliminate the effect of special conditions on profits by determining the division of profits that independent parties would have expected to realize from engaging in the transactions. The method can be used when there are no comparable transactions between independent parties. Under **the transactional net margin method**, the profit levels of similar firms serve as a guide to help determine the arm's length price to be applied to the transactions between two or more internal units. This method looks at the net profit margin relative to an appropriate base (e.g. costs or sales) that a tax-payer makes from a controlled transaction. [4]

In general, the use of transfer pricing is an effective way to allocate resources. In construction, transfer pricing seems to be used seldom. Herein, transfer prices are seen as a viable tool when the overall solution is sought for a procurement dilemma within construction corporations.

2.5 Corporation Synergy and Internal Partnering

The basic idea of **corporation synergy** can be described by an equation of 1 + 1 > 2. A construction corporation should be more profitable and effective than each of its divisions alone. It seems that **internal partnering** is one of viable ways of achieving corporate synergy. [5] Or, if you are not partnering internally - communicating with your colleagues, your members and customers; working as an integrated client team - then it is unlikely that you will successfully partner with external organisations. [6] There are many advantages to be exploited but cooperation cannot be taken for granted. In particular, internal partnering forced by corporate management is leading nowhere. Herein, a set of alternative ways of achieving corporate synergy is compiled. This initial list consists of ways coupled with **hard values,** i.e. benefits that are (fairly) easy to measure as follows (Table 1, the left column):

- Vertical integration consists of benefits available from managing contractual business relationships between internal units, with the goal of improving capacity utilisation, price realisation, and market access.
- Economies of scale can be achieved in several construction processes or functions both through increased project volume and internally benchmarked learning.
- Combined new business creation can be based on the utilization of know-how within several related units and the extraction of activities from these units and the establishment of a new unit as well as internal joint ventures or alliances.
- Shared tangible resources may involve achieving benefits through economies of scale and the elimination of duplicated efforts when physical assets and resources are shared, e.g. two or more business divisions are using the same manufacturing facility or research laboratory.
- In procurement, the pooled negotiation power of the corporation comprises the cost or quality benefits that can be gained typically from the bigger scale. It can also be extended to achieve many benefits through joint negotiations in various transactions with other stakeholders such as customers, governments, and universities.
- Coordinated strategies enable to reach for benefits that arise when the strategies of two or more businesses are aligned. For example, internal competition is avoided or reduced between units (e.g. allocated markets). Similarly, the competitive reactions of two units are coordinated against shared competitors (e.g. multi-point competition). [7]

In practice, the value of many operational synergic benefits is difficult to measure. The potential of **these soft values** is inherent in trust, avoidance of litigation, common values and rules, and the use of the outcomes of shared development projects (Table 1, the right column). Typically, shared know-how covers the benefits associated with the sharing of knowledge and core competences across the business portfolio. It may involve the sharing of best practice in certain business processes, the leveraging of expertise in functional areas, or the pooling of knowledge upon how to succeed in specific geographical regions. The know-how may be written up in manuals, policies, and procedures. In many cases, know-how is less formally documented, i.e. it is a dilemma of sharing the implicit, tacit ways that skilled managers master.

On the other hand, **an equation of 1 + 1 < 2** is not unknown. In construction corporations, there are typically internal obstacles that more or less prevent corporate management from mobilizing the huge potential of internal synergy and partnering. In practice, when internal units are unable to operate as a single project team, the resultant performance is probably lower than the level they would achieve under a contractual relationship between independent parties. Typically, the economies of scale are seldom achieved fully. In many cases, internal divisions are too autonomous. In other words, each division is simply focusing on the minimization of its costs and the maximization of its profit. [5]

Table 1: Alternative ways of synergic performance within a construction corporation.

MEANS FOR SYNERGY	
Hard values –benefits are easy to measure	Soft values –benefits are difficult to measure
• Corporate management • Economies of scale • Combined new business development • Synergic software • Shared human resources • Marketing (e.g. corporate brand) • Shared space (e.g. office building) • Procurement (incl. also personnel related procurement) - company telephone subscriptions - vehicle leasing policy - etc.	• Cooperative leadership • Organization • Joint training programs • Personnel rewarding methods • Shared customer relationships • Joint development teams • Shared know-how • Shared company values and policy • Trust • Avoidance of litigation

3. Construction Project Management (CPM) as a Core Competence

3.1 CPM as One of Corporate Competences

Herein, the management of a construction corporation with **a capacity to remain balanced** through the conflicting demands of the daily operations of the units is seen as a significant achievement. However, the strategic use of core competences does not end at the boundaries of the focal corporation. Rather, a corporation that uses core competences as an avenue to focus on growth opportunities must also focus on the external market. In targeted markets, the strategic focus transfers from keeping the corporate units directed toward a balanced system to retaining a cohesive focus in relationships with external clients. At the first level of this external focus is each external client. Paralleling a focus on internal activities, an external focus on clients is needed to pursue individual clients or projects that fit within a corporation’s strengths. Retaining this client focus is a central component of a core competence concept. [8]

Construction project management (CPM) consists of a management system and personnel's individual skills. The key is to place individual competencies into a proper pattern that builds the corporation into a set of dynamic units that are capable of moving beyond their current focus and limits. [8]

3.2 Characteristics of an Effective Project Manager

Traditionally, **CPM** is emphasized in terms of management systems. CPM focuses on planning, controlling, and other management functions. Luckily, the effects of human actions in project processes are being guided more and more. Even in projects with technical challenges, a technical competence is not the factor that makes the difference between effective and bad project managers. It is vital that a project manager is capable of interacting and communicating while managing project processes and tasks. Herein, **the five key characteristics** of an effective project manager are put forth as follows: (1) do explain complicated things simply, (2) do not panic in difficult situations but stay calm and find a step-by-step way forward with the CPM team, (3) do face up the problems, find out causes, and make proposals to remove them, (4) do let people know what is happening all the time, and (5) do keep in mind the big picture of the project environment while performing the project processes and tasks. The criteria for a project manager's success involve factors having to do with both a manager's characteristics and project results. The former are clearly split between the two aspects of management: production-orientation and people-orientation. [9]

3.3 Problematic Variation of CPM Skills between Internal Divisions

In general, **everyday CPM problems** on construction sites are well-known: too little time is spent on CPM both in planning and execution. This is resulting in difficulties in holding project schedule and budget. One barrier for fluent cooperation between contractors involved in the same project is a lack of common language, policies, and CPM skills. Communication and information sharing between the project manager of the main contract and the ones responsible for the subcontracts is vital. When CPM information is not shared effectively, a large number of problems are emerging on sites. Herein, it is argued that **the variation of CPM skills** is large also within construction corporations, between international divisions, in part due to variations in educational background and corporate culture. On the one hand, divisions assuming a role of a main (principal) contractor in projects are well equipped with CPM competences. On the other hand, divisions acting as subcontractors seem to possess more technical competences (e.g. HEVAC) and less CPM competences. A lack of CPM skills causes problems in coordinating schedules, communicating between project actors, and actually leading specialty works.

4. Case YIT

4.1 YIT – Finnish Multi-Service Corporation

YIT is the leading Finnish-owned construction corporation which is also engaged in extensive international operations. YIT offers technical infrastructure investment and upkeep services for the property and construction sector, industry, and telecommunications. In all these sectors, YIT's services cover the entire life cycle of investment objects (projects). **YIT Corporation** is managed along its four businesses: building systems, construction services, services for industry, and data network services. The corporate organization consists of four subsidiaries, respectively. In tens of projects, **the subsidiaries** of YIT are acting together through contractual relationships. Typically, Construction Services Oy operates as a main contractor and Building Systems Oy (with HEVAC services) as a specialty subcontractor. In addition, the role of Data Networks Services Oy is growing in internal contracting in the future.

YIT is **a project-driven organization**, i.e. various projects (contracts) are the most important sources of revenues. (Construction) project management is thus seen as a core competence for YIT. Each project involves several contractors in these project-driven businesses. Each contractor is dependent on each other's schedules and milestones. So it is assumed herein that effective cooperation between contractors requires the same kind of (C)PM skills (Figure 3).

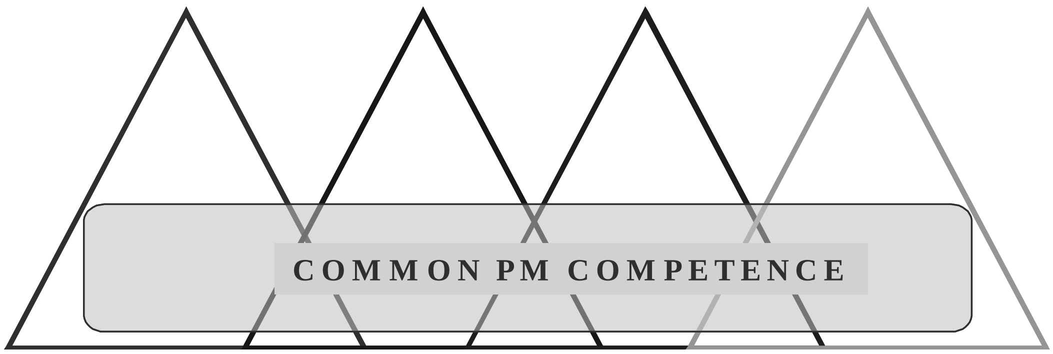

Figure 3: YIT's four businesses with their distinct spearhead competences and (C)PM competence as a common core competence of corporation

4.2 Questionnaire Survey on CPM Training Needs

Within YIT, **the questionnaire survey data** is being collected on a regular basis to get better understanding of the need of CPM training in the future. A questionnaire has certain advantages compared to an interview, e.g. hundreds of people can be reached at a relatively low cost. Respondents are given a possibility to answer anonymously. CPM is divided into 17 areas based on the literature and the accumulated experience within YIT. The CPM areas are considered as rational internal training modules (Table 2).

Herein, it is reported on the results of the recent surveys among the personnel who participated in YIT's internal CPM training during the last quarter of 2004 and the first quarter of 2005. The 149 respondents include project managers, project administrators, cost estimators, and middle managers in both the corporate offices and the regional offices in Finland. The questionnaire included one major question: **In what kind of CPM training are you willing to participate in the future?** Overall, the results are a bit surprising, i.e. 65 % of project personnel desire for deeper knowledge on project cost management, nearly 50 % time management and scheduling, and nearly 40 % contractual matters. Thereafter, project planning, design and engineering management, and project handover process are also highly scored (Figure 4).

In terms of **YIT's three businesses**, 46 % of the respondents belong to Construction Services (CS), 39 % Building Systems (BS), and 15 % Data Network Services (DNS), (Figure 5). Within both the CS and BS, the CPM interest of the personnel is fairly high. The two distributions are surprisingly near each other despite a few differences (e.g. design and engineering management). Broadly, the high needs for CPM training seem to indicate that some past conflicts of joint projects may have been caused by a lack of proper CPM culture. The lower rates of the CPM interest within DNS may be due to the different nature of this third business.

Table 2: Seventeen modules of CPM training within YIT.

1. Project Time Management and Scheduling	10. Management of Life-Cycle Issues
2. Project Cost Management	11. Design and Engineering Management
3. Contract Management	12. Environmental Management
4. Risk Management	13. Cost estimating and bidding/tendering
5. Procurement and Logistics Management	14. Customer Relations Management
6. Project Planning	15. Project Handover Process
7. Internationalization and Language Skills	16. Safety and Health Care
8. Site Management and Quality Management	17. Leadership training
9. Project Data Management and eService records	

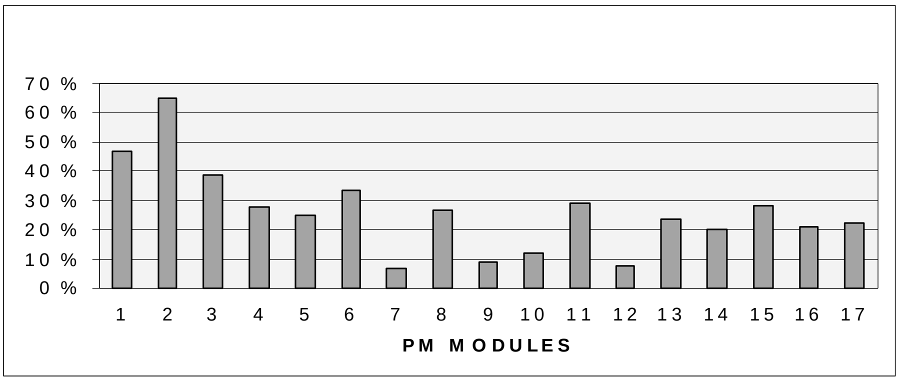

Figure 4: Total rate of interest in CPM training modules within YIT around a turn of 2004/05.

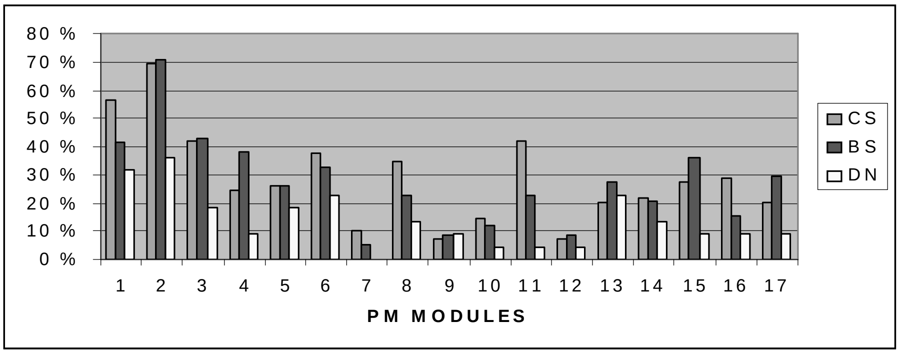

Figure 5: Rates of interest in CPM training modules in YIT's three divisions around a turn of 2004/2005

5. Conclusions

In this paper, the two issues within effective corporate management are addressed, namely, managing a corporate synergy despite many barriers and enhancing CPM skills up to a synergic core competence of a construction corporation. In principle, corporate management should thrive on **corporate synergy** especially when economy is down. In turn, corporate management may allow the outreaching for higher profits during booming periods. The corporate goal is to grow the synergic businesses, not only to share the contracted total profit. In the case of YIT, a potential of corporate synergy is high due to the relatedness of its four businesses. However, this kind of business portfolio is vulnerable to a risk of two businesses going down at the same time at least in one of YIT's primary markets.

In concepts of **partnering**, cooperation and the search of common goals are praised. In practice, real project life is more complicated than these concepts let us assume. "Project (wo)man" operates fundamentally with her/his own interests and this tendency needs to be taken into account when planning internal partnering and synergic joint projects. For example, project goal-setting can be done jointly by the internal project managers. No single project manager (team) should be left alone with less (when her/his/their colleagues are gaining more) without the compensation in one form or another. At the end of the day, other ways of seeking after higher profits through corporate synergy, i.e. ways that are not directly related to projects may remain obscure in the minds of CPM teams.

For construction corporations, **some conditions of effective internal partnering** are suggested as follows. Every partner (unit) acts on a truly profitable basis. Market price seems to be the only encouraging pricing method. Negotiated price is also possible. The competitiveness of each unit needs to be measured also against the direct external competition in terms such as quality/price ratio on an annual basis. An "open book" cost model and a flexible, open frame contract are used to create and maintain trust. Some elements of internal competition are preserved. Through a chain of projects, cost efficiency, time-saving scheduling, and team spirit should be advanced. In addition, the internal partners need to act as the seamless front in the eyes of primary external clients (owners). In the case of YIT, the principal contractor and the HEVAC contractor are obviously aiming at the flawless contract fulfilment with each external client. In the future, these subsidiaries could analyse a potential of the resale price method and the one of the profit-split method.

Finally, **CPM** is herein advocated as one of core competences within construction corporations. In practice, the effectiveness is highly dependent on personnel's CPM skills. Also the enhancement of high, balanced CPM skills across the corporation is one of the conditions for profitable synergy. [10] In the case of YIT, the survey results indicate that the personnel are aware of their needs for higher CPM skills. Obviously, one of the ways to advance CPM as a synergic core competence involves the hands-on training and learning by accomplishing more demanding CPM tasks under professional guidance.

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Construction Project Cost Management Tools In-use: a UK Perspective

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Abstract

The effective control of a construction project budget from project inception to completion and occupation is one of the primary tasks of any organisation employed to deliver construction project management services irrespective of the projects actual global location. This paper sets out the key issues and problems involved in the delivery of this service to construction industry clients in the UK.

The main features of a project cost management system are identified in the paper before it addresses the principal problem areas of initial cost budget or baseline setting and project cost performance management. The literature reviewed identifies the potential project management tools that can be used to contribute to the management of each of the principal problem areas. The paper reports evidence collected from previous data collection exercises with practitioners based in the UK that allows current practice to be illustrated. The data on project performance measurement reported in the paper have been collected by mailed survey from one hundred and fifty two organisations involved in delivering project management services in the UK in 2004. The survey achieved a 42% response rate and its results raises questions about the claimed benefits of a bespoke project cost performance management tool termed as earned value analysis. The paper concludes by considering the direction of future construction related project cost management education and the role that can be played by professional institutions to promote change in practice.

Keywords: project management, cost budgeting, cost performance, tools in-use

1. Introduction

The UK construction industry, like others around the world, has a reputation for delivering its projects over budget. The latest high-profile example of this phenomenon is the new Scottish parliament building that, when completed, was nearly ten times over its originally forecasted budget. The Fraser Report [1] on the public inquiry into the project highlighted, amongst other issues, that a poor quality feasibility stage budget estimate and a poor level of cost control provided by the construction organisations involved were to blame for general dissatisfaction with the project. Other high profile instances of such poor performance were identified by Jackson [2] and include projects such as the British Library, Portcullis House, and the Welsh Assembly building. Jackson [2] reports repeated survey work by HM Treasury (1995), the Construction Clients Forum (1997) and the DETR (2000) that have shown clients to be generally dissatisfied with the service provided by practitioners involved in the provision of building project budget stage cost advice and subsequent construction phase cost performance management processes. Therefore the issue of poor project cost management is an ongoing problem for the construction industry and its clients. It is now timely to investigate the processes involved in this business advice function and determine the current state of the art in terms of cost control tools in-use so as to ensure clients' are better able to achieve value for money from their inter-actions with the UK construction industry.

This paper is structured to provide a review of relevant previously published material before it goes on to present the results of data collection exercises with UK based organisations that have enabled a snap-shot of current practice to be established. The paper concludes by considering the direction of future construction related project cost management education and research and the role that can be played in the development of this business service in the UK by professional institutions.

2. Context

Green and Simister [3] cite Hammer and Champy's (1993) definition of a business process as being, "a set of activities that, taken together produce a result of value to the customer". Currently, the processes used in the construction industry to deliver its clients' projects are being subjected to a period of re-design and accelerated change to ensure that they deliver greater value for money. Increasingly the assessment of value-for-money is being considered from a broader perspective that includes social, environmental, and economic features [4]. Winch and Carr [5] maintain that this the generation and communication of reliable early stage project budget estimates and the implementation of effective project cost control measures that are related to the construction and commissioning of building assets are sub-processes within their standardised project related process map. As such it has been asserted that industry would benefit from their further development and as a result of actually using the output of research. Similarly, the generic design and construction process protocol developed by Kagioglou *et al* [6] also indicates that such business activities would be considered as a sub-process within their model, namely the feasibility stage of a project's pre-construction cycle and the project's construction cycle. It can be seen that effective construction project cost management processes are a fundamental component in any project's value appraisal system.

Kerzner [7] and Lock [8] amongst others, identify the principal components of a construction project's cost management process as being; the establishment of a realistic budget, the determination of a system of work authorisation and release, the collection and analysis of timely performance cost data across the project lifecycle, the establishment of effective cost change management systems, and the creation of meaningful cost account and variance reporting mechanisms. This broad analysis has a strong relationship to the main components of a cost control process set out by the Project Management Institute (PMI). The PMI indicates in its body of knowledge (BoK) that its cost management processes are concerned with creating what it terms as being a project cost baseline as well as managing changes to the cost baseline. For instance the PMI [9] indicates that the main features of such a project cost control system need to address cost inputs, the tools and techniques used to assess performance and the cost reporting mechanisms used to provide timorous information to decision makers. There seems to be broad agreement on the principal components of an effective project cost management process. As a result this paper addresses two features of any cost management system namely, the building project baseline budget estimating processes and then secondly, the tools and techniques used to assess the cost performance of the project during its production phase.

2.1 The Building Project Baseline Budget Estimating Process

Skitmore *et al* [10] considered pre-tender budget price estimates which within the construction industry form the project cost baseline position and asserted that the ‘dominating presence of uncertainty in the construction process militated against the production of accurate estimates by numerical analysis alone’. As a result building project budget estimating must involve a mixture of calculation and judgement. In order to develop an understanding of how building project budget estimates may have their quality enhanced it is necessary to identify the processes involved. Bowen [11] developed a communications based theory of building project price forecasting. That model was based on the Shannon and Weaver’s linear or process model of communications and it indicated a major divide in the process between the phases of forecast formulation and forecast transmission. The formulation phase of this theoretical process was divided into iterative cycles of investigation and application. There remains a need to fully investigate the construction project budget estimating process as a means of addressing the performance gap of practitioners that can result in the incidences of inadequate business services indicated above in terms of poor quality project cost advice. What is acknowledged is that an essential part the building project budget price advice process is the selection and use of the most appropriate tools or models.

Repeated surveys by Fortune and Hinks [12] and Fortune and Cox [13] have established the ‘state of the art’ in terms of building budget estimating models in actual use in the UK. In general these large-scale empirical studies have found that there were over twenty models currently in-use. The results of the surveys show that in general terms the paradigm shift towards the newer non-traditional models, called for by academics such as Brandon [14], has not been generally achieved. What can be seen is that the results of successive waves of the prevailing engineering or product or tool centred research that has been funded by government grant has not been found to be useful in practice. Examples of such an engineering or product-related research paradigm are the knowledge-based models, the regression models, the whole life cost models, the fuzzy logic and neural network models, which have been developed over a period by academe for the industry to use. The repeated surveys show consistent evidence of low levels of usage of such models and the continued overwhelming use of manual, deterministic models that have been found to formulate inadequate cost advice over a period of time. Latterly there has been much research effort directed to the development of models or tools that can take account of the sustainable impact of proposed projects. The survey work reported in Fortune and [13] again reveals that such tools have not yet been adopted for widespread use in practice. Given the slow rate at which changes in practice can be achieved in the construction industry then it is too soon to suggest that these new models that address the assessment of sustainable impact of projects have been abandoned by practice. However, the same cannot be said for the paradigm change called for by Brandon in 1982. The results of the research reported above indicate that such a paradigm change has now been abandoned by practice and as such this finding will have implications for the education and training of future professionals.

2.2 Construction Phase Cost Performance Tools In-use

Lock [8] considers that the emphasis given to project management cost control is unique in the UK construction industry due to the existence of quantity surveyors and detailed bills of quantities. As a result the standard tools suspected as being in use in the construction industry to manage the construction phase project cost performance management process included milestone monitoring, variance analysis, valuation analysis and standard s-curves. Milestone monitoring uses predefined stages or phase completion of projects as the trigger mechanism for contract payments to be made. Lock [8] indicates that the data required to set up the milestone approach to construction project cost control are the project schedule or programme and the budgeted cost of the activities required to be completed to achieve the milestone. A potential drawback to the use of this approach to production cost control is the re-active and delayed nature of information availability. The cost information generated by this technique takes no account of the actual work achieved on site and assumes one hundred per cent efficiency of site operations. However, Abdomerovic *et al* [15] do acknowledge that the great advantage of using this approach is its simplicity and resource efficiency in operation.

The use of variance analysis as an approach to construction phase project cost performance management acknowledges that changes are endemic on construction projects. Ronald [16] asserts that this approach can be used to highlight the inefficiencies caused by such changes in terms of their cost consequences on the project's baseline budget figure. Pilcher [17] argues that this technique is well suited to construction project production phase cost control due to the prevalence of bills of quantities but nonetheless it is generally accepted that such a system is itself costly to set up and does not focus on overall project costs. The valuation analysis approach was asserted by Walker and Wilkie [18] as being the most popular in-use. This approach calls for the practitioner to carry out valuations of the work executed on the project at the end of a given period. Such an approach provides data for the contractor to use in benchmarking performance against payments received for each of the resource centres required for project production, namely. labour, materials, plant, and sub-contractors. However, Pilcher [17] points out that the approach can lead to inaccurate data and that often contentious items are excluded from timorous payment although resource has been expended in their execution. In addition this approach does not facilitate the forecasting of overall project costs. This is a claimed advantage of the S-curve approach to providing construction phase project cost performance management. This approach provides data against the formation of standard cost curves for the project. Such curves are usually s-shaped and are derived from data from previous similar projects. Control can be achieved by plotting actual expenditure against budgeted costs on a periodic basis. Galley [19] pointed out that the main flaw with this approach was that the s-curves produced could indicate performance gaps but on their own it is not possible to say whether the project is behind or ahead of the planned schedule.

Wake [20] asserted that earned value analysis was an approach that was developed to overcome the combined problems of the conventional approaches to project cost management during the production phase of projects. Support for this position comes from the PMI which indicates that the main tools available to project managers looking to control project cost performance in general include tools such as performance reviews, variance analysis, trend analysis and earned value analysis. Of the tools indicated by the PMI BoK [9] as being generally available it was asserted that it was *"earned value analysis (EVA) in its various forms is the most commonly used method of project performance measurement"*. EVA is based on the combined work breakdown structure (WBS) and the organisational breakdown structure (OBS) for the project being constructed being drawn together so as to develop a task responsibility matrix (TRM). Winch [21] determines that such an analysis can facilitate what he terms as a cost control cube to be formed and that such an approach provides a disciplined framework for the organising, planning, budgeting, measurement monitoring, and reporting of a project's performance.

Fleming and Kopplemann [22] asserted that if EVA was to be implemented efficiently then it was best employed from the earliest stages of the project's development. If this was the case with the use of EVA on construction projects in the UK then it would be necessary for consultant quantity surveyors and other built environment professionals to develop appropriate skills to ensure its application. However, Baker [23] identified that many such practitioners see EVA as being a complex process, which is shrouded in terms, acronyms and formulae that can be intimidating to the uninitiated. On the other hand sources such as Webster [24] asserts that the use of EVA provides a uniform measure for reporting progress on a project and a consistent method of cost performance analysis. The benefits of using EVA as a tool for the measurement of project production cost performance was also given emphasis by its inclusion within the BS6079 and the PMI BoK [9]. Such sources maintained that the use of EVA would allow a more disciplined approach to planning and risk management, as well as providing good programme visibility, and encouragement to the objective and quantitative performance measurement on projects. It was asserted that such an approach would enable timely indications of problems to be developed which would facilitate a more reliable prediction of programme cost schedules.

As this paper is concerned with establishing the tools currently used in practice to manage construction phase cost performance it was now resolved to conduct a questionnaire survey amongst construction project management organisations in the UK. It was determined that the questionnaire should gain measures to determine the current usage of the tools indicated as being available to practice in the literature reviewed above. Accordingly a sample of one hundred and fifty two organisations drawn from both consultant and contractor based construction project management organisations was constructed from the 2003 yearbooks of the Association of Project Managers (APM) and the project management faculty of the RICS. The questionnaire was administered by surface mail and good practice ensured the questionnaire was appropriately piloted before dispatch. Similarly good practice required a covering letter and a stamped addressed return envelope to be included and each form had its own unique reference number that facilitated follow-up in the case of non-response. As a result the survey attracted a response rate of 43% which was considered adequate enough to provide meaningful data.

3. Questionnaire Survey – Results, Analysis and Discussion

Responses were evenly divided between those organisations that classified themselves as being a contractor based organisation and those organisations that classified themselves as being a consultant organisation and these classifications were later used as the principal variables to analyse the data. The first question in the questionnaire asked the respondents to confirm their involvement with construction project management. The results of the question showed that none of the respondents to the survey indicated that that they had no involvement in construction project cost management. This was essentially a checking question that provided data that confirmed the appropriateness of the sample and an indication of the validity of the results. Respondents were then asked to indicate the usual point in a project's lifecycle that they were engaged to provide their project cost management services. The results of the survey have been summarised below in Figure 1. It can be seen that generally respondent organisations start to provide their project cost management services during the pre-construction phase of a project's delivery cycle.

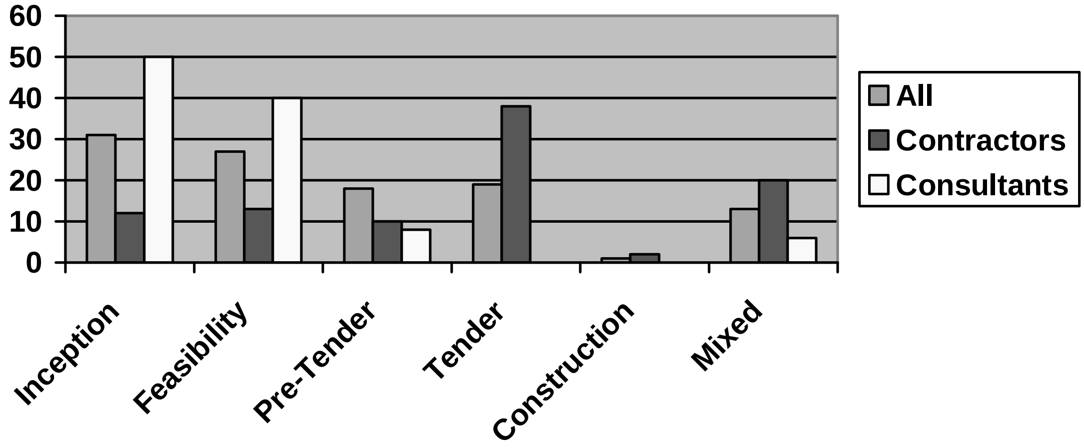

Figure 1: Project Cost management services and the project lifecycle

Figure1 shows that there is difference in approach between consultant and contractor based organisations that responded to the survey. It can be seen that contractor based organisations are more likely to start to provide project cost management services to their clients at the tender and construction phases of a project's lifecycle which would reflect the prevailing procurement pattern in the UK. As the changes in the operational practices of the UK construction industry alter following the calls for change made in recent UK government reports then it is likely that project cost management services will be delivered from project inception to completion and occupation. This change in practice should help UK construction industry clients to achieve better value for money from their business investment decisions.

Respondents to the survey were then asked to indicate the project cost control system they were using in practice. Figure 2 provides a summary of the results obtained and it shows that in general the most popular method is the conventional monthly valuation analysis (70%). The other techniques such as milestone monitoring, variance analysis, s-curves and earned value analysis were used by an approximately similarly sized minority of the respondents to the survey (15%).

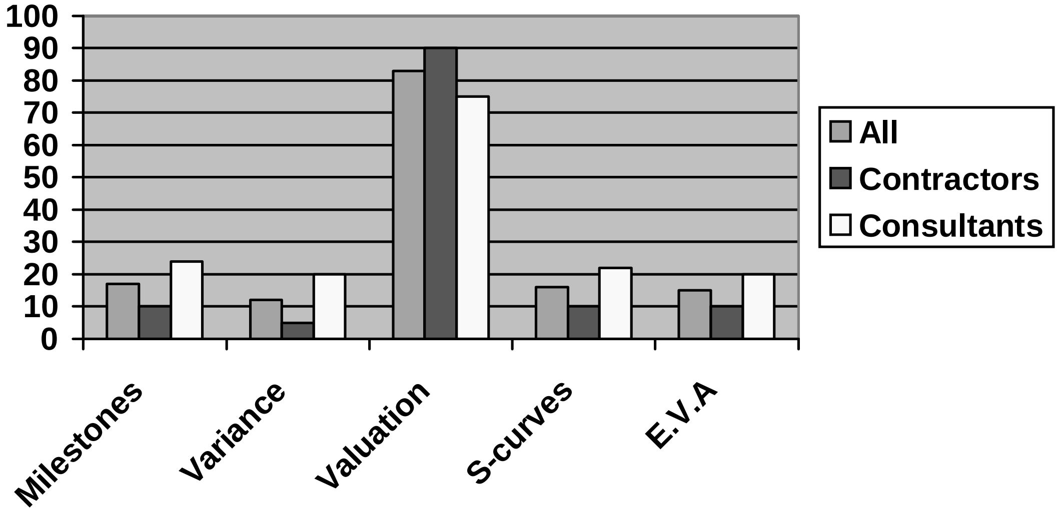

Figure 2: Types of cost control system in-use

This result indicates that the conventional approach to project cost control is still in widespread use despite the claimed advantages of the new wave tools such as earned value analysis. The literature reviewed above indicated that of the newer techniques that were available it was earned value analysis that offered the most to project mangers involved with the provision of cost performance management services. The next question in the questionnaire explored the reasons why the respondents to the survey were not making use of earned value analysis as a cost performance measurement tool. Firstly the respondents were asked to indicate whether they were actually aware of the existence of earned value analysis as a tool to use in project cost control. Figure 3 indicates that the majority of respondents (73%) claimed that they had no awareness of earned value analysis. It can be seen that there was some difference between the consultant (80%) and contractor (65%) organisational types responding to the survey.

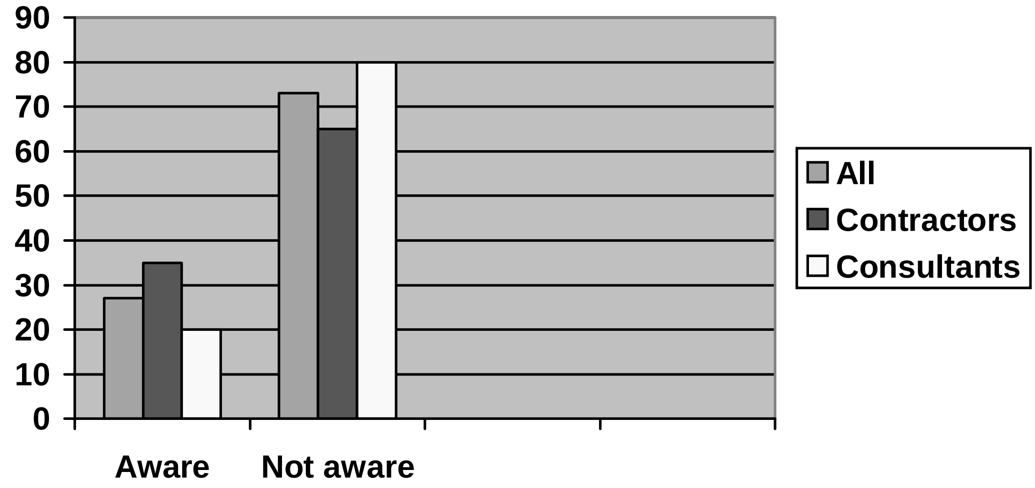

Figure 3: Level of awareness of EVA as a cost control too

This result indicated that contractor based respondents are more likely to be aware of EVA but as revealed above a concern must be that such organisations do not enter the project lifecycle under the tender and construction phases of a project's lifecycle. This late entry to the project was acknowledged to be a real disadvantage in terms of using EVA to its optimum effect. This result also confirmed the finding of earlier work undertaken by Brandon [25] which asserted that earned value analysis was little used in the UK construction industry due a lack of commercial awareness of its potential benefits. This was surprising to Brandon [25] as he pointed out that earned value analysis was indicated as being the preferred tool for project cost control in key documents such as BS6079. However, an earlier survey reported by Fortune and Lees [26] found that in the UK the majority of project managers did not adopt BS 6079 as the co-ordinating vehicle for their project documentation.

The respondents that indicated that they had made use of EVA as a technique to control project cost performance were then asked to give their assessment of the technique in-use in terms of the accuracy of the data it generated and the usefulness of the information it provided. Figure 4 shows that only 31% of respondents that had used EVA found that it was able to generate more accurate data than the other more conventional methods of cost control.

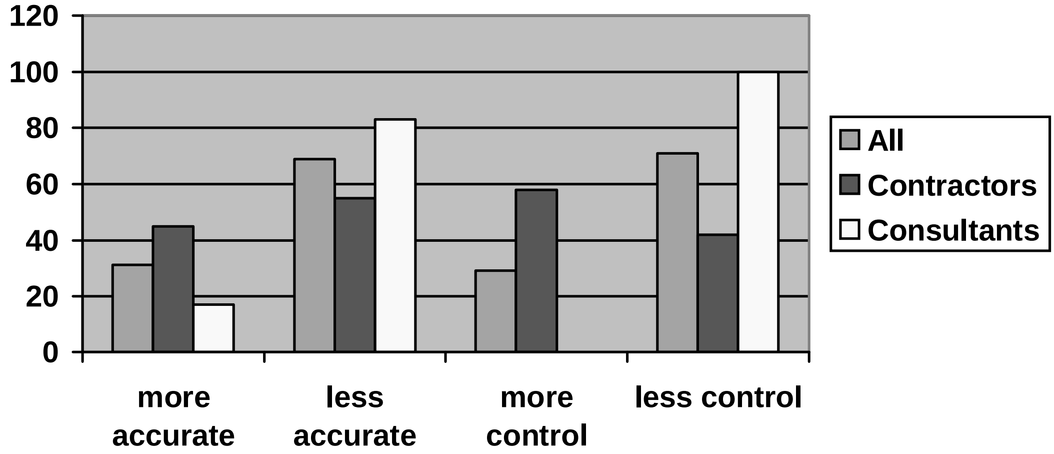

Figure 4: Capability of EVA to generate more accurate data and exercise budgetary control

The results show that there was some difference of opinion between the respondents to this question that were located in consultant and contractor based organisations. It can be seen that only 15% of respondents in consultant and 45% of respondents in contractor based organisations agreed that EVA was capable of generating better budgetary control for their projects. This difference in response was further tested using chi square test and it was found that the difference was not statistically significant. Nonetheless the overall result of this question is in direct contradiction of the finding found in the work of Fleming and Kopplemann (2001) who asserted that the use of such a tool enabled practitioners to generate more accurate data for use in project cost control. Figure 4 also shows that only 24% of respondents that had made use of EVA considered that the technique enabled them to exercise greater levels of project cost control than the other more conventional tools that they had previously used. The results of this question call into question the claims of Wilkens [27] that EVA was a tool that was better than other techniques at keeping projects within established budgets. The results shown in Fig 4 provide clear evidence that practitioners on the ground have not found that newer project cost control techniques such as EVA provide real improvement over their tried and trusted techniques. In such circumstances it is not surprising that EVA is not in widespread use in providing construction project cost management services to UK based clients.

The respondents to the survey that indicated that they had not yet used EVA as a tool for project cost management were asked to indicate the reasons why they had not as yet adopted the method as a tool for use. Figure 6 shows that of the reasons listed, namely cost to set up and maintain, high satisfaction levels with existing tools, and unfamiliarity with the technique. Of the options listed it was found that general unfamiliarity with the approach was the main reason for its non-adoption (58%) and that 30% of this type of respondent felt that their more conventional cost control technique was providing satisfactory levels of service.

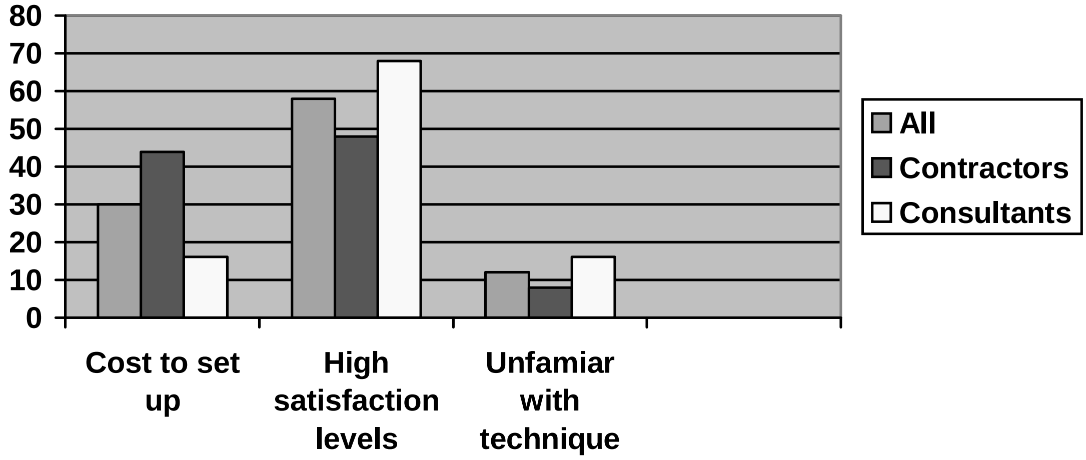

Figure 5: Reasons for non-use of EVA as a cost performance tool

Such results confirm the general level of response generated in response to earlier questions in the survey and provide a measure of internal consistency within the questionnaire which generates confidence in the survey' results.

4. Conclusions

The survey work reported in this paper indicates that the newer tools and techniques advocated by academe for use in UK construction industry for the delivery of project cost management services have so far been rejected. This finding applies equally to the tools used to generate the initial project budget and the tools used to provide data for effective construction phase project cost control. The paper focused on these two key aspects of project cost control as being central features that construction related project managers needed to get right to ensure the effective delivery of project cost management services. The finding in relation to the tools used to set the initial budget for the project is of concern given that academe has been calling for a move away from the conventional tools in-use for over twenty years. Such continued non-use of tools such as regression analysis, probabilistic models, neural models, and neuro fuzzy models raises questions about the effectiveness of previous research paradigms in this topic area. The non-use of sustainable assessment models for projects and the newer construction phase cost control tools such as milestone payments and earned value analysis do not as yet raise the same questions. In terms of the widespread non-use of sustainability models and EVA it is probably to soon to conclude that they have been rejected for use by practice. Rather it points out the time lag that can exist between academe and practice in terms of performance advancement. Nonetheless the survey rejects the findings of other non-construction focused investigations and helps make the case for the approaches adopted in construction related project cost management services to be seen as being non-generic in nature. The lack of awareness of the newer project cost performance tools such as EVA calls into question the effectiveness of the curricula driving courses of formal and informal education. Such lack of awareness also flags up to the relevant professional institutions the need for greater emphasis to be given to this topic in terms of CPD type training programmes.

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Section II

Production Processes and Control

Introducing Last Planner™: Finnish Experiences

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Abstract

The Last Planner method1 represents a radically different manner of controlling production in construction. Even if its benefits are widely observed, it is also a common observation that the introduction of the Last Planner method to a site, into a company or into a country is not an easy and uncomplicated task. This paper reports on the experiences and lessons gained during the introduction of the Last Planner to Finland. A simplified explanation of Last Planner is presented. The experiences and lessons gained are contrasted with those presented in prior literature.

Keywords: Last Planner System, production control, implementation

1. Introduction

During the last few years, Last Planner has been implemented systematically in a number of contracting companies in different countries. The results have been most encouraging in regard to productivity, duration and safety. The Last Planner method represents a radically different manner of controlling production in construction. Even if its benefits are widely observed, it is also a common observation that the introduction of the Last Planner method to a site, into a company or into a country is not an easy and uncomplicated task.

The authors undertook to implement and disseminate this method in Finland since 2003. The goal of this paper is to report of the experiences gained.

The paper is structured as follows. First, the salient characteristics of Last Planner are recapitulated. Then, the first Finnish pilot project is presented, and after that, the learning gained in the subsequent projects. Then, the Finnish manual on Last Planner is briefly described. Next, the simplified explanation of Last Planner is discussed. After considering the present status and prospects of Last Planner in Finland, the concluding remarks are presented.

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[1] Last Planner is a trademark of Lean Construction Institute

2. The Last Planner System of Production Control

Last Planner, developed in the United States in the 1990's [1] [2] [3] is a method for production planning and control on construction sites. Last Planner addresses short term planning and control of operations. The goal is to ensure, through different procedures and tools, that all the preconditions of a task exist when it is started, that the task can be executed without disturbances, and that it is completed according to the plan. The share of tasks completed as planned is monitored on a weekly basis. The reasons for lack of completion are investigated. By influencing the reasons found, an increase of the degree of realization of weekly plans is sought. One further element of the Last Planner method is rolling look-ahead planning, in which the preconditions for tasks are made ready for the next 4-6 weeks. The goal is to maintain a sufficient backlog of ready tasks.

Last Planner production control is based on a new theoretical foundation [7]. Production is conceptualized as flow, leading to an emphasis on reduction of uncertainty and on stemming the penalties of uncertainty. The primary concern of weekly planning is not merely, which tasks should be started according to higher-level plans, but also, which tasks can be started regarding their preconditions. The execution of weekly plans is seen to be based on a conversation, where the responsible person commits himself to the completion of a task as planned. Control is positioned as a starting-point for continuous improvement.

3. The First Pilot Project

The first Finnish pilot project in introducing Last Planner took place in the year 2003. Four major construction companies, YIT Rakennus Oy, Skanska Talonrakennus Oy, NCC Rakennus Oy and Rakennusosakeyhtiö Hartela, each with one project and site took part in the training and testing project. Testing and training lasted for six months on each site.

How did the project go ahead? A detailed theoretical explanation was prepared and it was initially used in training. However, a simplified way of explaining and justifying the Last Planner method for construction professionals was also developed and it turned out to be more effective in training. The training time could be reduced, and justification of the method to managers was made easier.

Training started with a one day teaching and discussion session. About twenty persons involved in site management took part in learning the basic principles of Last Planner and discussing the practices which were to be tested. We also wanted to learn what were the major reasons for difficulties of production planning by making the participants to choose among the following reasons:

- Managing concentrates in control (monitoring) and forgets “making ready” the pre-requisites and resources required to do the work.

- Planning isn't systematic, but instead it depends only on the ability, skills and motivation of the managers in charge.
- Planning is considered to be same as drawing a schedule.
- The capability of the planning system is not measured.
- When targets and plans are not met, the reasons are not sought and analyzed.

All of the possible answers above were chosen. This shows clearly that the problems of production planning are wide. Solving them requires understanding of the theories, too. In this regard, our one day of training was just a start.

In our site testing we concentrated in

- Making weekly plans, where tasks don't have any constraints and the pre-requisites are taken care of.
- Getting participants to make commitments in the weekly plans.
- Checking the PPC (percent plan complete).
- Arising interest and starting systematic look-ahead planning, where the pre-requisites for the tasks to be done in the next couple of weeks are realised.
- Finding the reasons and explanations why the weekly goals were not met and also trying to learn from the past to prevent similar difficulties recurring in the future.

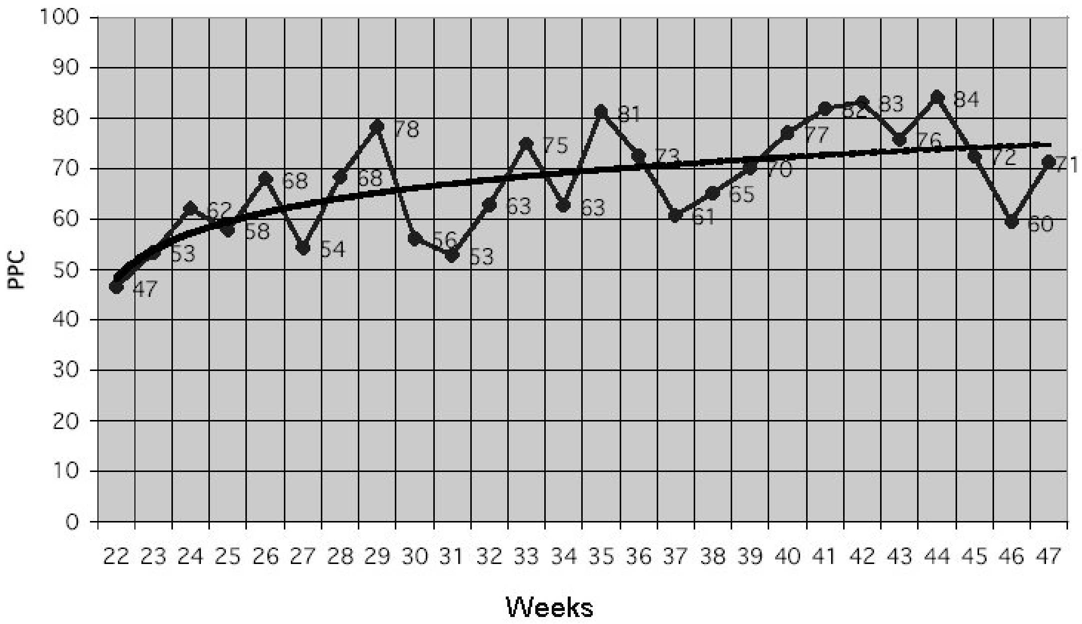

Figure 1. The development of the PPC as an average on all four test construction sites in Finland [8].

The results of the introduction of Last Planner on four domestic construction sites are parallel to those abroad. The PPC got better rising from the average of 47 % to over 80 % before our second day of teaching (Figure 1). After having a day of feedback and benchmarking the intensity of planning and following the Last Planner method probably somewhat dropped.

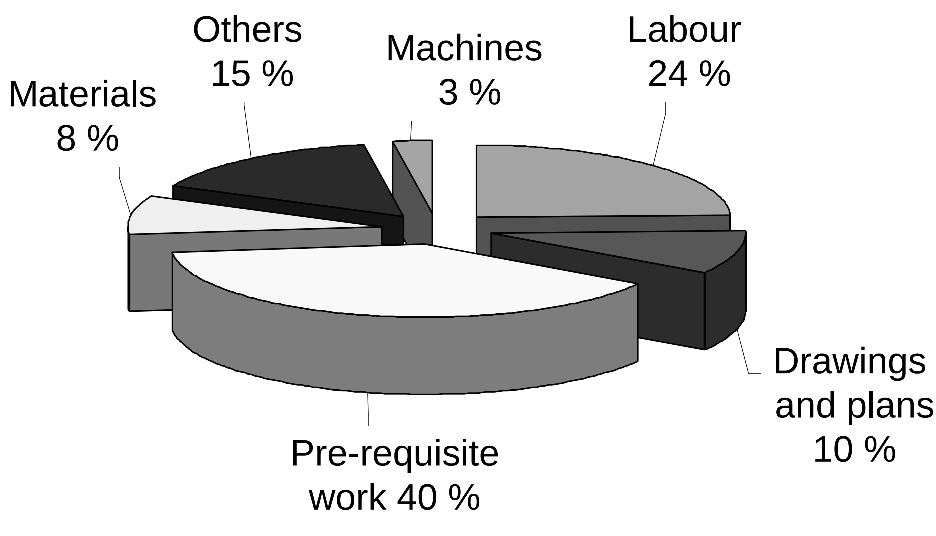

Figure 2 The reasons for non-completion of tasks in weekly plans in the Finnish experiment [8].

The reasons for non-completion of weekly tasks were not those expected. The two biggest groups of reason were pre-requisite work and the labour (See Figure 2). Our test showed that maybe too easily we are looking someone from the outside to blame. Drawings and plans are often said to be the reason for delays and changes. In our test only ten percent of weekly plan failures were due to drawings and plans.

The quality and degree of realization of weekly plans clearly increased. The site personnel considered the method useful especially regarding that the quality level of task ready-making increased and that getting tasks completed in one pass became easier. The quality and quantity of tasks could be controlled, when tasks were clearly defined. This made it easy to measure the productivity of a particular task and its variation. The amount of ad hoc work decreased. The weekly planning sessions made coordination between tasks, workgroups and contractors easier. Also, having reasons for lack of task completion was experienced useful, and it was seen to contribute to the elimination of problems.

Taking the positive results of the experimentation and the foreign cases into account, the implementation of the Last Planner method was recommended in short term production control on construction sites in Finland.

4. Subsequent Pilot Projects

After the first experiment and the report [8] written about it, interest to Last Planner arose among the construction firms. Similar experiments as in the pilot project were conducted in a couple of firms. Some firms made experiments on their own. In the following, related observations and findings are presented.

Phase planning was tested in a middle-sized reconstruction firm. They wanted to get the HVAC-contractors to make commitment to a tight schedule. This was established by making the participants and performers to know each other and collaborate in dividing the building in to parts which can be the basis for phase planning. After that schedules were made in co-operation and committing to one another. A tight four month plan was made to be the basis. Even a great number of changes, as in reconstruction so often, didn't mess up the phase plan because the promises and commitments were so clear and the tasks due to changes were fitted in with the motivation of keeping the due dates.

The problem with planning ahead seems often to be caused by a failure to plan ahead. Very often the tasks just seem to come from nowhere and we have to start them without all necessary prerequisites. This produces problems in quality, safety and productivity. Although for some managers in Finland it seems to be hard to believe that it is more efficient to wait and make things ready than to just go ahead, lookahead – planning became reality in several projects when a simple worksheet was taken into use (see Figure 3).

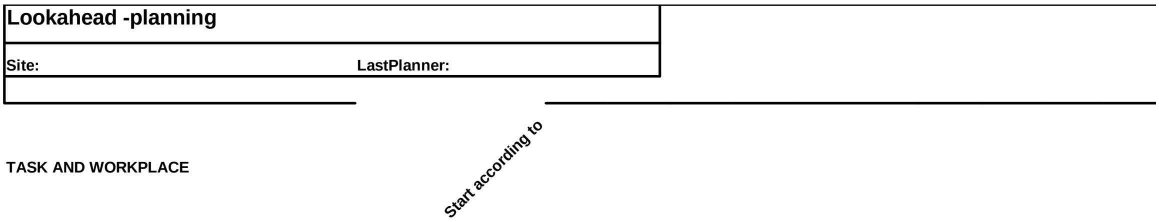

Figure 3. Lookahead –planning spreadsheet on one Finnish construction site.

A belief in the almighty power of the master schedule sits very tightly in the Finnish construction. Master schedules are mainly produced by special scheduling programs on computers. Maybe the colourful, nice looking schedules seem to be something to trust in. In one reconstruction project there were more than 1400 master schedule tasks. So many tasks but very little actual information on task contents, people who are to do the work, with what equipment and even less on commitments. The reality in this project was that the master schedule was of no use.

One key instrument on Finnish construction sites is task planning. It is a systematic way to plan one task from all the production aspects. For example time, cost, quality, safety and pre-requisites are taken into account. Tasks are prepared as whole from beginning to end. Still there is the continuous need for look-ahead planning.

The success in planning and controlling production comes from reliable commitments to the client, phase planning done together, task planning by each subcontractor, rolling lookahead planning and weekly plans into which participants have committed (Figure 4).

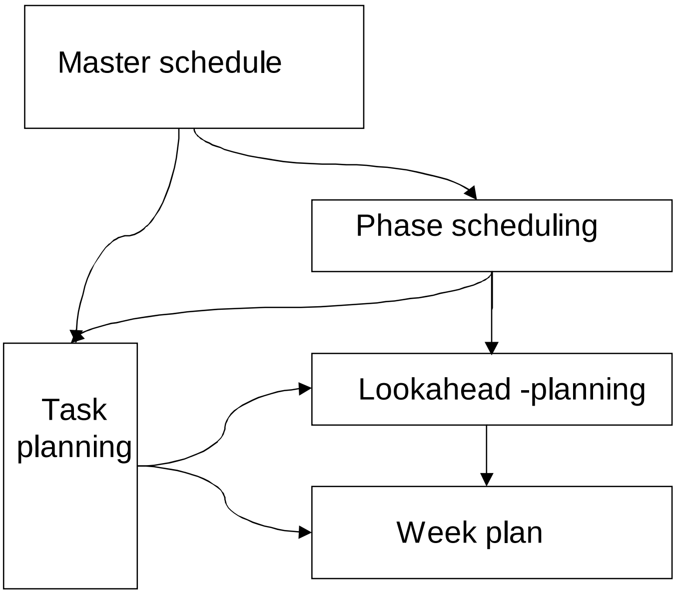

Figure 4. Overall picture of the Last Planner stimulated production planning and control, which is being implemented at the moment in Finland [8].

In view of the first, successful pilot project, the Confederation of Finnish Construction Industries organized a project for creating a manual of Last Planner, to be used both in company training and college and university education. The outline of the resulting manual [9] is presented in Table 1.

Table 1.The outline of the Finnish Last Planner manual.

Koskela, Koskenvesa, Sipi: Työmaan toimiva tuotannonohjaus: Opas Last Planner™ menetelmään. Rakennusteollisuuden Kustannus, Helsinki. 42 p. 2004.
Introduction Guideline for using and reading this manual Last Planner production control: why and what? What is the goal of LP? The totality of the LP production control **Methods and practices of LP production control** Phase planning Why? Basic procedure Advanced practice Examples and observations Look ahead planning (this heading and all below in this section have the same subtitles as above) Weekly planning: making ready Weekly planning: conversation and commitment Weekly planning: checking task completion Weekly planning: finding reasons for non-completions Continuous improvement **Introduction of the Last Planner production control** Implementation on site when LP is new for all parties Implementation in a company Training effort needed Information technology as a support to LP Interfacing Last Planner to existing production control system of the company Higher level plans Task planning **Further information** References, links etc.

In the manual, the method is structured into seven parts, and the rationale, basic procedure, advanced practice as well as related examples and observations for each part, connected to the overall explanation of the method, are presented. Also the implementation issues are discussed.

5. Explaining Last Planner

In the introduction of Last Planner, there are two challenging moments of explanation and persuasion. First, the method must be sold to the management of the contracting company, so that pilot test can be launched. Second, the method must be explained to the site personnel participating in the pilot test. To some extent, the method can be sold referring to good results abroad. However, inevitably the question emerges: Why is Last Planner more effective than the conventional method? Thus the problem is as follows: How can Last Planner be shortly explained in a plausible way to an experienced professional of site construction? The authors came to think that the explanation must be anchored in the everyday experiences of these professionals.

The observations of Jaafari [5] on productivity in a construction task were taken as a starting point:

> While the size of samples is not large enough to yield conclusive results, the general pattern remained similar. Productivity showed a gradual build-up at the start (often associated with unavailability of specific tools or materials at the time required, or lack of foreman instruction, or absence of key craftsmen). Steady progress in productivity continued unless interrupted externally, then followed by unexplained drag at the end, or often unfinished 10-15 % for a variety of reasons such as urgent start elsewhere, technical problems, or breakdown of tools.

Indeed, for every person experienced in site construction, it is evident that there are problems related to *starting a task*. After they have been solved, new problems *during the task* emerge. And finally, there are problems related to *completing the task*. However, these problems are assumed away in task planning, where a constant productivity is usually assumed (Fig. 5). This is reinforced by the habit of representing tasks as neat, well-defined rectangular boxes. However, if we consider productivity (or output), tasks cannot be considered as rectangular boxes – rather, the productivity increases slowly to its maximum, decreases through interruptions and typically there is a tail end to be completed later, often just before handover (Fig. 6).

In view of this, the simplified explanation[2] of Last Planner is as follows: *The Last Planner System endeavors to recreate the neat rectangular form of a task output, starting sharply,, reaching the sustainable and stable output level immediately, maintaining it to the end, and thus finishing the task as planned, without any tail end.* For so doing, Last Planner utilizes its seven features, the contributions of which can be allocated to the solution of these three problems (Fig. 7).

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[2] Note that this explanation is parallel to the argument that Last Planner is primarily addressing the waste of *making-do* [7] but avoids the use of difficult operations management terminology.

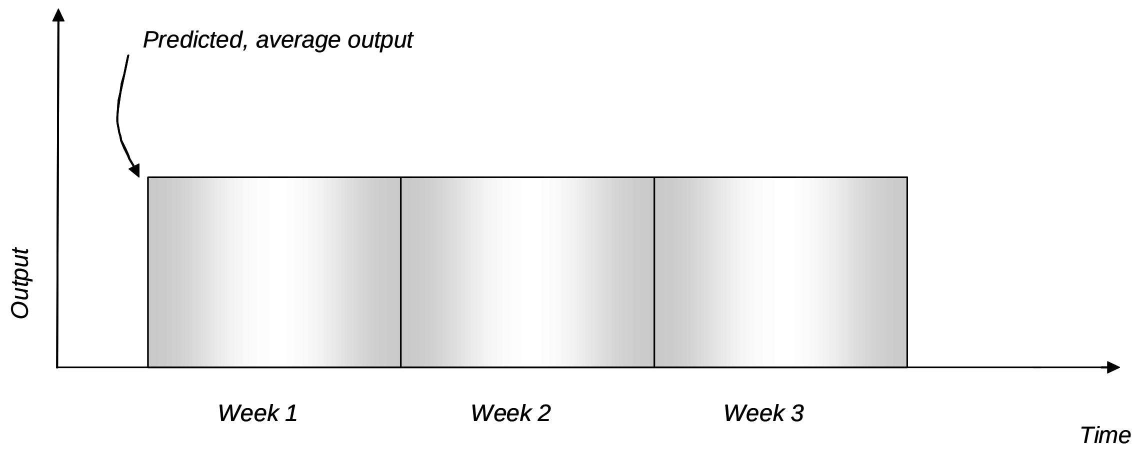

Figure 5.Task output as assumed.

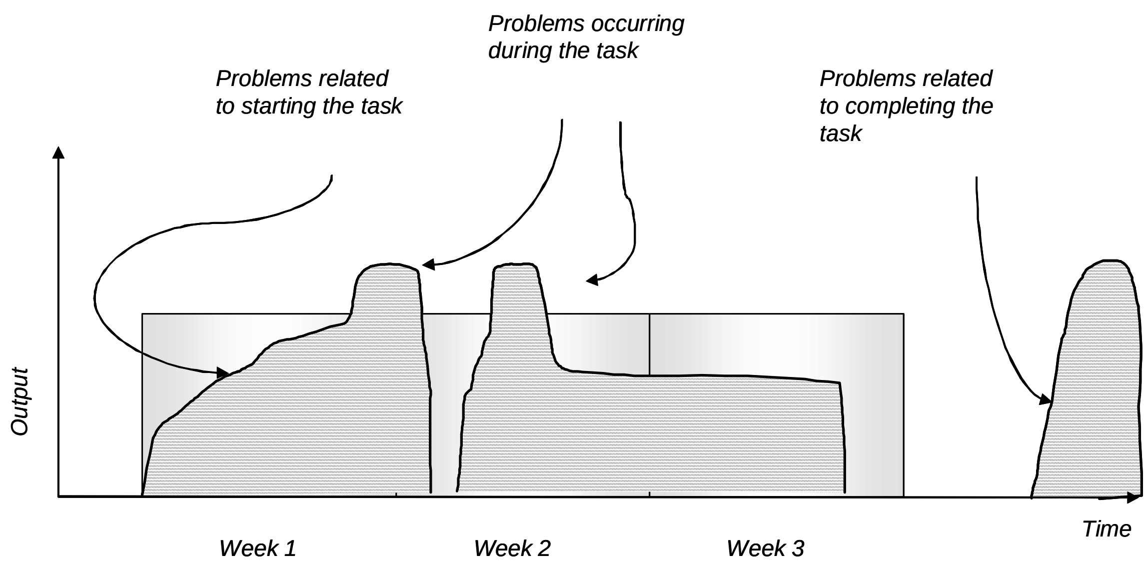

Figure 6. Task output in reality (illustrative example).

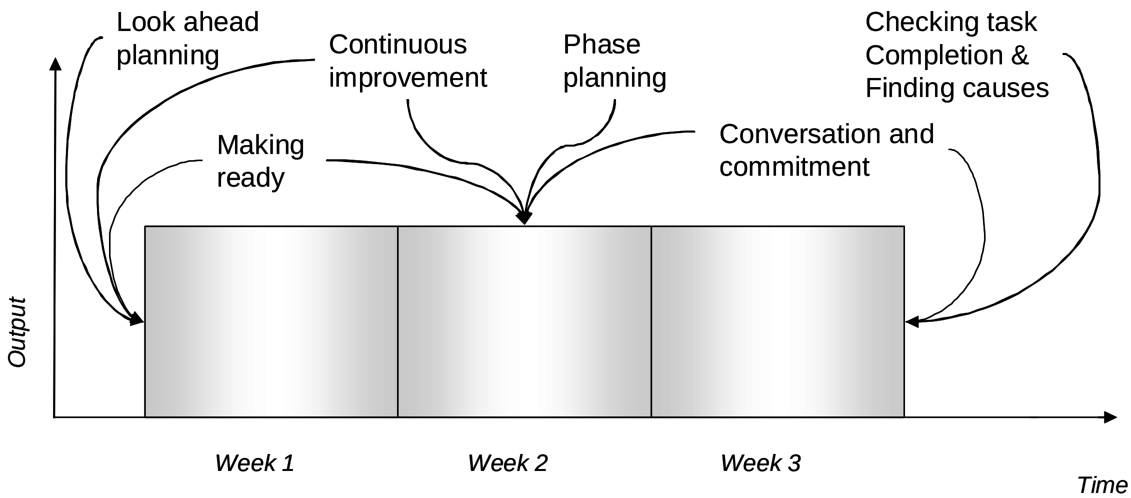

Figure. 7. Using the features of Last Planner for ensuring a sharp start, constant uninterrupted progress and planned completion of the task (only the primary mechanisms indicated).

The problems related to starting a task are addressed in three ways. In *lookahead planning*, there is a focused effort towards eliminating constraints for starting tasks: prerequisites are pulled (rather than pushed). Secondly, the *ready making* function ensures that only tasks with all prerequisites available are actually started. Thirdly, *continuous improvement* will for its part contribute to the reduction of starting problems on longer term.

Regarding problems during the task, there are three mechanisms. First, *phase planning*, carried out in collaboration between different teams and subcontractors, ensures that the best order of tasks is determined, and thus the risk of unforeseen interference between tasks is diminished. Second, *ready making* is focused on weekly tasks, and thus the prerequisites of longer tasks are checked weekly, rather than only at the start of the task. Third, all the weekly tasks are covered in the weekly planning (*conversation and commitment*), and thus in principle there should not be unplanned tasks emerging during the week, causing interruption or interference to planned tasks. However, in practice, there often is unplanned work to be carried out, but as plan reliability progressively increases along with use of the Last Planner, its amount will decrease.

When it comes to problems related to completing the task, first, all features mentioned above in relation to the two first problems help to avoid these completion problems. For example, a problem related to starting (say, shortage of materials) or a problem emerging during the task (say, necessity to move the gang temporarily to another work) may halt the task for the rest of the week. Second, task completion is specifically addressed by the planning conversation resulting in *commitment* to realize tasks as planned. Thirdly, *checking of task completion* as well as *finding reasons for non-completions* emphasize the need to realize and complete tasks as planned.

Next, the benefits of Last Planner can be explained. The elimination or at least alleviation of these three problems leads to direct benefits in terms of productivity, safety, quality and duration:

- Productivity. Each task can be sharply started, when all prerequisites are at hand. Interruptions and interferences are minimized. There are fewer tail ends, requiring a revisit by the gang.

- Safety. In comparison to the prior situation, a bigger share of tasks can be carried out as planned (including safety issues) and within regular conditions.

- Quality. A bigger share of tasks can be carried out as planned, in regular conditions, in one pass.

- Duration. Plan predictability increases along with the elimination and alleviation of the mentioned three problems. Thus, the time buffer between consecutive tasks can be shortened, with leads to a shorter total duration.

6. The Present Status and Prospects of Last Planner in Finland

At the moment, Last Planner seems to have firmly settled down in Finland. It is used by several individual construction managers, and there are pilot projects underway in two major contracting companies. There is training and facilitation available to companies through a Last Planner trainer certified by the Lean Construction Institute. There is a manual for Last Planner, published by the Confederation of Finnish Construction Industries.

However, it would be wrong to assume that the production planning paradigm has already changed in the country. The diffusion has been more bottom-up than in other countries – there has not yet been a locomotive company implementing Last Planner systematically and widely in its activities. Likewise, the curricula in universities and technical colleges tend to stress the conventional production planning mode, even if Last Planner has been point wise introduced.

One explanation to the inertia observed is that many key professionals seem to passionately subscribe to the conventional production control methodology. For them, the rejection of the master schedule as the primary tool for controlling a project is not something that could be accepted easily. Also, the temptation of automating the preparation and monitoring of the master schedule through IT tools has been irresistible to many.

7. Conclusions

The Finnish experiences on the introduction of Last Planner are to a great part similar to those gained in other countries, but to a certain degree there are novel emphases. There is similarity especially in the observation that Last Planner is a powerful method, which has already been demonstrated in pilot implementations and provides clear benefits (compare [4]). Other significant observations, some novel, others adding to prior evidence, emerging in the framework of Finnish experiences include the following:

- *Theory-based approach*. A simplified way of explaining and justifying the Last Planner method for construction professionals was developed. The training time could be reduced, and justification of the method to managers was made easier. Also, the introduction of the Last Planner into the national educational and training system seems to require that a detailed theoretical justification, especially in comparison to the traditional way of production control, can be presented.

- *Incremental introduction*. The method was structured into seven parts, and a logical order for their progressive introduction on site was developed. A rationale for each part, connected to the overall explanation of the method, was developed.

- *Need-based facilitation*. A method of facilitation emerged where the intensity of facilitation progressively decreases according to the advances and learning made on site.

- *User acceptability*. The user acceptability of the method emerged as a critical feature. The users of the method must themselves realize the superiority of the new method, if a successful implementation is targeted.

- *Contextual tailoring*. The method has been tailored in operational details to match the existing production control methodology of the company.

Acknowledgements

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Case Studies of Using Flowline for Production Planning and Control

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Abstract

Flowline, or Line-of-Balance, has recently gained attention in Lean Construction literature because of its capacity for facilitating control of production flow and planning of continuous work. In the broader technical literature, previous work has concentrated on the analytic properties of flowline, such as learning curves, and is generally silent on how the method should be used to improve productivity. This is because internationally the technique has received relatively little application. However, in Finland, flowline has been used as the principal scheduling method since 1980s.

This paper takes a practical approach and describes the use of flowline based planning and control in two real case projects. One of the projects is a large residential construction project in Sydney, Australia. The other project is a Finnish retail park construction project. These pilot projects were done at the same time and the projects were able to learn from the experiences of the other. The cases highlight the differences between the Finnish way of planning a schedule with buffers between activities with synchronized production rates and the Australian way of driving a schedule with a tightly constrained CPM schedule.

A methodology using flowline as a visual planning tool but using familiar CPM logic as the underlying engine was appropriate in the Australian case. In this methodology the objective is to improve site control by including information about location and to be able to plan continuous work for subcontractors and to visualize the effects of planning decisions. The result is much clearer communication to the trade contractors about the timing and location of their work, improved control systems and better work flow. The Finnish project team was already familiar with the basic use of flowline so the more advanced risk management based approach was used. The risk management based approach includes using quantities estimated by location as the starting point and optimizes the crews so that the risk of schedule disturbances is minimized. The planning happens on two levels: the master schedule has less detail and the task plans are detailed plans of individual tasks which are done by persons responsible for the work when all the necessary information about implementation is available. The results from the Finnish case include a methodology for effectively controlling production flow and how to include the subcontractors in the process.

Comparison of the two different strategies reveals important knowledge about the role of custom in scheduling, and reveals potential barriers to adopting innovative approaches.

Keywords: Flowline, line of balance, scheduling, implementation

1. Introduction

1.1 Flowline and its Applications

There are two main methodologies for scheduling work: activity-based scheduling and location-based scheduling. These two methodologies in turn have many methods and techniques, often designed to achieve the same purposes in different ways [1].

The dominant scheduling technique is activity-based scheduling and it was first developed in the 1950s [2]. The technique relies on the construction of a logical network of activities in three visual forms; activity on the arrow, activity on the node and logical dependency constraints [3], with four levels of complexity; deterministic (for example: CPM), probabilistic (for example PERT) generalized activity networks [3] and arguably the more recent critical-chain method [4].

A familiar to many, but relatively little used, alternative scheduling technique is that of location-based scheduling, more frequently known as repetitive scheduling. Originally developed by the Good Year Company in the 1940s and expanded by the US Navy in the 1950s [5], the suite of techniques has found strong support in continuous production systems (more typical in engineering construction) but only limited support in commercial construction. Finland is a notable exception to this, as the technique is the dominant method in the Finnish construction industry. Harris & Ioannou [6] summarize the various names (and sources) given to the variations in the method, including 'Line-of-balance', 'Construction planning technique', 'Vertical Production Method', 'Time-Location Matrix model', 'Time Space Scheduling method', 'Disturbance scheduling' and 'Horizontal and vertical logic scheduling for multistory projects'. Interestingly they do not identify perhaps the most evocative term, that of 'Flow-Line' [7]. Harris & Ioannou [6] also identify the terms used in engineering construction such as highways, pipelines and tunnels, as 'Time versus distance diagrams' (TD charts), 'Linear balance charts', 'Velocity diagrams' and 'Linear scheduling'. [8] also identify 'Horizontal and vertical scheduling', and 'Multiple repetitive construction process'–but aims these at the specific case of vertical replication repeated in multiple buildings.

All these methods involve repetitive activities and for this Harris and Ioannou suggest a new generic term 'Repetitive scheduling method (RSM)'. However the methods also strongly suggest location or place, and thus the use of the term 'Location-based scheduling' proposed by Kenley [1].

1.2 Background

Activity-based scheduling dominates most of the world's construction industries. This is certainly the case in the Australian industrial context. Little needs to be said to describe the common methods for planning projects, as they will be familiar to most. Essentially they are driven by software such as Primavera (the most commonly used package), Microsoft Project and equivalent CPM tools.

The education system in Australia generated students with a deep understanding of the underlying mechanisms of CPM planning until the mid 1980s. These students were also generally exposed to alternative manual methods such as Flowline [7]. Students of Walter Mohr [7] were more exposed than many. The advent of powerful software on micro-computers subsequently lead to a reliance on packages for the teaching of planning. It is fair to say that nowadays, construction management courses teach the use of software, paying only a cursory interest in the underlying principles and methods. A consequence of this is a lowering of planning skills, except in the use of software, and a reliance on common approaches. Accordingly, it would be extremely rare to see application of location-based scheduling in Australia, indeed few people would have the skills to understand the method.

Furthermore, location-based scheduling is best driven by location-based measurement (BOQ). The standard method of measurement in the Australian industry does not allow for location-based measurement. The industry has also substantially moved away from measurement of commercial building projects, particularly those procured using Design and Construct methods, and many commercial contractors simply do not have adequate measurements to support location-based techniques properly.

In contrast, location-based planning methods have been used widely in Finnish construction since the 1980s. The methods were brought to Finland and adapted to commercial construction by professors Kankainen and Kiiras from Helsinki University of Technology [9], [10]. In research tests it was established that the use of modified flowline planning increased productivity and decreased waiting hours for own workers and for subcontractors [11].

Finland suffered from severe economic recession during 1990s during which many construction companies went bankrupt and the value of real estate plummeted. During the recession, training of construction management professionals and construction engineers practically stopped because jobs were not available. This has resulted in a lack of skilled engineers in the field when the economy began to recover. During the recession the flowline scheduling skills were forgotten and the industry reverted back to using gantt charts which could be easily drawn by using computers. The only available flowline software was a drawing tool and wasn't suitable for complex planning.

New research efforts to improve the scheduling skills of the industry were started at the end of 1990s by professor Kankainen's research group. The results included tools such as task planning [12], project control charts, checklists to assess schedule's feasibility [11] and new contracts to support location-based control. The research results were used in a software development project to design a new software able to be used as a planning and control tool. The features of the software DynaProject™ have been described [13].

Because of popularity of the location-based graphical methods, Finnish construction companies had never really adopted CPM –based methods. Activities which are linked by precedence logic are rare in Finnish schedules. The schedule is used as a visual planning tool and the planners check for logic errors by examining lines which cross in the flowline diagram.

It is clear, therefore, that a comparison between the Australian industry and the Finnish industry, the methods and practices of planning, would cast valuable light on the culture of planning in both countries. In this paper, the experience of planning using location-based scheduling techniques on a specific project case study from each country is discussed; allowing comparisons to be made and conclusions drawn about the differences in the culture of planning in each country.

2. Case 1: Residential Construction Project in Sydney

2.1 Description of the Project

Victoria Park stage 302 is a residential complex in inner Sydney. It comprises four residential towers of varying heights, joined through a common podium. The largest tower was fifteen floors, the next nine, then eight and four. There were approximately 300 apartments in total. The schedule was from May 2004 to June 2005.

2.2 Available Starting Data

Walter Construction Group was totally new to flowline based production control systems. All their systems revolved around CPM and Primavera. As this was a trial to develop more efficient management systems, both CPM schedules and flowline schedules were developed.

There was no quantity take-off done corresponding to the physical locations of the building. Nor was there any available database of production rates. This is common within the Australian industry, where sub-contract packages are generally allocated a number of days of work for each task, in precedence logic, and no attempt is made to ensure continuity of work flow.

2.3 Scheduling Process

Because of the poor starting data, it was difficult to schedule the project using location-based methods. It was necessary to take the CPM schedule and artificially apply it to a location-based methodology. This presented the first significant barrier to implementation: the automatic systems designed into the software could not be used and the inability to use quantities and productivity data exposed the shortcomings of CPM only systems which are not sensitive to designed productivity changes.

The CPM schedule was never fully completed due to the complexity and scale of the projects. Therefore, the CPM schedule calculated a typical floor in detail, then replicated this for each floor. This is understandable, as with 300 apartments and with approximately 50 activities to schedule, it would be necessary to schedule around 15,000 activities. In contrast, the location-based methodology required only 50 activities, with the approximation of quantity in each of 300 locations. A simple trick was employed to achieve this: The unit of quantity measured was a standard shift, with the number of days of work being the actual measurement. This rough approximation allowed reproduction of the CPM schedule, but exposed the problem of manipulating the productivity to improve the schedule (and indeed the problem of a culture of fixed durations existent within the industry – a topic for future research).

One important lesson is that this sort of power leads to extremely rich and complex schedules. The loss of dominance of the critical path, replaced by dominance of work-flow, results in project models with large quantities of information – all very powerful for managing the project. To illustrate the complexity, a small section of the finishes schedule for one part of one building is displayed in figure 1.

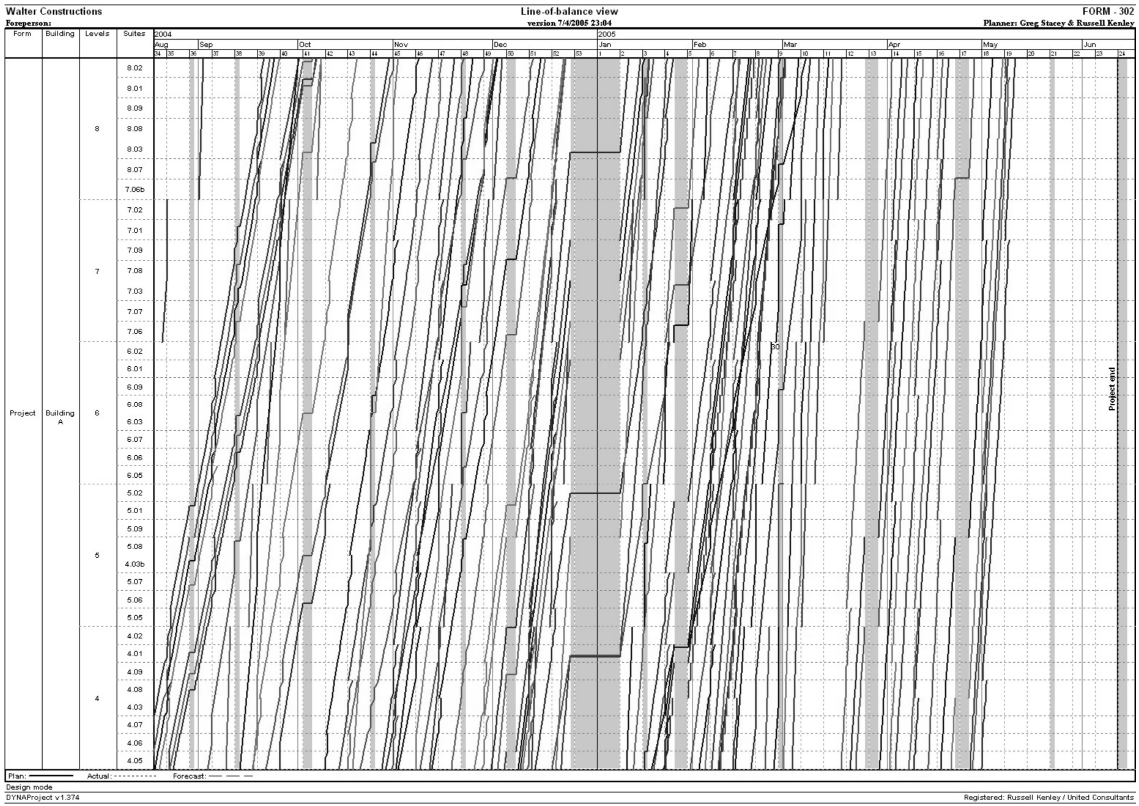

Figure 1: Section of finishes schedule for Victoria Park.

The initial schedule resulted in a duration far in excess of the required duration. In order to simulate alteration of work-crew productivity (the normal method), activities were resourced with work-crews with $1/10^{th}$ productivity – and a base multiple of 10 units. Thus 20 units would double productivity and 5 would halve the productivity.

After manipulation, a schedule was developed which conformed to the duration requirements, but which ensured that each work-crew was able to work continuously, without interruption, from start to end of the project. In the words of one site manager on a later project, “Do you mean to say that we can not only finish on time, but also have continuous work?”

In contrast to the finnish methods described below, the contractor wanted to continue their use of scheduling in extreme detail. This may be termed micro-management [1] and scheduling to such detail was considered most unusual by our Finnish colleagues. Their risk management approach results in less detail and simpler schedules. The detailed approach dictated by a CPM culture results in much more detailed schedules, more complex models but powerful management tools when used correctly.

2.4 Control Process

The project schedule was completed prior to commencement of the finishes work on-site. The planned control process was to work with the sub-contractors to ensure their productivity rates matched with the plan. Once this was done, each work-crew would be able to work continuously, systematically and without interruption – this greatly enhancing their financial performance and that of the project.

The reality was very different. A competing process was being employed on the project in the design stage and unfortunately spilled over into the site-work phase. This process, called *Project Blue* [14] involved intensive focus on team work and integration – very valuable aims. However, the methodology for site work was strictly CPM – and followed the original CPM planning method. A typical floor was worked out according to the original plan and trades were told to "pass work on" to following trades. Unfortunately, this method fails due to the conflict between a typical floor schedule and the need to flow resources through multiple floors and buildings. The result was largely chaos, work out of sequence and a loss of control. Such performance was largely accepted however, because this is unfortunately normal practice on any Australian project.

The result of this conflict is that the location-based control system was never implemented. The company subsequently reviewed the project and determined that on future projects the method would be implemented rigorously and not be sabotaged. A special project team was initiated to follow this through.

Unfortunately, it must be reported that, due to the failure of the German parent company, Walter Construction Group failed in February 2005 and this implementation project has now stopped.

2.5 Lessons

This project highlighted that CPM scheduling done in the traditional way presents major problems for site management which are generally managed by the site staff though working out of sequence, discontinuous work and work interruptions.

In contrast, a location-based approach such as flowline has the capacity to deliver more efficient site work. However, successful implementation requires significant cultural change before it can be successful. Even with senior management support, the project management team must support the innovation.

3. Case 2: Business Park Project in Helsinki

3.1 Description of the Project

Opus business park is a 14 500 m2 office building in eastern Helsinki. It is composed of two sections, which can be built independently of each other and of parking hall below the main building. Both sections have six floors. The total schedule is from August 2004 to December 2005.

3.2 Available Starting Data

NCC Construction has devoted a lot of resources to implement flowline based production control systems [15]. The quantity take-off is done corresponding to the physical locations of the building. In this example, all the quantities had been distributed to sections and floors so that they could be directly utilized in flowline planning. Labour consumption information has also been standardized within the company allowing for a very fast planning of first drafts of the schedule. Also the building services quantities are estimated based on project characteristics and size. The productivity and quantity databases include information about subcontracted work. The main principle is that subcontracted work should be planned as if it were done with own resources because otherwise effective control is impossible.

3.3 Scheduling Process

Because of good starting data, it was possible to create many different alternative schedules in a short period of time. Two main alternatives were examined:

- Completely continuous schedule
- Work continuous in sections but a break between two sections

Completely continuous schedule would have had the same end date as partially continuous schedule but both sections would have been finished at approximately the same time. Partially continuous schedule achieved much of the same benefit but enabled the first section to be finished earlier thus reducing the risk of exceeding the total duration. The project team decided to implement the partially continuous alternative and take the break between sections into account in contracts with subcontractors.

It was not possible to change the sequence of sections because the parking hall had to be handed over before the second section could be started. This was because the second section was used as a temporary parking lot for customers of the neighboring supermarket. If the second section could have been built first, the project duration would have decreased by one month.

In the final schedule the production rates have been synchronized and a buffer has been planned between the most important activities. All task durations are based on quantities, resources and productivity data from earlier projects or from Finnish productivity database, which has been created as a joint effort of the industry [16]. The final master schedule is shown in figure 2 (only the space-critical activities shown).

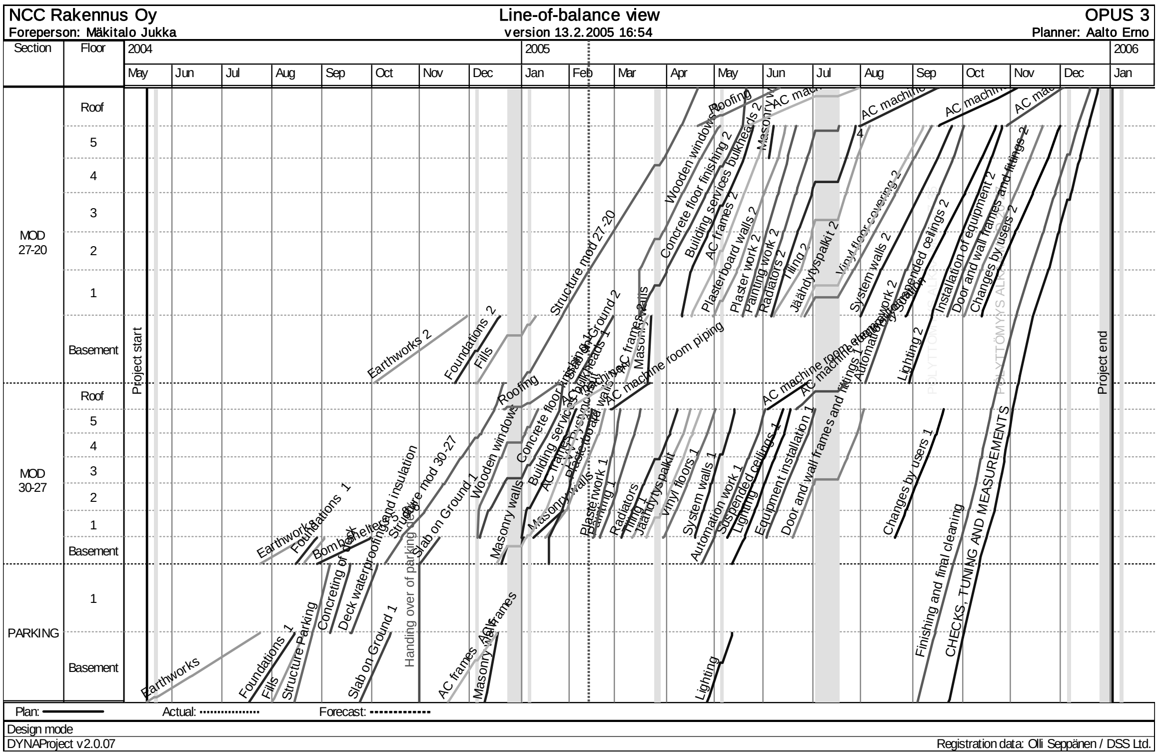

Figure 2: Master schedule of OPUS project – only the space-critical activities are shown

3.4 Weekly Control Process

The weekly control process was based on task planning method [17]. The schedule of upcoming master schedule tasks was exploded into more accurate level and the quantities were updated. This process started in the beginning of the project so by planning just one task accurately each week it was possible to always be well ahead of production. While the master schedule looks at production flow at "macro" level, the task schedules schedule continuous work for each worker and assure that the same worker won't be in two locations at the same time. Task schedules are constrained by the master schedule so that task schedule must finish all subactivities in a location before the next master schedule task begins in that location. Task schedules are updated weekly to always correspond with the current situation but the master schedule is never updated. This is because updating the master schedule has been shown to fool the site management into false sense of safety. In reality updating the schedule shifts the problems towards the end of project and leads to hurry in the end of project [11].

Every week on Tuesday, the actuals from the last week were compared with the weekly assignments derived from all of the task schedules. The data was collected from site by using the control chart, a matrix of locations and tasks which shows with color codes the status of each location [13]. The reliability of task plans was measured by calculating the percentage of planned assignments completed (PPC) during the week. This measure is the same as in the Last Planner™ system of production control (e.g. [18]) but the assignments are the result of flowline-based task planning process.

All existing task schedules were updated next to take changed circumstances and actual production into account. Actual production rates were used in task schedule updates to make schedules more accurate and to show increased resource needs. The master schedule sets the boundaries for planning so the problems couldn't be pushed farther than the end of master schedule task in a location. All the updating was done using best possible information. The aim was to make best possible forecasts for the rest of the task while preserving continuous production for as many workers as possible. Most effort was expended on updating the next week's plan because the next week's task schedules were commitments by the planners.

If there was sufficient information on a master schedule task which was about to begin in the next few weeks, new task schedule was planned. The first draft of the task schedule used accurate quantities taken from current drawings and estimated production rates. It was planned by the site engineer. Before beginning of production, the task schedule went through multiple rounds of comments by the subcontractor, the superintendent and procurement people.

After updating the task schedules the status of master schedule was evaluated based on computer-calculated forecasts. [19] If the delay of a task endangered the continuous flow of another task, control actions were planned by updating the task schedules to minimize the risk of interference. Actual situation and resource availability of the subcontractor as well as the cost effects of acceleration were evaluated to arrive at the best solution. If interference couldn't be avoided, task planning was used to estimate the optimal time to continue production for the disturbed trade.

The resulting set of task schedules were up-to-date, took into account the availability of resources and were based on actual circumstances. From these task schedules the production objectives for the next week were established. These objectives were communicated to the subcontractors and superintendents. Their success was evaluated in the next Tuesday's schedule update by calculating the PPC.

This weekly control process took two to four hours time from the project engineer and one of the authors (OS). In addition, the project engineer used time in communicating the plan, assessing the circumstances and getting the actual data from site.

3.5 Results

The project was still on way during the writing of this paper. The structure of the first section and the parking hall were finished and the interior works of the first section were on way. In spite of many deviations from the plan, the project was overall on schedule. Main problems included earthworks and structure. Structure had too tight a schedule in the master schedule, a fact taken into account in risk analysis. Because of the buffers between structure and interior work, the delay of structure didn't have an impact on the interior works and their flow wasn't disturbed. However, the structure of the second section started late because it was using the same tower crane. Control actions are needed in the immediate future, or there will be interference in the second section. Figure 3 shows actuals (dotted lines) and forecasts (dashed lines) on top of the original schedule (solid lines). Master schedule hasn't been updated and can still be used to control production. The results indicate that the master schedule was on sufficiently rough level of detail that it could accurately forecast how the project would be carried out.

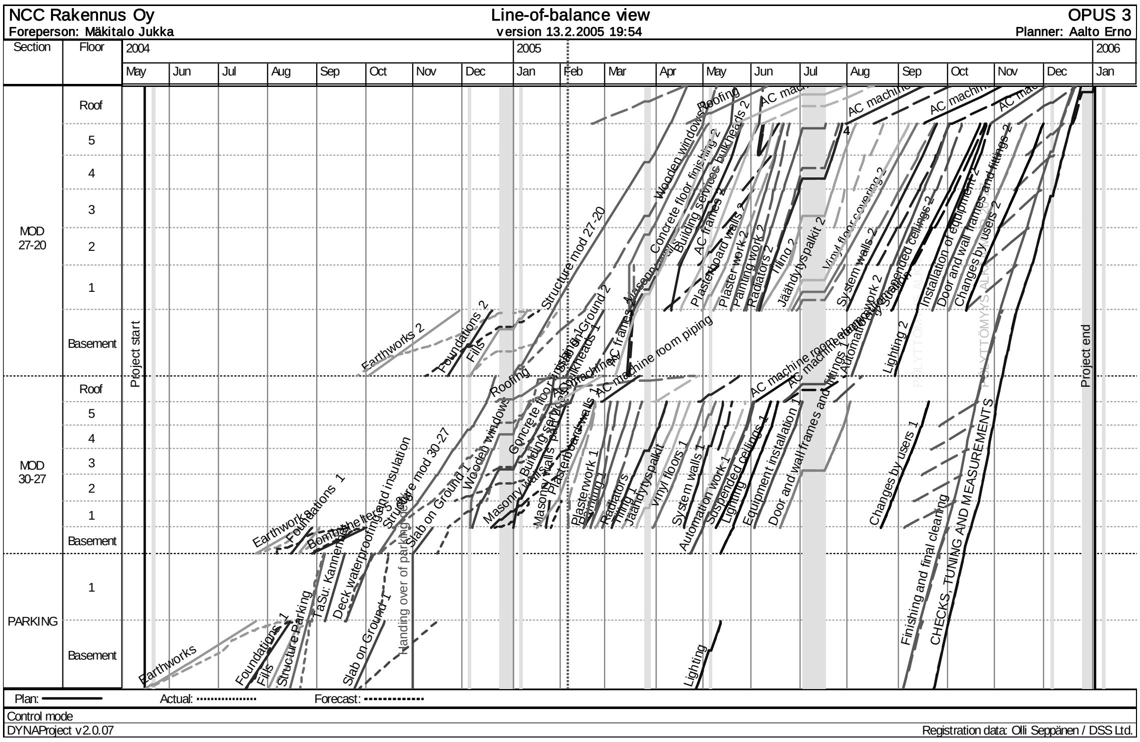

Figure 3: Master schedule of the Opus project planned lines (solid), actuals (dotted lines) and forecasts (dashed lines)

Systematic weekly control process improved the project team's feeling of control. Measuring the percentage of weekly assignments completed (PPC) was found to motivate the team to take planning more seriously and to strive for best possible results. This showed in an increase of the PPC from 50 % level to near 80 % level during the initial stages of the project. Improvement in PPC correlated with the catch up of the schedule.

Combining task planning with master schedule based schedule forecasts worked well because if the site set too relaxed weekly targets, the master schedule forecasts alarmed that there will be problems in the future. If the site set too tight, unrealistic objectives, the PPC value plummeted. Catch up can be planned to be incremental by updating the task plans. By combining the systems, the site can set realistic objectives, commit to them and maintain control of the overall schedule.

4. Discussion

There are very significant cultural differences between the methods, despite the fact that the same software tool was being employed. Indeed, it was realised that neither group could really understand the schedules generated by the other.

The Australian planners, while they liked the idea of the risk management schedules and the rapid construction of schedules from quantities and templates, could not accept their validity in their context and insisted on their detailed CPM-like, micromanaged, flowline schedules. They didn't understand the concept of buffers, preferring instead a fixed lag (delay) between activities in the network.

The Finnish planners, in contrast, had never seen such large and complex models, and were fascinated by the complexity, but equally could not justify the approach, fearing that such precision and detail without buffers in time or location, would lead to problems in implementation.

This illustrates that the risk management approach and the CPM approach provide two completely different planning systems. Improving our understanding these differences, now identified, will be an important research project for the future.

5. Conclusion

Flowline, as a technique, and DYNAProject^{TM} as a software tool, have demonstrated their capacity to be used in completely different ways according to the underlying planning culture. This project demonstrated that flowline can provide a powerful planning and control tool for projects, with two completely different methodologies available.

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Procurement Strategies for Dynamic Control of Construction Projects and Supply Chain

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Abstract

The efficiency and the effectiveness of construction processes have previously often been discussed and criticised. Obviously the final goal of parties within a construction project is the completion of the project. However it is not necessarily a goal in itself to organise the process as fast and efficient as possible. Most practitioners in construction consider that 'quality versus time versus cost' is a zero sum game, and hence, whenever there is a choice among the three, usually quality is often the first to be sacrificed. The core of this problem lies within the classical project delivery methods not aiming to bring together the different interests of the value demanding and the value supplying parties, and not shielding the process against negative effects from outside the project. Most project delivery methods are set up in such a way that an increase of profit for one party often means a loss of profit for the other party.

The concept of dynamic control aims at bringing together the different interests of the value demanding and value supplying parties within the building process. It aims at the improvement of added value for demanding parties as well as profit levels of supplying parties, and thus the total benefit of built facilities, i.e. the sum of added value for clients and profits for suppliers. However contracting practices and procurement strategies need to support this positive mechanism and build-in positive incentives for parties to join in a collective effort to search for the optimal solution and overall benefit.

In this paper the concept of dynamic control is combined with alliance contracting principles and delivery method. It is argued that alliance contracting is a beneficial procurement strategy to achieve the goals of dynamic control, i.e. achievement of joint benefit through a collective process of progressive development of value and costs, and thus added value for demanding parties and profit for supplying parties. This results in a basic alliance framework for dynamic control and project delivery, illustrated with practical solutions and methods.

Keywords: Construction, dynamic control, incentives, procurement strategies, project alliance, supply chain.

1. Introduction

The efficiency and the effectiveness of construction processes have previously often been discussed and criticised. The characteristics of construction, such as fragmented demand and supply chains, the complexity of projects and long lead times are basic causes, often leading to cost and time overruns, delivery of less value than agreed, and dissatisfied clients and users [15].

The concept of dynamic control aims at bringing together the different interests of the value demanding and value supplying parties within the building process. It aims at the improvement of added value for demanding parties as well as profit levels of supplying parties, and thus the total benefit of built facilities, i.e. the sum of added value for clients and profits for suppliers. However contracting practices and procurement strategies need to support this positive mechanism and build-in positive incentives for parties to join in a collective effort to search for the optimal solution and overall benefit.

In this paper the concept of dynamic control [9, 10, 11, 12, 13, 14, 15] is combined with alliance contracting principles and delivery method. It is argued that alliance contracting is a beneficial procurement strategy to achieve the goals of dynamic control, i.e. achievement of joint benefit through a collective process of progressive development of value and costs, and thus added value for demanding parties and profit for supplying parties. This results in a basic alliance framework for dynamic control and project delivery, illustrated with practical solutions and methods. The illustrated solutions are derived from three cases that were examined in three MSc. theses delivered at Delft University of Technology [7, 20, 26].

2. Value Engineering and Value Management

Crum [8] defined value engineering as a disciplined procedure directed towards the achievement of necessary functions for minimum cost without detriment to quality, reliability, performance and delivery. Heller [17] defined it as a shift from finding the lowest cost way to produce the product finding the lowest cost way to perform the desired value.

Kelly and Male [19] observed value engineering as a subset of value management. Value management can be structured across the life cycle in three phases: value planning (definition, development), value engineering (design implementation) and value review (operation, end of asset) [23]. The process is integrated through systemic planning and feedback across the entire process. Through a value management and teamwork approach value criteria and benefits of all stakeholders must be assured in a lifecycle perspective. It is argued that the cost savings potential of value management decreases along the life cycle and must therefore be applied from the early phases of construction projects (i.e. design) [22].

Project delivery methods should therefore give room to value management in the earliest stages of the project. Not only by integrating the value demanding and supplying parties in the early phases of a project, but also by making both parties aim for the same goals in the project by raising the difference in interest. Only then will the different parties within a project work together on the same goals. This is the creation of as much as possible added value, within the set boundaries of cost and time.

3. Interests and Goals in Construction

The value demanding parties have different interests then the value supplying parties within a project. The value demanding parties' interest is to gain as much as possible added value (benefit) for the lowest price possible. The value supplying parties' interests on the other hand is to gain as much as possible profit (difference between price and costs) from the project (see figure 1).

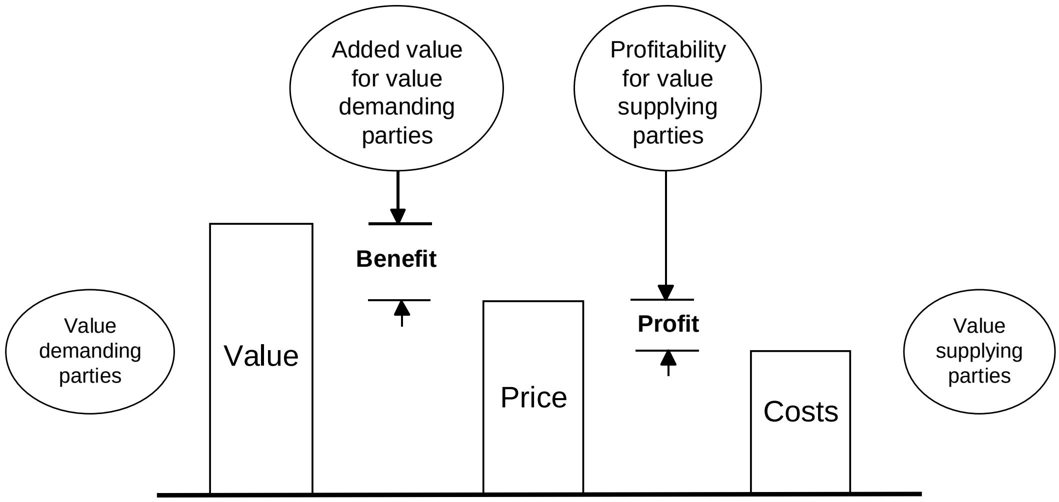

Figure 1: Goals of value demanding and supplying parties in construction projects [15].

The classical project delivery methods do not address this problem. Thus keeping the different parties having different interests within a project.

The interests of both parties have to be aligned to be able to form an integrated team that aims for the same goals. This means that the amount of profit of the value supplying parties has to depend on created added value that is delivered to the value demanding parties.

De Ridder and Vrijhoef [15] have proposed this idea also in their Value-Price-Cost leverage model for the integrated control of value, price and costs of construction projects. The ultimate objective of this idea is to optimize the total benefit of the built facilities through the lifecycle. This paper looks at how this idea is integrated into the project alliance delivery method.

4. Dynamic Control

Previously De Ridder [9, 10, 11, 12] has introduced the concept of dynamic control. The concept is based on the paradigm shift from a discrete process of fixed prices on fixed contract moments between the different phases in the life cycle (static control), towards a continuous process of establishing and monitoring the VPC balance through the life cycle, and acting in case of changing demands or circumstances (dynamic control). In short, dynamic control aims at the improvement of added value as well as profit levels, and thus the total benefit of built facilities, i.e. the sum of added value for clients and profits for suppliers

In order to maximize the benefit, two basic strategies can be distinguished (Figure 2). The first strategy is to add extra value against a small amount of extra costs. The second strategy is to accept a bit less value against substantial less cost. In terms of quality, Bogenstätter [6] approaches these strategies by proposing 'more quality for the same money' and 'same quality for less money'.

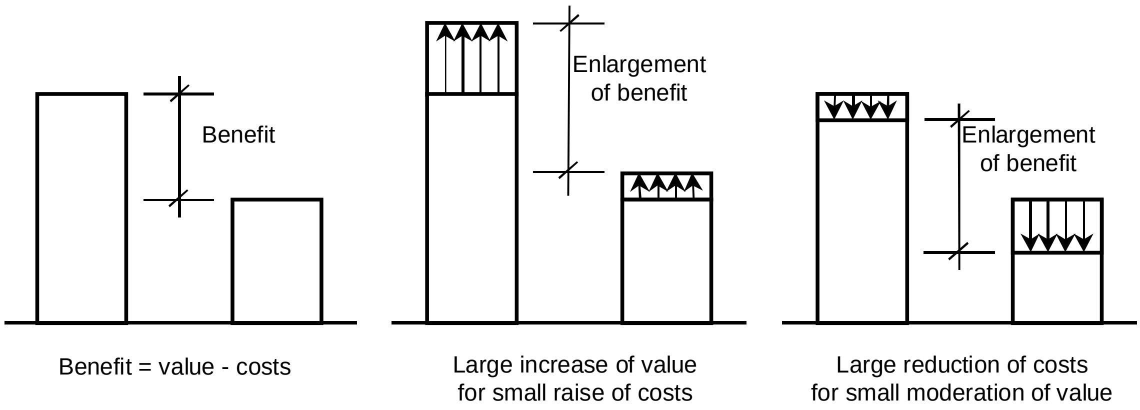

Figure 2: Two basic strategies for the maximizing benefit [15].

The coupling between value, price and costs is essential for dynamic control. The coupling is two directional. This means that value, price and costs must be balanced in the most beneficial way for the all involved parties, thus for value demanding parties as well as value supplying parties.

The two respective couplings between value, price and costs are represented by the brief (value-price) and the working concept (costs-price). The two couplings are the basis of the dynamic control concept. The brief (program) balances the desired value and the price the demanding parties are willing to pay for the built facility. This balancing is a continuous process, and takes place in all stages of design and construction, however on an increasing concrete level. The concept represents the coupling between price and costs. In the design, the supplying parties work out a concept that meets a maximum cost level based on the demanded value and the desired price. Balancing price and costs is also a continuous process, in which additional costs, risks and uncertainties influence the balance between price and costs, and determining the ultimate price, that is often higher than expected.

Demanding parties and supplying parties each have a different focus on the balance they want to optimise. The interests are basically opposite. Demanding parties want to maximize the difference between value and price. Supplying parties want to maximize the difference between costs and price. As a consequence, the interaction between demanding and supplying parties should be focused on integrated balance of the value, price and costs, and maximizing the total benefit through the integrated development of the brief (design program) and the concept. The price is the "lever". Due to the dynamics of the process, this calls for a convergent process of continuous price forming, ultimately leading to a realistic price level in between the emerging desired value and an optimal cost level.

5. Project Alliance: An Applied Dynamic Control Method

5.1 Basic Concept

The concept of dynamic control has been applied in several project alliance projects [20]. It is done by the coupling of the term value of the value demanding parties with the possible profit of the value supplying parties. This is done is such a way that when value rises, the possible profit rises and when the value declines, the profit declines (see table 1).

Table 1: The coupling of the delivered value with the profit of the value supplying parties

Delivered Value (performance)	**Profit**
Good	Good
Normal	Normal
Bad	Bad

By the coupling, the value supplying parties shift from a price-cost (profit) mindset to a value-profit-cost mindset, because the final profit is directly dependent of the delivered value.

In a project alliance the partners bear a portion of the total risk, profit and losses. This way the partners are stimulated to collaborate in order to achieve maximum profit in relation to the delivered value. This contributes to the philosophy of partnering, which says that performance in terms of cost, time, quality, buildability, fitness for purpose and whole range of other criteria, can be dramatically improved if participants adopt more collaborative ways of working [2, 3, 4].

5.2 Condition One: Define Value

The first condition in being able to couple the delivered value with the final profit is by defining the term value. The term value will be different for every value demanding party. Globally the term value for the value demanding parties can be defined as the balance between time, price and quality [24].

5.3 Step Two: Setup a Benchmark And Set Incentives

The following step is to define the minimum quality level (process and/or product), the maximum price level and maximum time the project may take and setup a benchmark to measure these levels. Through the benchmarks the value is quantifiable, thus the profit can be made dependent from the measured levels. In a project alliance this is done through the so-called Risk/Reward schedule. The Risk/Reward schedule puts incentives on the measured levels of quality, price and time (for example see figure 3).

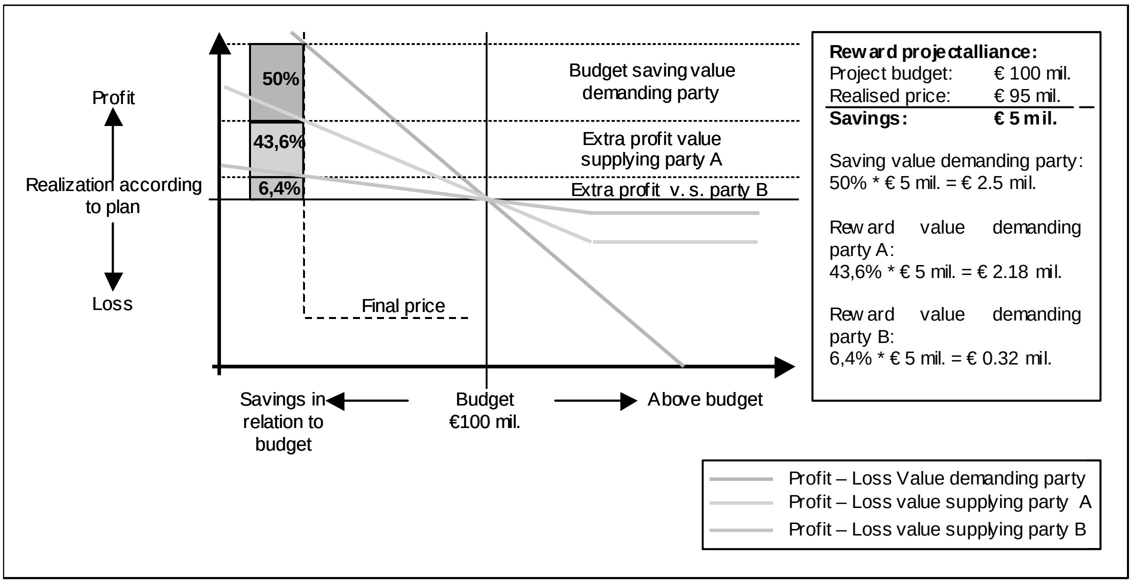

Figure 3: Example of incentive put on the realised price of a project (Risk/Reward-price) [7]

The Risk/Reward schedule (the three incentive schemes placed on time, cost and quality) should be balanced in such a way that the profit of the value supplying parties starts hitting zero as soon as the expectable minimum balance between quality, cost en time is in sight. The following example (figure 4) shows a project in which the quality level of the project is leading. When the quality of the project is low, even when the project is delivered on time and far under the budget, there will be no profit. This way the quality level is secured. There will only be a profit when the quality that is delivered is on the minimum adaptable level and the project is on time and within budget.

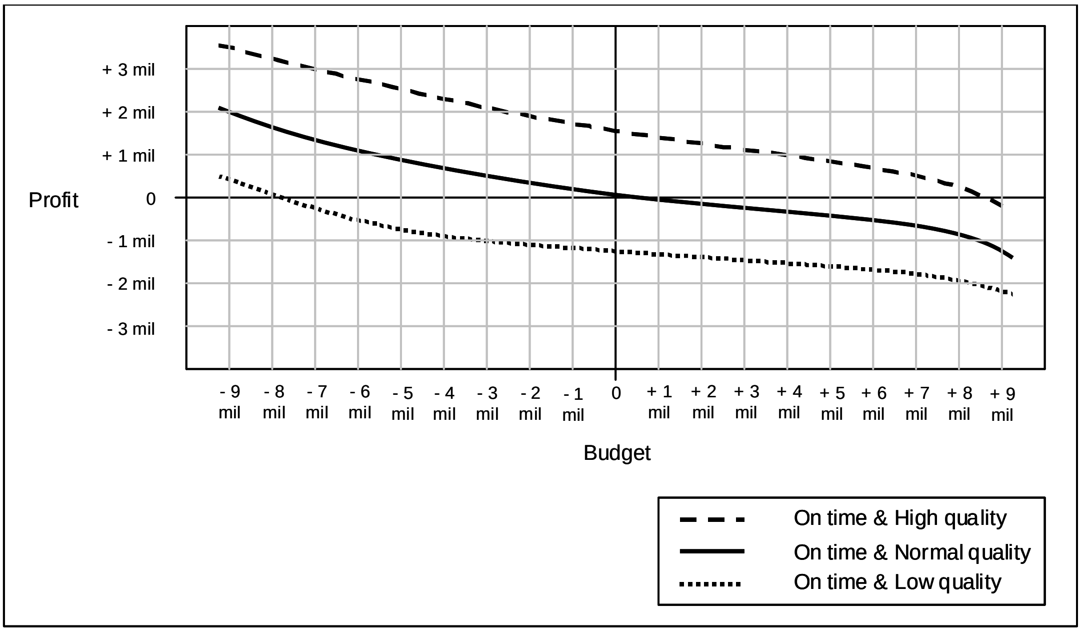

Figure 4:Example of profit coupled with the balance of quality, price and time, where the quality is leading [20]

There are however other aspects that need reckoning. In order to develop collaboration between the partners, only relying on incentives is too simplistic. Open communications, supporting policies, systems and practices are needed to stimulate and maintain collaboration [5,20,26].

5.4 Step Three: Open up the Building Process for Dialogue

The third condition is to open up the building process. Where normally the value demanding parties define the wanted value before starting the dialogue with the value supplying parties, it is now necessary to open up this phase to the value supplying parties. This is done because the value demanding parties are not yet certain about the product that has to be delivered [25]. This can be done for instance by putting the development phase after the selection phase of the project (see figure 5). This way possible optimisations and value enhancing ideas from the supplying parties can be integrated into the design, the phase where the cost for changes are low and the possible influence is high [22]. This means that the method of selection cannot be based on the evaluation of the bid or lowest price. It means the selection should be based on the qualities of the value supplying parties and their possible input into the project.

A direct consequence of the selection based on the qualities of the value supplying party is that the project has to be shielded for the selection of the wrong value supplying party. Selection based on the quality of a party can result into the selection of the wrong party, because this selection methodology is much less developed to date, than the lowest price criteria. The following steps should be incorporated [20] (see figure 5).

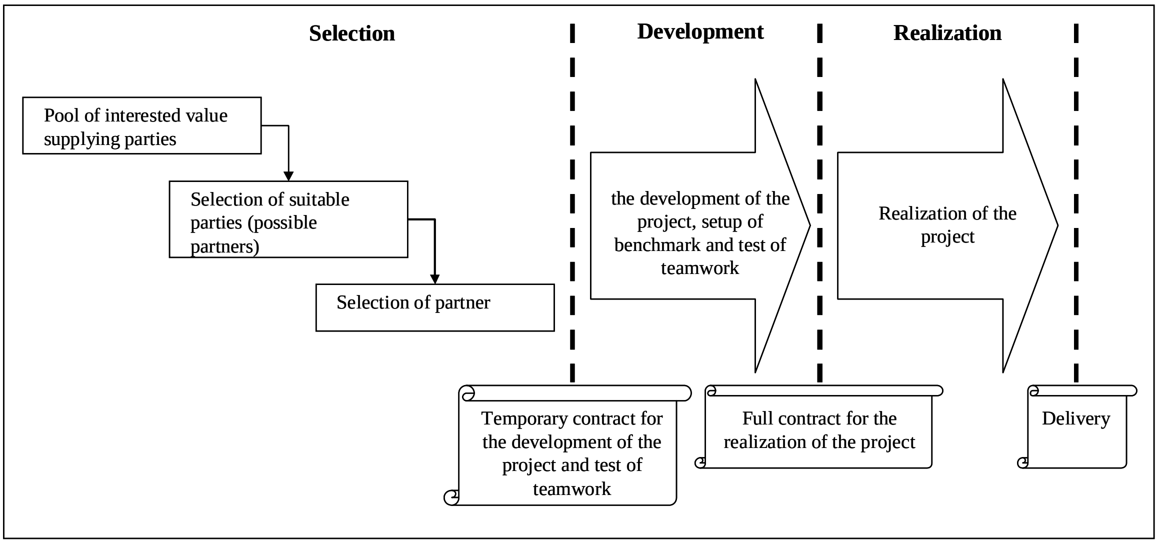

Figure 5: Steps in the tendering process of a project alliance

Figure 5 shows the tendering process for a project alliance. In this process the development phase has been placed behind the selection process. As a result the value supplying parties (including the contractor) will be contracted before the full scope of the project is visible. This is the reason why a temporary contract is installed. Under this contract the partners (including the value demanding parties) develop the project and the benchmarks (for the Risk/Reward-scheme). If the development phase is satisfying for the value demanding parties, the temporary contract can be converted into a full contract for the realization of the project.

6. Demand and Supply Chain Integration In One Organisation

A project alliance can be seen as a delivery method that integrates the demand and supply chain. Client, contractor, architect, consultant and even subcontractor can form a joint venture for the duration of the project [20]. For the duration of the project, the members form a temporary organisation that operates independently from the organizations that gave birth to it. The goal of the organisation is to deliver the project on time, within budget and with an acceptable level of quality, guided by the Risk/Reward scheme. The alliance members, including the client, make all decisions in relation to the project. In case of a dispute the members are kept to solving this internally. This can be done through multiple alternative dispute resolution methods [21].

The main contractors role during the process of construction is mainly focussed at facilitating and coordinating the production process. Subcontractors carry out most of the production nowadays [1]. Most subcontractors are contracted by the main contractor through traditional contracts, which means that the subcontractors are only asked to deliver as certain amount of production and not to utilise their specific knowledge for the benefit of the project. In project alliances it is possible to utilise this specific knowledge by integrating the subcontractor into the alliance [20]. By making the subcontractor part of the alliance, the subcontractors' profit will also be part of the Risk/Reward scheme, thus stimulating the subcontractor to collaborate with the alliance partners to deliver more overall value to the client [20]. This way specific knowledge of the subcontractor, which can have a decisive role in the project, can be integrated into the project.

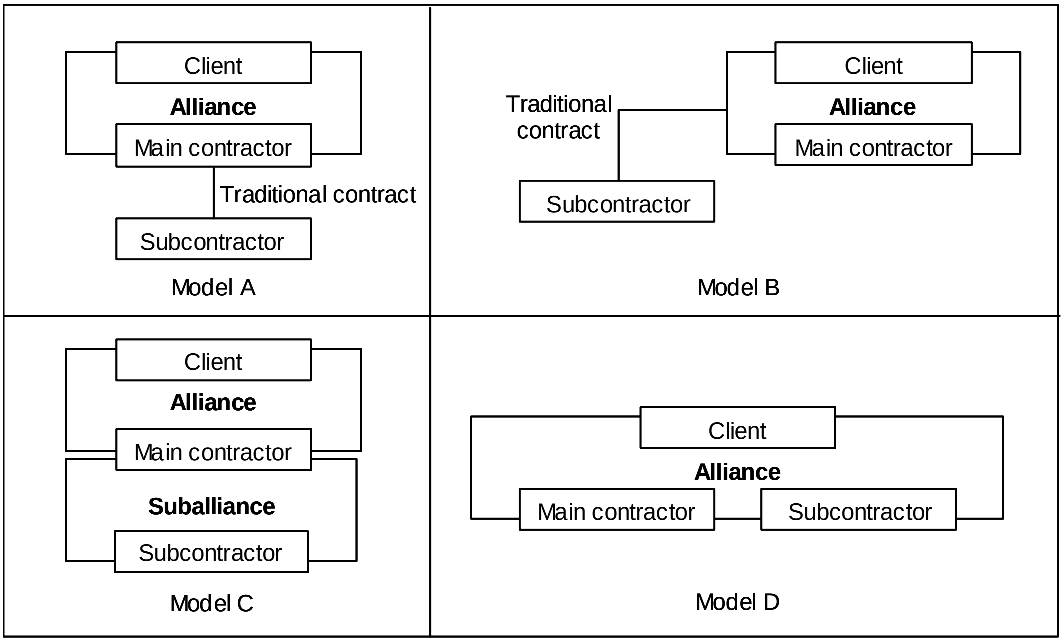

Figure 6: The position of the subcontractor in relation to the alliance [Based on 7, 20]

The position of the subcontractor in respect to the alliance can be realised multiple ways, these are [7] (see figure 6):

A. Subcontractor outside the alliance and under the responsibility of the main contractor (traditional contract);

B. Subcontractor outside the alliance and under the responsibility of the alliance (traditional contract);

C. Subcontractor as part of the alliance through a sub-alliance between the contractor and subcontractor;

D. Subcontractor as a full member of the alliance.

Model A and B represent the more traditional position a subcontractor can have in the building process. Models C and D represent possible ways to integrate the subcontractor into the alliance. In model C the subcontractor remains under the control of the main contractor, but will share in the possible risks, losses and profits of the alliance made on a particular part of the project (for instance the steel construction) for which the subcontractor is contracted. When the subcontractor is responsible for a large portion of the total work or the subcontractors' work can be seen as a critical part of the project, model D can be an option. In model D the subcontractor is part of the alliance as a full partner, this way the subcontractor will share in the full risks, losses and profits of the alliance. This will stimulate the subcontractor even more to work closely together with other partners in the alliance in order to deliver maximum value and thus receive maximum profit.

Models C and D can also be applied for the integration of suppliers and consultants with the alliance. This integration makes dynamic control of the supply chain reach far further than just the contractor.

7. Discussion and Conclusion

The project alliance delivery method can be seen as a first direction to achieve dynamic control of a project's value. It is done by the coupling of the value of a project with profit of the value supplying parties through the so-called Risk/Reward scheme.

The Risk/Reward scheme puts an incentive on the value of the value demanding parties. The incentive should be placed in such a way that there will be no profit for the value supplying parties as this value reaches minimum acceptable levels. Extra profit can be gained by supplying extra value to the value demanding parties. This way the Risk/Reward mechanism supports the concept of dynamic control, because the value supplying parties will always search for solutions that will optimize their profit and thus stimulate the delivery of extra value.

One of the more important steps that have to be taken in order to make project alliances (and dynamic control) possible is to open up the development stage of a project. During the development stage value demanding and supplying parties should be able to work together on maximising the possible outcome of the project. This means that the development phase should be placed after the selection phase and that the selection should be based on the quality a value supplying party could deliver into the project.

In a project alliance demand and supply chain are integrated to the extent that they form one organisation for the duration of the project. The goal of the organisation is to deliver the project on time, within budget and with an acceptable level of quality, guided by the Risk/Reward scheme.

Subcontractors, suppliers and consultants can play a decisive role in the success of a project. In order to fully utilise their specific knowledge for the benefit of the project they should be made part of the alliance. In this way the subcontractors', suppliers' or consultant's profits are made dependent of the success, thus stimulating full dedication. Subcontractors, suppliers and consultants can made part of the alliance by the means of a sub-alliance or by making this party a full member of the alliance. By doing this dynamic control further into the supply chain is made possible.

Project alliances should be seen as a starting point from which we can further develop the dynamic control of construction projects. In order to develop dynamic control into the lifecycle of a building, further research is necessary. The first direction given is that dynamic control can only be fostered by procurement methodologies that leave room for value being developed in a dialogue between value demanding and value supplying parties. Selection methodologies will need to address other issues like fit for project, alliance thinking, collaboration, creativity, past performance and so on. In order to be able to select a contractor (or other party involved in the project) that is able to deliver maximum value for the value demanding party. Performance based procurement [18] for instance aims at selecting high performance contractors who deliver value against competitive prices.

Integrated project delivery asks for high performers who are able and willing to collaborate with the client in order to deliver maximum value to the client and optimise the possible profits. This could be further stimulated by having the alliance deliver multiple projects instead of one. This implies the formation of a strategic alliance [16]. By having multiple projects being developed by the same alliance, the partners will be more willing to keep good relations between each other. Further, the learning effects of the first project could be stored into the alliance and utilised for the benefit of the following (similar) project. Not only will the organisation of the alliance will become better structured and adjusted, mistakes made in the first project will be prevented in the following projects.

This concept should be further developed over the lifecycle of a project. Data about the lifecycle costs and performance of a building should be gathered and used by the construction of the following similar project. When this is done within a strategic alliance, the possible benefits during construction period and the lifecycle can be utilised fully to the benefit of the value demanding parties.

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Procurement Methods are Not Set-up for Lowest Cost!

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Abstract

This paper argues that general contractors' procurement methods in the Finnish construction industry are generally focusing only on a small part of cost, namely, on the seller's margin of the product price. The margin is often only a few percentages in some cases it may be up to 15% of the product price. The rest and the major part of the product price consist of labour and material costs, and overhead. The general assumption is that the market forces suppliers constantly to reduce labour, material, and overhead cost in order to stay competitive hence it is enough if buyers of building products such as contactors and owners have means to identify the lowest market price. However, evidence demonstrates that in many cases buyers of construction products can significantly impact on suppliers' labour and material cost; and moreover, on the process cost. Still, current procurement methods are lacking systematic methods to address other costs than margins.

This paper proposes a framework for buyers based on Transformation-Flow-Value theory and lean methods to reduce both process and product cost during the procurement phase. Here the supplier and buyer aim in collaboration to reduce waste from the supply chain installed. Waste is a non-value adding activity such as, inventories of goods awaiting for further processing or consumption, unnecessary production, unnecessary transport of goods, defect products, design of goods and services that fail to meet user’s needs, and make-do. With help of examples in procuring wood-framed windows and pre-fabricated concrete elements, it is demonstrated that certain waste can only be reduced through supplier-buyer collaboration. The savings from the reduced waste can be significantly larger than what can be reached in traditional procurement through competitive bidding based on nominally complete plans and specifications.

Keywords: Procurement, market price, supply chain, lean construction

1. Introduction

In construction, procured material and labour can be up to 70% of project cost [1, 2]. In Finland, the large general contractors source mainly with help of annual purchasing agreements, where unit prices are set for a pre-determined time period; or through the spot market, where products and services are bought based on the prevailing availability and lowest cost. However, in both cases, when the supplier is selected, the product price is the decisive factor and the transaction cost and the cost of waste are not considered. The transaction cost consists of the cost of specifying the details of procurement contracts, the cost of discovering what prices should be, the cost of negotiating the procurement contract, and the cost of monitoring the fulfilment of contract [3]. Several studies has shown that the transaction cost can be significant, 10% or more, of the product price, e.g., [4, 5, 6, 7]

Waste is a non-value adding activity [8] such as, inventories of goods awaiting for further processing or consumption, unnecessary production, unnecessary transport of goods, defect products, design of goods and services that fail to meet user's needs, and make-do. In mid 90s, the Swedish construction company, Skanska, studied how much non-value adding cost where embedded in various material deliveries in the Swedish construction industry. In the study it was found that a large part of the cost is waste, e.g., if gypsum board cost 100 the non-value adding part of the delivery cost is 140 (Figure 1), hence the actual price of gypsum board as it reaches its final consumption on site is 240 [9].

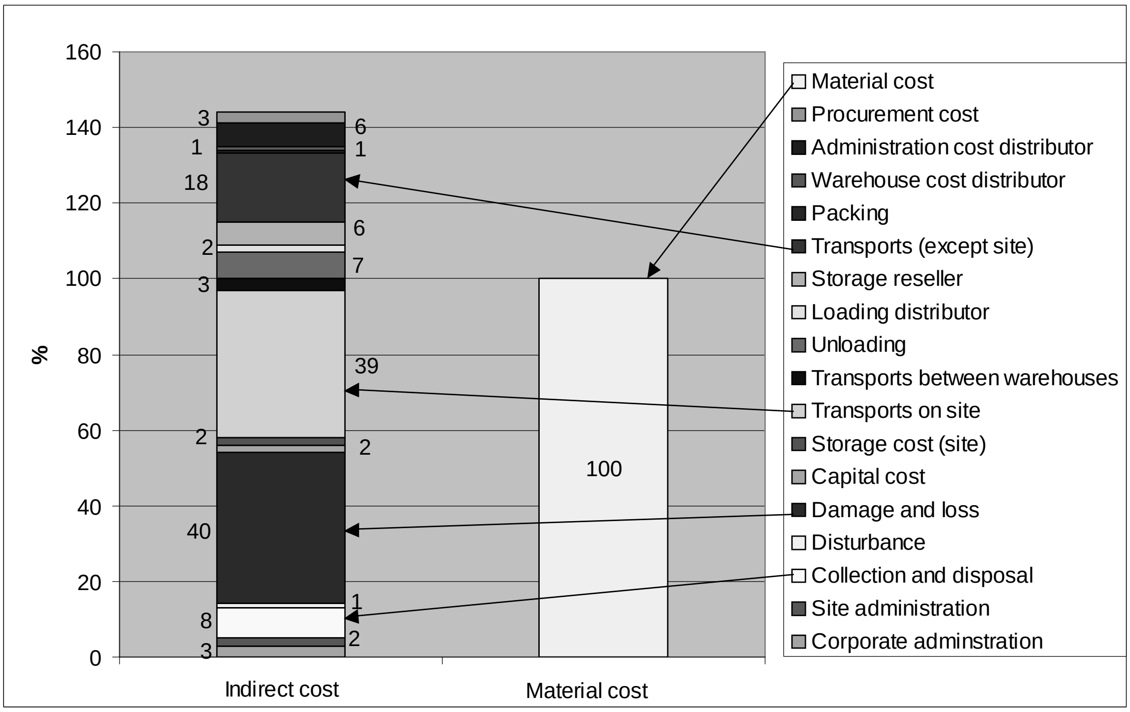

Figure 1: Indirect and direct cost for gypsum board [9]

In construction, one reason why the transaction cost and waste are poorly considered is that they are tedious to capture thus their value tend to be underestimated. Also, even if there is a sense of the magnitude of the costs; there is a lack of means to address them. The purpose of this paper is to present a framework that captures the transaction cost and waste during the procurement phase.

Next, a brief description of the key concepts, some case examples, followed by a description of the framework. Finally, the paper ends by discussion and conclusion of the preliminary findings.

2. Theory

2.1 Lean Construction

Lean construction was sparked by two main motives. First, the construction industry had long been criticized for lacking a production theory, which by several scholars, e.g., [10, 11], have been considered as the reason for poor performance of the industry. Second, the extraordinary achievements in “lean manufacturing” inspired scholars in the construction industry to rethink lean production methods and tools to project-based production, such as construction. Even if the term lean manufacturing was coined in 80s the underlying theory of lean manufacturing was not explicitly explained until Koskela [12] studied production theories in-depth. He identified at least three different conceptualizations of production that have been used, namely; transformation, flow, and value (TFV). Further, he argued that all three conceptualizations are necessary and should be used simultaneously. These concepts form the theoretical foundation of the TFV theory. According to the TFV theory, the design, control, and improvement of production should be conducted as an integration of transformation, flow, and value concepts and not as alternative concepts [12].

The concept of transformation is based on the idea that production is conversion of inputs to outputs and the goal is to make the transformation as efficient as possible. Although this concept has dominated the construction industry, it has severe shortcomings. It does not aim to reduce wasted resources and does not focus explicitly on customer requirements [12]. The flow concept recognizes that production consists of inspection, waiting, transportation as well as transformation [12]. The first three factors are non-value-added; hence, they should be eliminated. Ohno [13] and Shingo [8], who termed non-value-added tasks “waste”. Ohno [13] and Shingo [8] observed that by merely eliminating waste from the production system, significant productivity improvements were achieved. The goal of the value concept is to generate best possible value to the customer, based on his requirements [12]. Value is not the same as quality. Quality is an assessment of how well customer needs are met, whereas value can be understood to also include the sacrifice to meet the needs [15] (Table 1).

Table 1: Summary of TFV theory [16]

	Transformation concept	**Flow concept**	**Value concept**
Conceptualization of production	As a transformation of inputs to outputs	As a flow of material composed of transformation, inspection, moving, and waiting	As a process where value for customer is created through fulfillment of his requirements
Main principle	Getting production realized efficiently	Elimination of non-value-added activities	Elimination of value loss
Methods and practices	Work-breakdown structure, MRP, organizational responsibility chart	Continues flow, pull, production control, continues improvement	Methods for requirement capture, quality function deployment
Practical contribution	Taking care of what has to be done	Making sure that unnecessary things are done as little as possible	Taking care that customer requirements are met in best possible manner

2.2 Procurement Based on Transformation (T)

Procurement is a process that defines what, when and how much to purchase and ensures that what is required is received timely according to the specifications [17]. Project Management Institute's PMBoK [18] identifies as the major process in procurement: procurement planning, solicitation planning, solicitation, source selection, contract administration, and contact close-out (Table 2). PMBoK's description of procurement is a based on transactional contracting. In construction the contracts are typically transactional contracts [19], where contracts are short and limited, and past or future relations between the parties are not considered [20]. PMBoK's description of procurement is a good example of the application of the transformation concept, where the focus is to transform inputs to outputs, without explicitly considering on reducing process waste and customer requirement (primary focus on contract requirements). The contract and its follow-up are the key outputs.

Table 2: PMBoK's procurement processes

Major process	Description
Procurement planning	Determine what to procure and when.
Solicitation planning	Documenting product requirement and identifying potential sources.
Solicitation	Obtaining quotation, bids, offers and proposals as appropriate.
Source selection	Choosing from among potential sellers.
Contract administration	Ensuring that seller's performance meets contractual requirements.
Contact close-out	Completion and settlement of the contract, including resolution of any open items.

2.3 Procurement Based on TFV

Procurement may generate significant amount of waste. If procurement is performed according to PMBoK, it forces upstream players to commit early to design solutions and to pursue large design batches. The design cycle time becomes long thus the probability of changes increases and the change-order process is typically tedious and disputes are common [7]. From a supply chain approach, where the product detailing, procurement, manufacturing, shipping, and site installation of the product is included (Figure 2), most of the time is pure waiting, and re-designing and re-work are common [7, 21]. The design is driven by the need for contract documents not actual site conditions. Also, it is rare that detailing, manufacturing, and site installation are performed in the same sequence and batch sizes (e.g., [22]).

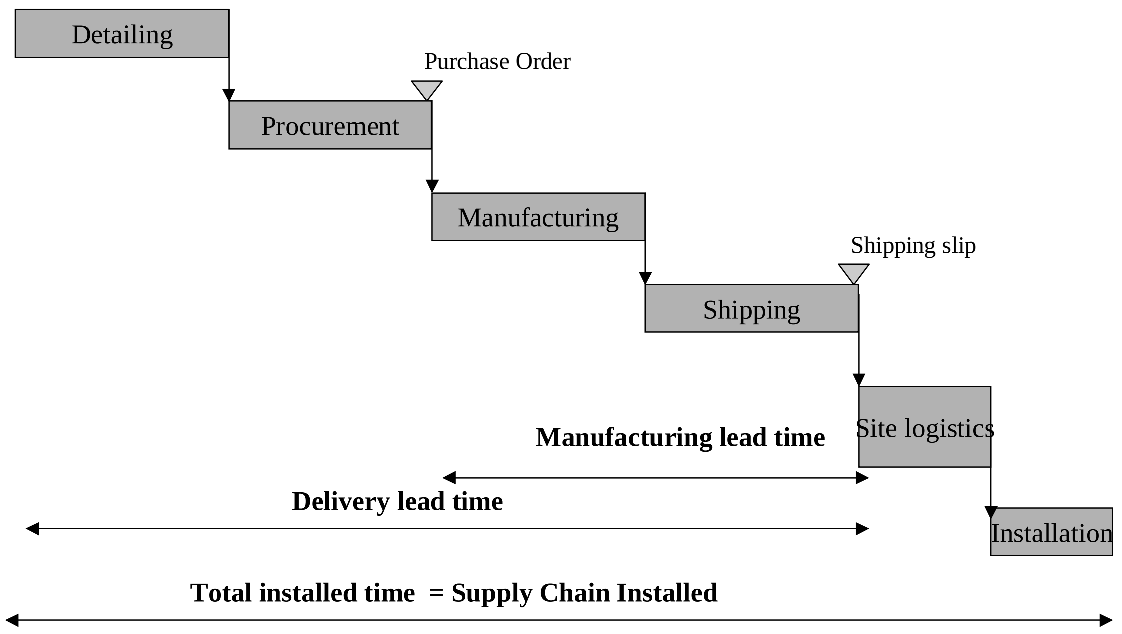

Figure 2: Phases of supply chain

This does not mean that the transformation approach is not needed rather than there has been too much focus on the transformation and too little focus on the flow and value concept. From a flow approach the procurement should be conducted so that it reduces process waste. In waste reduction, the main principles are to reduce variability and overall lead time [12]. From a value approach the procurement should be conducted so that the customer requirements are fulfilled. The nature of project-based production is iterative; where as the process progresses more information and knowledge become available. Consequently, project stakeholders' requirements sharpen and may even change. Therefore, it is of value not only to fulfil the initial requirements but also be able to fulfil by minimum waste customer requirements that result from the "organic growth" or change-orders. In summary, in procurement based on TFV, all three concepts are included, and the main emphasis would be on flow and value (Table 3).

Table 3: Procurement based on TFV

Approach	Description
Transformation	Procurement is able to efficiently turn product specification and delivery requirements to products that are ready to install.
Flow	Procurement generates minimum waste in supply chain.
Value	Procurement is able to maximize customer value throughout the project including the organic phase.

3. Case examples: Procurement based on T

The two case examples are randomly chosen without a special intention to find worst or best cases rather they are cases that probably every practitioner can assimilate to.

3.1 Wood-framed Windows

The company A has procured wood-framed windows from company B. The focus is on product price; hence, the process cost is forgotten. As a result, plenty of waste in the process is generated, which can be picked-up from the correspondence between the two companies:

- Building permit April 2004 (master schedule and project completion date set)
- 27.5.2004, company A informs company B windows needed beginning of September, 2004 (Company B makes capacity reservations at the plant)
- 12.8.2004, company A informs company B windows needed beginning of December, 2004 (Company B re-schedule capacity)

- 2.11.2004, company A informs company B windows needed beginning of December, 2004

- 3.12.2004, 200 windows ready by company B.

- 11.12.2004, company A informs company B windows needed beginning of January, 2005 (Company B runs out of storage space)

- 14.12.2004, windows are delivered to logistic centre

- 11.01.2004, company A informs company B windows needed mid February, 2005

- 19.01.2004, window installer expects installation starts, mid March, 2005

The original schedule was 27 weeks wrong and the windows waited 19 weeks in "logistic centre". The supply chain installed was 84 weeks and manufacturing lead time 4 week. The process cost was significant but never addressed.

3.2 Pre-fabricated Concrete Walls

This project was on a strong schedule pressure and the structural and the MEP engineers were working significant overtime and in an irrational engineering sequence to meet the milestones set during the procurement by company C (contractor) and company D (supplier). As result, there were expensive design details, particularly caused by lack of time during detailing; and waste, particularly waiting (Figure 3, Figure 4). Interestingly, some pre-fabricated elements that waited (element details and ready elements) 100 days or more; and still, there was a rush! This is another example where procurement was based on T and product price but the process cost was ignored. The design paid a price but also company C, the buyer, because of the expensive design solutions and indirectly for the capital tied in ready products waiting to be installed.

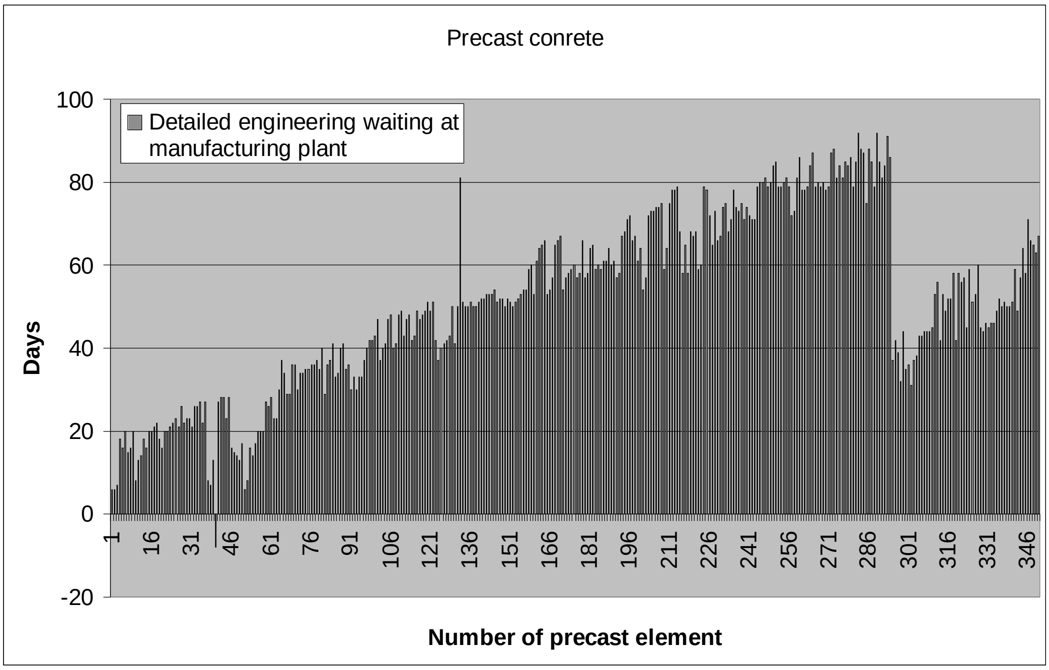

Figure 3: Waiting of detailing at manufacturing shop

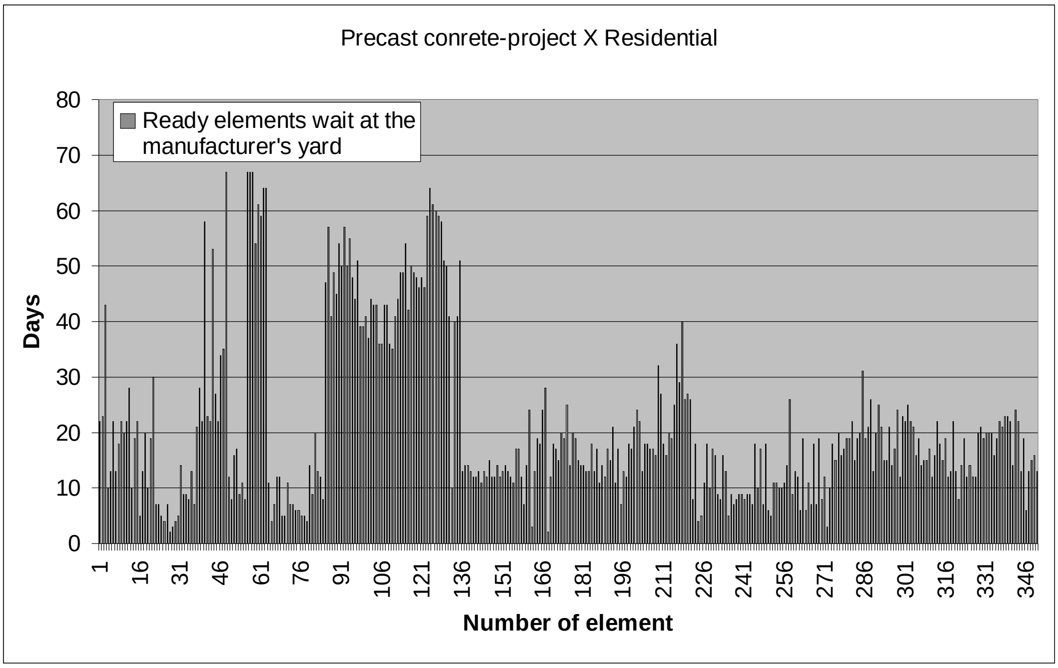

Figure 4: Waiting of ready elements at the manufacturer's yard

4. Framework for "Lowest Cost" Procurement

This section provides an alternative to procurement based on T. The alternative aims to consider TFV simultaneously in procurement. The cost scope of the framework is either Total Installed Cost (TIC) or Total Cost of Ownership (TCO), depending on how much contractors and suppliers are able to influence customer requirements[1]. In TIC, the cost of installing the equipment to its final location in the building is considered along with purchase price, logistics cost, and transaction cost (e.g., the time and effort needed to exchange data between the buyer and the supplier during design, detailing, on-site assembly, and start-up). TCO is the broadest definition of cost. It includes transaction costs product purchase price, shipping cost, operation and maintenance cost, and disposal costs [21]. The framework of the "lowest cost" procurement is described in Figure 5. Essential is that the procurement process is designed, controlled, and continuously improved.

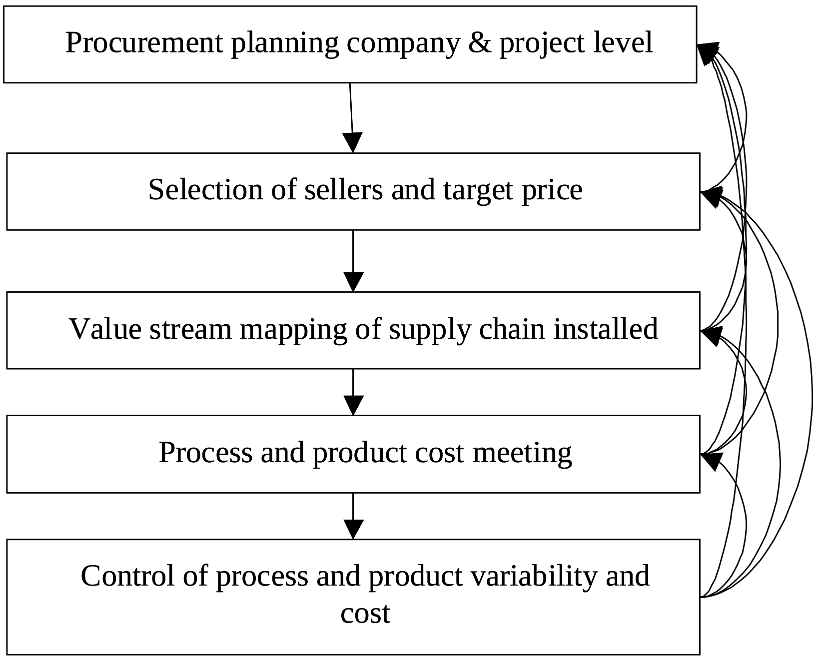

Figure 5: Framework for "lowest cost purchasing"

4.1 Procurement Planning Company and Project Level

The procurement planning is separated between company and project level so that innovation and volume can properly be addressed. On company level, procurement planning is conducted on those items, where multiple projects will benefit, e.g., where product innovation and close co-

[1] In some instances the building code, municipal, and owner may have defined specification prior to contractor or supplier involvement; therefore, TCO may not always be fully applicable.

operation between supplier and contractor are needed, and where purchasing power of multiple projects can be applied. Project level planning addresses project specific needs, what is needed and when.

4.2 Selection on Sellers and Target Price

The selection of suppliers is based on supplier reliability and TIC or TCO. The reliability is described in sub-section 4.5. The target price of a product or service is set in prior to the value stream mapping. The target price is based on past projects, or in some cases, a supplier is consulted.

4.3 Value-stream Mapping of Supply Chain Installed

In value-stream mapping each task from specifying the product to installation (Figure 2) is in detailed mapped out (see [7] for detailed value stream mapping). The mapping provides a tangible opportunity to address flow and value issues. In mapping important characteristics are the visualization of hand-offs between organizations by clearly separating organizations from each other and the use of a minimal amount of symbols for clarity. Besides tasks and their inter-dependencies, inputs and outputs, also time is mapped out. The time mapping includes the lead time of the supply chain installed and each tasks duration.

4.4 Process and Product Cost Meeting

After the target price is set and the value stream mapping is completed, both product and process costs can be estimated. The process cost is calculated from the labour hours consumed in the process excluding manufacturing or installation hours. Based on the estimated process and product cost process participants will meet to find ways to reduce both product and process costs. Besides the contractor and supplier the meeting often requires a representative of the particular engineering discipline and/or architect depending on the purchased item.

4.5 Control of Process and Product Variability And Cost

In order to continuously improve the procurement and to lower TIC the actual procurement process and installed product is measured and compared to the planned. The root causes of variability is captured and used to control variability in future procurement initiatives.

5. Discussions

The author is currently working with an architect, a contractor and a window-frame manufacturer and installer according to the proposed framework. Currently the team has advanced to the forth stage, process and product cost meeting. So far, the contractor has chosen wood-framed windows to be a company level purchase item, where innovation and consolidating company wide volumes are considered beneficial. The seller has been identified and target prices have been set based on historic data. The value stream mapping has been completed. So far, with help of object-oriented product libraries, the information flow between parties has significantly improved as well as the task durations for the stakeholder, e.g., the architect needs only a third of the labour hours required before for the detailing, and the procurement needs only a tenth of the labour hours required before in purchasing. Currently the team is working on finding means to reduce more waste and product cost (manufacturing). The team has identified major opportunities in reducing waste thus increasing the productivity in the site installation. A major issue is to share real-time production schedules between the stakeholders and to increase reliability. This requires close co-operation among the manufacturer, installer, and contractor. The major challenge has been the slow pace of change. Even if there are good ideas that the team has found, the implementation of these ideas to multiple organizations is tedious. Also, although success is achieved in one project it still does not mean that other project teams will change their current practice.

6. Conclusions

In the Finnish construction industry, it is not typical that transaction and process cost (waste) are considered during the procurement phase. One of the reasons is that procurement is based on the transformation concept. As a result, there seem to be a significant opportunity to reduce procurement cost that goes far beyond in just cutting suppliers' margins. A framework was proposed to address also the flow and value concepts during the procurement phase. Key parts of the framework are value stream mapping and control of variability. Although the framework has been only partially tested and the framework may still change as it is applied, the preliminary results have been encouraging. There has already been significant reduction in transaction cost. Currently, the target is to reduce waste and product cost of the wood-framed windows. This may require moving from transactional contracts to relational contracts.

In addition to wood-framed windows, the author is applying the proposed framework for the MEP and site prep supply chains. However, these studies are still in an early phase. Future research is needed to better understand how flow and value concepts can be used during the procurement phase. Also, more data needs to be collected about transaction cost and waste caused by procurement. It is time to fundamentally re-think the procurement in the construction industry, and continuously work for lower cost, and not just hunt for "low" spot market prices.

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Barriers and Opportunities for Offsite in the UK

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Abstract

The UK still falls behind most equivalent economies in terms of the take-up of industrialisation in construction and techniques such as offsite construction. Interest in the UK in industrialisation and offsite has recently been increasing however, partly attributable to the increased demand for housing, and pressure by Government and industry to improve the performance of the UK construction industry, particularly its efficiency, quality, value and safety. This paper discusses the views of the UK construction industry on offsite. This work has been conducted by Loughborough University as part of a DTI and UK industry funded research programme on offsite technologies and prefabrication called prOSPa (*promoting Off-Site Production applications*).

This paper presents results from a recently completed questionnaire survey on offsite and prefabrication in the UK. A preliminary survey was used to guide and inform the development of a main survey involving three different questionnaires in order to target the three main groups of stakeholders involved with offsite - suppliers/manufacturers, contractors and designers/clients.

More than 90% of the respondents had used some type of offsite or prefabrication in at least one of their projects. Demand for offsite is clearly increasing in the UK and nearly three quarters of the suppliers surveyed thought that take-up of offsite by industry was increasing in their sector. The biggest advantages of offsite compared with traditional construction were thought to be the decreased construction time on site and increased quality. The belief that using offsite is more expensive is clearly the main barrier to its increased use.

Keywords: Offsite, offsite production (OSP), survey, questionnaire, prefabrication, industrialisation

1. Introduction and Background

This paper investigates the views of the UK construction industry on offsite production and technologies. It provides an indication of the opinions of the different sectors within the industry, including clients, designers and contractors, as well as the suppliers of offsite systems and components. Due to the fragmented nature of the UK construction industry it is not practical to assess the views of every organisation in every sector and so this study aims to provide a snapshot of the UK construction industry's views on offsite at the current time.

This paper is based upon research carried out by Loughborough University as part of the DTI and industry funded prOSPa research programme, which commenced in July 2003. The prOSPa consortium is composed of Co-Construct members (BSRIA, CIRIA, The Concrete Society, SCI and TRADA Technology) and Loughborough University. The programme aimed to promote appropriate applications of offsite and thus help improve the performance of the UK construction industry.

Although interest in offsite has been increasing in this country in recent years, the UK still falls behind most equivalent economies in terms of the take-up of modern methods of construction (MMC) such as offsite. This increased recent interest in offsite in the UK is partly attributable to the increased demand for housing and to pressure by Government and industry to improve the performance of the UK construction industry, particularly its efficiency, quality, value and safety.

There is almost a consensus amongst major developers over the need for more prefabrication in the future, in contrast to the actual amount employed, and it is the public sector client groups that are currently leading the way in the introduction of radical new systems [1].

For this study, offsite is defined as the manufacture and pre-assembly of components, elements or modules before installation into their final location [2]. Many terms have been used in the past to define and describe offsite, and many of these are still used today, including Off-Site Production (OSP), Off-Site Fabrication (OSF), Off-Site Manufacturing (OSM), Off-Site Construction (OSC), pre-assembly and prefabrication. This plethora of terms can at first be confusing for both the non-expert and expert alike, and so for this study we used offsite.

2. Methodology

The data for this study was obtained from four main sources of data:

1. a detailed review of existing recent surveys and publications on the subject;
2. a preliminary questionnaire survey of six organisations;
3. a main questionnaire survey of 75 UK construction organisations, including clients, designers, contractors and offsite suppliers and manufacturers;
4. a workshop held on the 6th July, 2004 by the prOSPa Programme Steering Committee to debate and refine the main findings of the survey.

Three different questionnaires were used for the main survey, one for clients and designers, one for offsite suppliers and manufactures and one for contractors. Although the majority of the questions were the same, a proportion of the questions were specifically targeted at the different industry sectors. 75 main survey questionnaires were completed and returned, including 39 from clients and designers, 13 from contractors and 23 from offsite suppliers and manufacturers. The types of organisation who participated in the main survey are shown in Table 1.

Table 1. Type of organisation.

Organisation type	% of respondents
Client / end user	27
Specialist supplier	24
Other	24
Main contractor	19
Architect / Designer	13
Specialist consultant / designer	12
Project / Construction Managers	8
M&E consultant / designer	4
Maintenance contractor / FM	1

Note: Some respondents selected more than one category.

The main '*Other*' types of organisation listed by respondents included multi-discipline consultants, modular building manufacturers and specialist sub-contractors.

Several other studies from the last three years have examined different aspects of the offsite industry in the UK and the results of these reports have also been included within this study where relevant [1, 3, 4, 5].

3. Results

3.1 Respondents Experience of Offsite

The overwhelming majority of the respondents from all the sectors had used some type of offsite in at least one of their projects (Table 2). A very small proportion of the client/designers had not used offsite before and 8% of the contractors surveyed were not sure if they had or not.

Table 2. Percentage of respondents who have used offsite on any of their projects.

	% of respondents	
	Clients/designers	**Contractors**
Yes	97	92
No	3	0
Maybe	0	8

Figure 1 shows the type of offsite product or system which is most commonly considered for construction projects by the clients and designers, and contractors in this study. Most of the types of offsite were used by more than half of the clients and designers surveyed, with framing systems, volumetric modular buildings, cladding systems and bath/toilet/kitchen pods all being used by approximately 70% of the respondents. More than half of the contractors surveyed had also used most of the types of offsite listed, with the exception of volumetric modular buildings and building services, which had been used by less than half of the contractors surveyed.

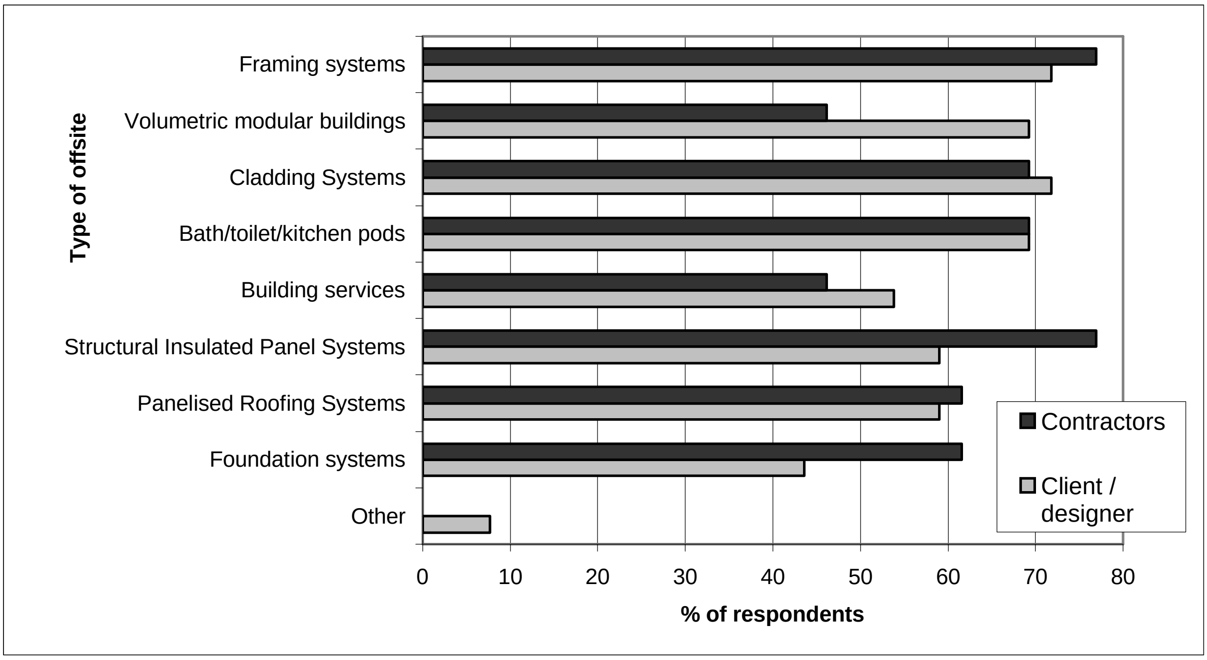

Figure 1. Type of offsite most commonly considered for projects.

3.2 Advantages, Barriers, Drivers and Take-up of Offsite

The majority of clients and designers surveyed (73%) claimed that they were sufficiently aware of the relative advantages and disadvantages of offsite over traditional construction, compared with just over half (54%) of the contractors surveyed. However, less than a third (30%) of the suppliers questioned thought that their customers were aware of the relative advantages and disadvantages of offsite over traditional construction.

This difference in awareness and knowledge of offsite is a frequent source of frustration for suppliers, with customers believing that they are aware of the relative advantages and disadvantages but suppliers knowing, or believing, that they are not. Some suppliers believe that there is an extraordinary lack of understanding in all sectors of the construction industry for the full benefits that offsite can bring and that the general understanding of offsite to some people just means volumetric modular boxes, usually grey. Many customers in the industry routinely use products and methods such as precast concrete without appreciating that this is a form of offsite. Conversely, some contractors complain that suppliers are not always fully aware of how tendering works in traditional construction, what the price means in contractual terms, and the importance of early notification if anything is done in the design development that will cause costs to rise.

The biggest advantage of offsite compared with traditional construction is thought to be the decreased construction time on site. This was stated by about 90% of respondents, including clients, designers and contractors (Table 4). Unsurprisingly, this factor is of particular benefit to contractors, with 69% ranking this as their number 1 advantage. Increased quality also ranked highly by all respondents. A more consistent product and reduced snagging and defects were also seen as advantages by the majority of respondents, although more so by the clients/designers than by contractors. Of the remaining possible advantages, a higher percentage of the client and designer respondents selected each of the possible advantages compared with the contractors who responded. This probably reflects the higher proportion of clients and designers compared with contractors who said that they were aware of the potential advantages of offsite.

Table 3. Advantages of offsite.

Advantages	Clients/designers		Contractors	
	% of respondents	% as 1st choice	% of respondents	% as 1st choice
Decreased construction time	87	38	92	69
Increased quality	79	28	77	15
More consistent product	77	18	54	0
Reduced snagging & defects	79	8	69	0
Increased value	51	5	23	0
Increased sustainability	49	3	31	0
Reduced initial cost	44	3	15	8
Reduced whole life cost	41	0	15	0
Increased flexibility	33	0	15	0
Greater customisation options	33	3	0	0
Increased component life	28	0	15	0
Other	18	15	8	8

Much research has been conducted into the barriers, both perceived and real, that are hindering the increased uptake of offsite in the UK construction industry. The study by Robert Gordon University [1] was based upon the premise that house buyers are so strongly influenced by negative perceptions of post-war ‘pre-fab’ that they will resist any innovations in house construction which affect what a ‘traditional’ house looks like.

The main barriers found in this survey stopping clients/designers and contractors from using more offsite are presented in Table 4.

Table 4. Main barriers hindering the increased use of offsite.

Barriers	Clients/designers		Contractors	
	% of respondents	% as 1st choice	% of respondents	% as 1st choice
More expensive	67	54	77	38
Longer lead-in times	46	8	62	8
Client resistance	38	13	31	23
Lack of guidance and information	33	5	46	0
Increased risk	36	0	15	0
Little codes & standards available	33	3	23	0
Other	31	18	15	8
Negative image	28	0	46	8
Not locally available	18	5	15	0
No personal experience of use	18	3	38	15
Obtaining finance	18	3	8	0
Insufficient worker skills	21	0	23	0
Reduced quality	13	0	15	0
Restrictive regulations	13	0	31	0

The belief that using offsite is more expensive than traditional construction is clearly the main barrier to the increased use of offsite in the UK, even though a large proportion of the respondents thought that one of the advantages of using offsite was both a reduced initial cost and a reduced whole life cost (Table 4). Suppliers often argue however, that offsite is not more expensive as costs are not compared in the right manner in order to take into account advantages such as reduced on-site construction time and economies of scale [3]. This issue is also addressed by the IMMPREST (*Interactive Method for Measuring PRE-assembly and STandardisation benefit in construction*) tool developed by Loughborough University, which seeks to provide a framework for comparing solutions in a holistic manner. Other advantages such as increased quality and reduced snagging are rarely included in costings and many projects are still judged purely on first or initial cost, either intentionally or unintentionally.

Longer lead-in times were also a significant barrier to clients, designers and contractors. This was a barrier to a higher proportion of contractors however, presumably because the use of offsite could delay the beginning of the project on site.

Who usually drives the idea of using offsite for a particular project depends upon who you speak to, as can be seen in Figure 2. Clients and designers think that it is the client who usually drives the use of offsite on a project, together with the contractor, designer and architect. Contractors however, feel that it is more themselves and the architect who are the drivers. Suppliers on the other hand, think they themselves are one of the drivers, together with the client and the contractor and that the designer and architect are less so.

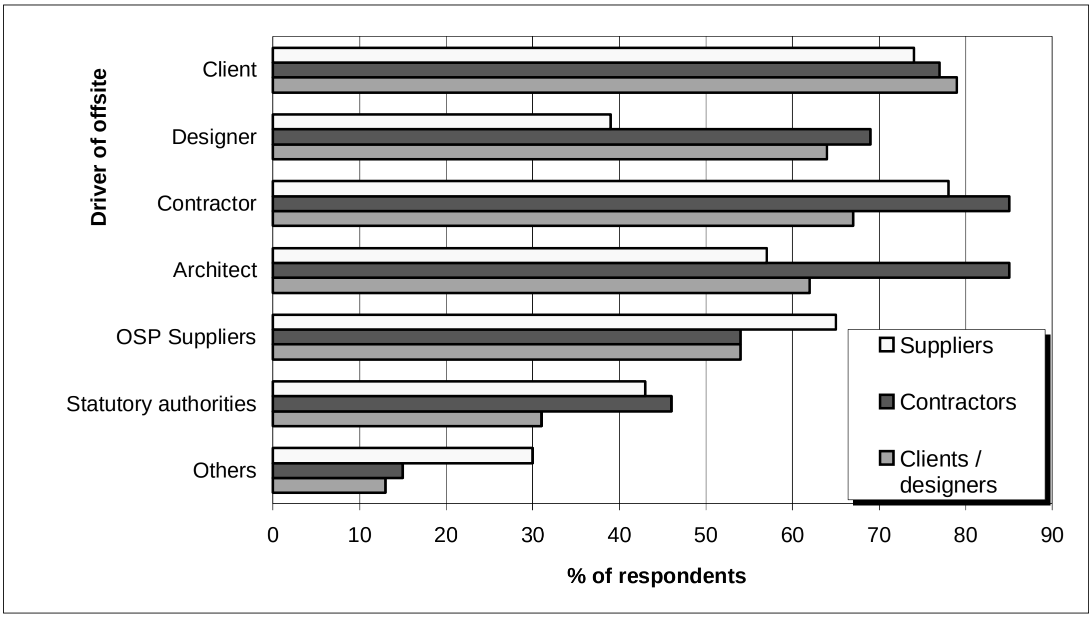

Figure 2. Main driver of offsite on a project.

3.3 Supply and Demand of Offsite

Nearly three quarters of the suppliers surveyed thought that take-up of offsite by industry was increasing in their sector, and only one respondent thought that it definitely was not. This agrees with other reports, which predict growth of 9.7% per annum (by value) by 2010 [4].

The main barriers stopping clients/designers and contractors from using more offsite were discussed earlier and presented in Table 5. Suppliers were therefore asked what means they used in order to overcome their clients' resistance to the use of offsite. The main method used was the provision of examples and case studies of previous successful uses of offsite (Table 9). The other main methods included client experience and increased partnership and marketing, all different ways of informing, educating and/or convincing the client of the possibilities and advantages of offsite. Reductions in price were only used by about a quarter of the suppliers in this survey, even though the increased expense of offsite was the main barrier to use quoted by clients/designers and contractors (Table 5). The majority of suppliers presumably sold the use of offsite on other factors such as speed of construction, quality and value rather than cost.

Table 5. Overcoming clients resistance to offsite.

Means of overcoming resistance	% of respondents
Provision of examples / case studies	68
Client experience	55
Increased partnership arrangements	55
Increased marketing / information	50
Price reductions	27
Other	23

3.4 Refurbishment

The suppliers in this survey were asked what percentage of their work was attributed to new build and how much to major refurbishment and maintenance. All of the suppliers were involved in new build, with almost 60% of the respondents being involved in new build *only*. About 40% of the respondents also supplied products for major refurbishment but only one supplier surveyed supplied products for maintenance.

When asked if the suppliers thought that there *was* a market for offsite in refurbishment in the UK, only about one third said definitely yes (Figure 4). Interestingly, this proportion was less than the number actually currently supplying products for this market. More than half of the suppliers surveyed were not sure if there was a market for this in the UK or not. This could be due to these suppliers waiting to see how the market for refurbishment develops before deciding what to do.

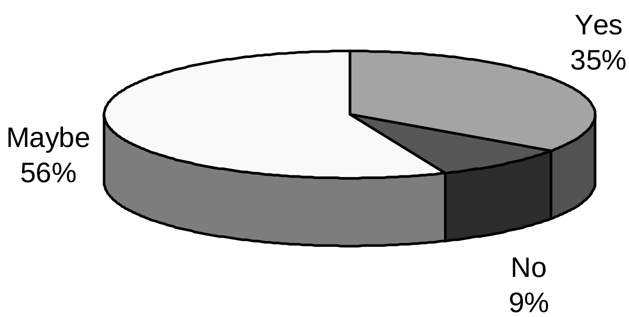

Figure 3. Proportion of offsite suppliers who thought that there was a market for offsite in refurbishment in the UK.

In recent years however, nearly half of all construction expenditure in the UK has been spent on refurbishment and repair compared with new construction. Furthermore, in the house building sector this proportion rises to approximately two thirds [6]. Refurbishment and repair is therefore a potentially large market for offsite in the UK into which it has already made some progress, but for which there is potential for significantly more. Not all of this market is suitable or practical for the application of offsite however, as a significant proportion can be classified as domestic DIY, but potential still exists for further expansion within this sector.

3.5 Labour and Skills

The UK construction industry has a historically low level of training compared with other countries and it is estimated that between 70 and 80% of the workforce in construction in the UK has no formal qualifications [7]. A large proportion of the workforce are labourers, many of them self-employed, and their skill-base is narrow and their training is limited. There is also an estimated annual turnover of between 65000 and 75000 people per annum in the UK construction industry [8].

Electricians, joiners and bricklayers were the three skills generally cited the most by all the sectors questioned as being in short supply and contributing to the increased demand for offsite products (Table 12). Contractors seem to be feeling the effects of the skills shortage as plumbers were the only trade which they felt was not increasing the demand for offsite to a significant degree. Conversely, the majority of suppliers thought that the lack of concreters, steel erectors and steel fixers contributed little to the increased demand for offsite. The other main skill mentioned by respondents which was not on the list was plasterers, which also seem in particularly short supply.

Table 6. Skill shortages contributing to the increased demand for offsite.

Skill	**% of respondents**		
	Client/designer	**Supplier**	**Contractors**
Electricians	65	38	67
Joiners	59	76	83
Bricklayers	44	71	58
Steel-fixers	35	19	42
Steel-erectors	32	10	33
Other	29	48	42
Concreters	26	10	50
Plumbers	12	33	8

It would seem at first that, with this general lack of skills, the UK construction industry would be perfectly placed for the increased use of offsite. Clarke [9] reports however, that a skilled workforce is required to enable innovations such as offsite to be applied. Workers here in the UK are generally not provided with an initial broad-based training after which they specialise. Instead, they are usually trained for just one role which consequently makes adapting and multi-skilling difficult, which is what is required for an increased uptake in offsite.

All respondents were asked what steps they thought could be taken by manufacturers, trade bodies and/or the Government to encourage people to enter careers in offsite in order to reduce the skills deficit. More written responses were received to this question than any other in this survey, reflecting both the importance and the far-reaching consequences of the skills deficit.

The two subjects that were mentioned most frequently were training and education and raising the awareness of offsite. Respondents mentioned that investment was needed in training and education at all levels, from school leavers through to university courses. The lack of, and need for, modern apprenticeship schemes was mentioned up by several respondents, as was the need for NVQ’s in offsite and multi-skilling. Government training grants were suggested by several respondents, both for offsite manufacturers and for training colleges. Partnerships between local colleges and offsite suppliers were also discussed, as was the inclusion of offsite topics in University courses for building professionals. Raising the awareness and increasing the perception of offsite, particularly to clients and the general public, was mentioned by several respondents in order to relieve the technology of its poor historical ‘pre-fab’ image. This could be done by promoting and marketing the benefits and advantages of offsite more widely, both by individual companies and by the Government, and by highlighting good practice.

4. Conclusions

This paper has presented some of the views of the UK construction industry on offsite production and technologies. It provides an indication of the opinions of the different sectors within the industry, including clients, designers and contractors, as well as the suppliers of offsite systems and components.

More than 90% of the respondents from all the sectors surveyed had used some type of offsite in at least one of their projects. Nearly three quarters of the clients and designers claimed that they were sufficiently aware of the relative advantages and disadvantages of offsite over traditional construction, compared with just over half of the contractors surveyed. However, less than a third of the suppliers questioned thought that their customers were aware of the relative advantages and disadvantages of offsite over traditional construction.

The biggest advantage of offsite compared with traditional construction is thought to be the decreased construction time on site, together with increased quality, a more consistent product and reduced snagging and defects. The belief that using offsite is more expensive when compared with traditional construction is clearly the main barrier to the increased use of offsite in the UK, even though a large proportion of the respondents also thought that two of the advantages of using offsite were both a reduced initial cost and a reduced whole life cost.

Who usually drives the idea of using offsite for a particular project generally depends upon whom you ask.

Nearly three quarters of the suppliers surveyed thought that take-up of offsite by industry was increasing in their sector. The preferred method used by suppliers to overcome the resistance of their client to the use of offsite was the provision of examples and case studies of previous successful uses of offsite.

All of the suppliers questioned were involved in new build, with nearly 60% of the respondents being involved in new build *only*. Approximately 40% of the respondents also supplied products for major refurbishment but only one supplier surveyed supplied products for maintenance. When asked if the suppliers thought that there *was* a market for offsite in refurbishment in the UK, only about one third said definitely yes.

Electricians, joiners and bricklayers were the three skills generally cited the most by all the sectors questioned as being in short supply and contributing to the increased demand for offsite products. The two main methods suggested to encourage people to enter careers in offsite in order to reduce the skills deficit were training and education and raising the awareness of offsite.

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Serviceable Foundation with Truss Structure

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Abstract

A new foundation method for housing is initially developed to be preparatory to tomorrow's industrial building requiring a basis that is accurate within some millimetres. However when studying possible alternatives it was also found that the process of making a foundation could become much more efficient by changing the sequence of activities. This paper describes a pilot project to test possibilities of the new foundation method in real building practice. It was observed that this fully prefabricated foundation required less material, less building time and less organisation effort. Another major improvement is obtained by simultaneous pouring of concrete for ground floor and foundation beams. These aspects make this foundation method already advantageous in today's building, where improved accuracy is reduced to a side issue.

Keywords: accurate-foundation, efficient-foundation, reduced costs, integrated design

1. The Need for a New Foundation Method

1.1 Preparatory to Industrial-produced Large-size Building Parts

Industrial produced components will become more and more important in modern building. Accordingly it is expected that house building will tend towards the use of large-seized components (prefabricated full wall-parts) and high exactness (feasible by manufactured products). In construction however, benefits of accurate large-seize wall elements can only be fully utilized if the foundation provides a similar exactness as the applied wall-elements. Current foundation methods don't provide this required accuracy without labour-intensive adaptations. With this in view a new foundation method is developed providing high accuracy (of overall +/- 2 mm) and befitting present-day chances in construction.

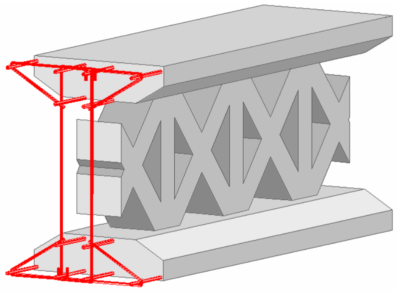

Figure 1: Outline of proposed foundation beam.

1.2 The Roman Already Knew How to Make Foundations

The way we make foundations today show many similarities with the mediaeval way of making foundations. As a matter of fact the principle itself probably goes back as far as ancient Romans since the foundation of villas and "insulae" (3-7 storied housing blocks) constructed in about 100 A.D. have "opus caementicium" beams with a kind of masonry on top to support ground floor and wall. This principle still serves as a model for present-day foundation in housing. Of course there have been numerous improvements, mainly in the last decennia, but these are primary alternatives for concrete beam or formwork, not regarding the composition itself. The original principle is designed for work done by hand and hardly changed by contemporary possibilities. As a consequence today's foundation work is fragmented and inefficient but this is hardly noticed in building practice due to common habituation to the arisen situation.

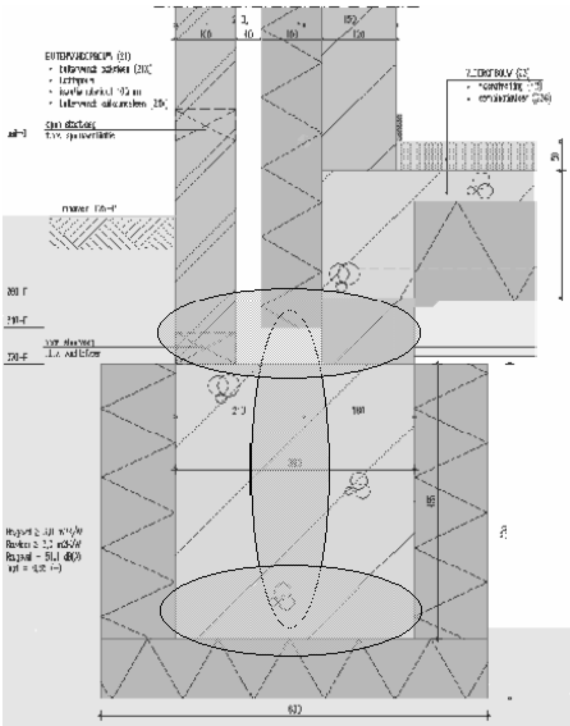

Figure 2:cross-section that is needed to meet demands of prescribed depth/width

1.3 A New Foundation as an Alternative for Inefficient Practice

Although it is obvious that the sight of a traditional foundation site displays a traditional scene with many fragmented activities few studies are known regarding alternative foundation methods. This is not explained by excellent performance of the traditional set-up as a study in 2001 observed at least 20 separate activities that have to be organised by a building company to make a "simple" strip foundation and about 25 separate activities for a regular foundation on piles [2]. With this in view the newly developed foundation method for housing was not only focussed on accuracy but also on improving efficiency. This became possible by applying fully prefabricated parts (of integrated formwork and reinforcement) and because the sequence of pouring concrete and refilling soil was swapped to get the required accuracy. This foundation principle is explained hereafter. The major improvement regarding efficiency is in excavating (excavator that dig and refill at once and thus completes all work in one activity), in omitting labour-intensive bricklaying and in reducing pouring of concrete (ground floor poured at the same time as foundation beam). Furthermore building organisation is simplified as the foundation is developed to be contracted out to a subcontractor resulting in only one activity for the building company to organise (instead of 20-25 in a traditional setting). This does not mean that difficulties are passed on to a subcontractor since the subcontractor can finish all work on site with two persons in running actions and with only four activities to organise (as sending for a plumber and ordering a truck mixer).

1.4 Inefficient Use of Material

Figure 2 shows a model regarding the effective cross-section of foundations. On top a width of 400 mm is required (to support brickwork wall and ground floor). The depth requires some 650 mm in the Netherlands to get a frost-free support. The base width depends on the foundation type: about 400 mm for a foundation on piles and 400-1200 mm for a strip foundation. The remaining I-shaped beam is almost equal strong and stiff compared to a common used rectangular beam but saves about 30% concrete.

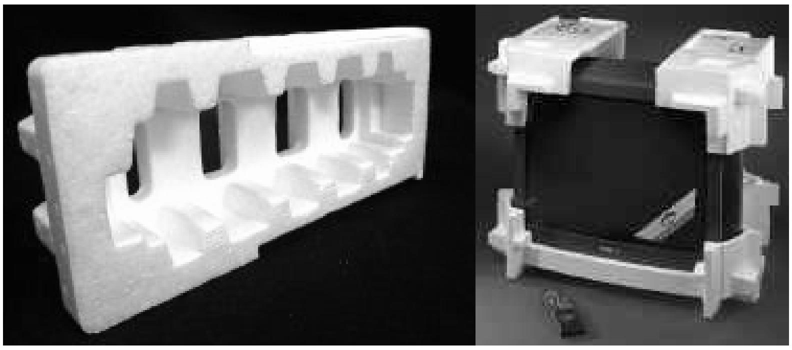

Figure 3: The idea of shells (figure 4) is picked up from packaging where EPS enables a complex form at very little expense (if mass-produced)

The detail in the background of figure 2 shows a permanent formwork made of rigid insulation material (expanded polystyrene-EPS some 100-120 mm in width) that is common used in the Netherlands. Here the thickness of EPS is governed by temporary loads of liquid mortar pressure. After hardening the EPS formwork is still useful as thermal insulation to reduce temperature drop nearby the skirting (a lower temperature might cause internal condensation). However the thickness of the permanent formwork required to resist the temporary loading is far too excessive for a later insulation use.

2. Three-dimensional Shells Used as Permanent Formwork

This paper describes a new foundation method with a typical feature of a swapped sequence of pouring concrete and refilling soil. For this purpose a permanent formwork is developed that is largely defined to resist temporary loading of refilled soil. The load of refilled soil mainly applies horizontal on both sides of the formwork. The easiest way is to link both sides of the formwork, and simply balance horizontal loads.

Linking both sides of a formwork is achieved by applying the principle of a truss structure (figure 1) to the I-shaped beam in figure 2. Forming a concrete beam as truss brings repeated spots in between diagonals, verticals and horizontals where connectors can be located to link both sides of the formwork. Just one step further is to apply three-dimensional shells with bulges in between diagonals, verticals and horizontals where both sides of a formwork can meet (figure 4). Implementing this truss structure is combined in this study with possibilities of shaping an EPS-shell in a mould. Figure 3 shows examples of three-dimensional foam elements used as packing material of a television set made of expanded polystyrene (EPS). Each element is shaped in a mould and in large numbers produced at very little expense. In packaging elements of EPS even can be very large up to (lxbxd) 2000x1200x450 mm^3 in a variety of possible shapes.

Because areas in between members of the truss (where horizontal load of refilled soil is balanced) are of reasonable size it is possible to leave openings in the EPS form (figure 4). These openings can be used to pass sewage pipes (and other pipes that have to be conducted through a foundation beam) at intervals of 0,3 m without specific adjustments during prefabrication.

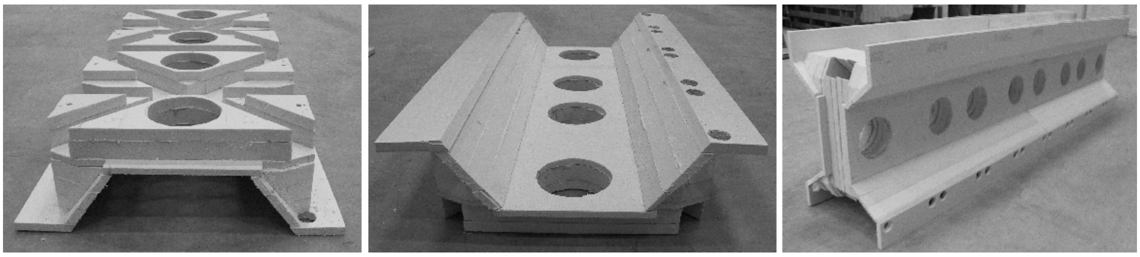

Figure 4:Three-dimensional shell as side panel of formwork. Left: seen from the inside. Middle: seen from the outside. Right: Two shells combined enabling prefabricated formwork

The three-dimensional shell (figure 4) is developed with various aspects at the back of mind:

- to save concrete by applying I-shaped beams with a truss structure put in place of the web;
- to save EPS by reducing thickness and by openings (advantageous since material costs of EPS is of the same order as material costs for concrete) ;
- to develop a standard shell fit for mass-production;
- to make solid prefabricated components out of the standard shells (put mirror wise in a row with large faces of contact);
- to have prefabricated reinforcement slot into the shells (with suitable concrete cover);
- to have openings at intervals in prefabricated formwork, enabling (sewage) pipes to be conducted through at numerous locations without special provisions (maximum Ø125 mm);
- to balance temporary loads of soil on both sides of the formwork (to save EPS, to minimize groundwork and to start with a well supported form when creating an accurate foundation);
- to have openings that can let through liquid mortar (and also have openings for compacting so the concept does not solely depend on self compacting concrete);
- to have minimum labour on site.

Another three-dimensional EPS-form is developed to be used as edge form of concrete mortar poured on top of the ground floor. This form (figure 5 and 6) will be put on top of two EPS-shells. There are two longitudinal notches on both sides to create a good-glued connection to the side of two EPS-shells that are put vertical. By means of covering rigid EPS-shells by rigid EPS-edge forms and by glued connections the prefabricated formwork becomes quite solid (if coinciding overlap of endings are avoided).

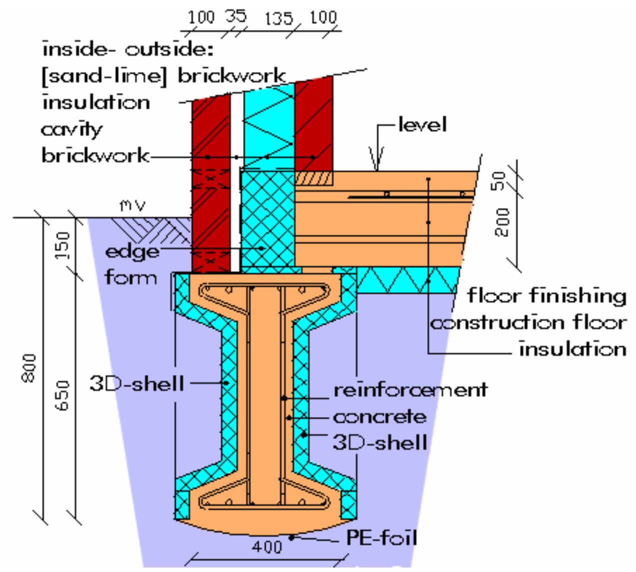

Figure 5: Detail of brickwork wall. 3D-shells, reinforcement and edge form are prefabricated. Concrete is poured on top of the floor and runs through openings of the EPS-edge form.

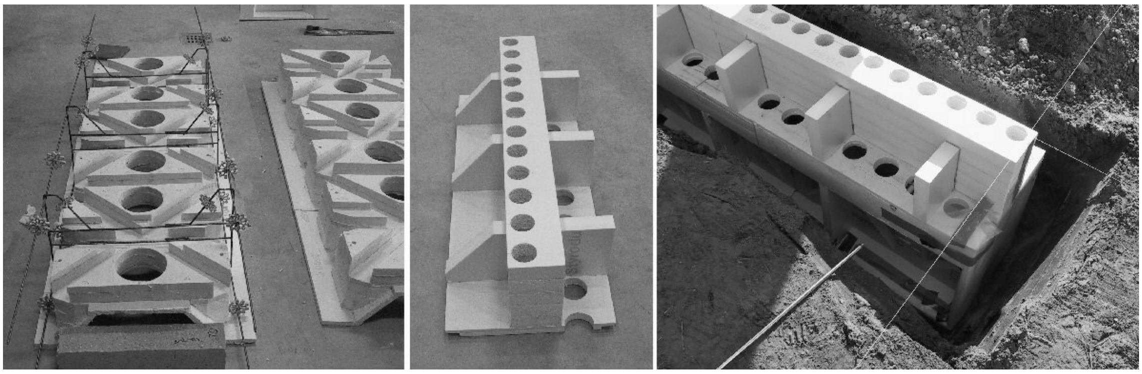

Figure 6. Left: three-dimensional shells put in a row with reinforcement put in. The formwork is closed and fixed by other shells and than turned a quarter. Another form (shown in the middle) is put on top. Middle: three-dimensional form used as edge formwork for ground floor. Right: prefabricated formwork brought to a building site and put into an excavated trench.

Although the edge form is primarily needed for pouring a ground floor (figure 10) it will also serve as cavity insulation after mortar is cured. In this respect the EPS-edge form connects the insulation underneath the ground floor with insulation in the cavity wall making a closed insulation layer (except for the small openings explained hereafter).

A third function of the EPS-edge form is to simplify progress of work for pouring a foundation beam. For this reason some openings are left in the lowest part (middle in figure 6) to let liquid mortar trough. With these openings it is possible to pour concrete mortar on the ground floor (figure 10) to fill the formwork of the foundation beam. In this way the ground floor acts as buffer when ground floor and concrete beam are poured simultaneously. And the row of openings in the top part of the EPS-edge form (as can be seen in the middle of figure 6) is meant to let through a vibrating needle for compacting mortar (as can be seen in the middle of figure 10). The vibrating needle can reach mortar at the underside of the foundation beam through verticals of the truss. Since the position of an EPS-edge form is not subjected to positions of three-dimensional shells the location of an opening and a vertical may change. For this reason a row of openings is provided so one of the openings is always located above a vertical. The practical test proved that these provisions are well applicable to get a good compacting. But the practical test also revealed that the openings turned out convenient because it provided a good visual check of the progress of filling the foundation beam.

Figure 7: The excavator makes trenches, puts formwork in and refills in running actions.

Figure 8:Left: the excavator is used to put in the prefabricated formwork. Middle: Formwork with refilled soil. Right: Next the ground floor is prepared, here a PS-combination type is used.

In developing the EPS-edge form special attention was paid to resist the effect of communicating vessels since the level of concrete mortar on the inside (floor) was some 250 mm above the level of the foundation (see also figure 5). In particular regarding the high specific gravity of mortar the different level was well considered. In the test seepage of mortar is barred by a proper glued connection of edge form to three-dimensional shell. Also the weight of mortar itself that rests upon the EPS-edge form helps to keep a closed formwork. The practical test (figure 10 and 11) showed that mortar pressure did not affect the form since seepage was not observed.

3. Practical Test

Students have carried out a small pilot project on the campus of Eindhoven University of Technology to study practical applicability of the developed foundation concept. All three-dimensional forms were made out of stacked Styrofoam sheets of 20-50 mm in width. There were two different types of EPS-shells and so also two different types of truss compositions made and tested. For the reason that the three-dimensional shape of the shell in figure 4 and 6 (resulting in the truss shown in the middle and right in figure 11) was rather complex to make out of stacked sheets the number of shells was reduced. As a result the length of this foundation beam is reduced to 1,8 metre. The main subject of research regarding this foundation beam is to test concrete filling of the quite small verticals, diagonals and under chord of the truss by practical experience.

The other type of truss (left in figure 11) was less difficult to compose out of stacked sheets so the length of this foundation beam is made 4,2 metre. In between the two foundation beams there is a small ground floor (PS-combination floor) with a span of 1,5 metre. Figure 6 shows prefabrication of formwork and putting in reinforcement. These photos do not show plastic foil that is attached to the underside of the shells (drawn in figure 5) to separate mortar from soil when pouring.

Figure 7 and 8 shows activities on site that took about 2 hours. The activities on site started with preparation of the site for building by a mini-excavator. After that the mini-excavator made a trench. Then the prefabricated formwork was picked up by the mini-excavator and placed into the trench. The prefabricated formwork had special provisions for exact positioning. The description of this falls outside the scope of this paper. When the formwork is positioned the mini-excavator immediately refills soil to fix the formwork.

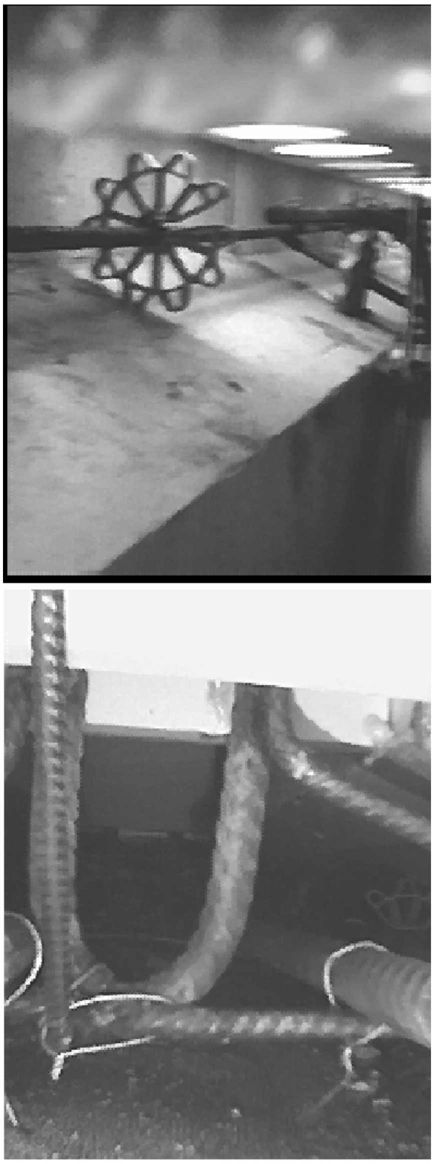

Figure 9: photo's inside a foundation beam (after refilling soil and before pouring mortar). Above: part of top flange of I-shaped beam. Below: part of bottom flange.

The second formwork is handled in like manner followed by placing the elements for the ground floor. The next step could have been pouring concrete, but since this was a pilot project the procedure was stopped to allow inspection and documentation. Inspection of the hollow section of the formwork was carried out several days later by a small video camera that was inserted through the openings in the EPS-edge form (figure 9). These video recordings showed no signs of pushed in insulation (for instance by loading of refilled soil). All reinforcement was still in its place with sufficient cover and also the bottom reinforcement was far-off from the subsoil. The PE-foil functioned well as separator of soil and mortar. Also all displacements of the formwork were measured to study the accuracy of this foundation method.

The next day concrete mortar was poured. This took about ½ an hour and is shown in figure 10. The concrete mortar directly ran out a truck mixer on top of the ground floor. A vibrating needle and shovel was used to displace mortar to all sides to flow into the hollow section of the formwork. It was observed that mortar flew well and could be well compacted by the vibrating needle via openings in the EPS-edge form.

Figure 10:Left: Mortar is poured on top of the floor. Middle: Mortar flows into the foundation with openings that make compaction possible. Right: Finished floor and foundation.

Three days later the foundation was dismantled. Both foundation beams were dug out and brought to the laboratory (figure 11). After removing all insulation covering it was found that both forms were completely filled with mortar and irregularities were not observed. The foundation beam of 4,2 metre in length will be tested in the laboratory in near future.

Figure 11: (Left:) the foundation beam is dismantled afterwards. (Middle:) and EPS-formwork is removed. (Right:) showing a completely filled beam with I-shape and truss structure.

4. Further Continuation

Since the small-scale test indicated serviceability in real practice, a patent is applied regarding working procedure and developed forms. The next study to carry out regards building economics. Based on observations and time registrations of the pilot project a comparison will be made to find the range of possible savings as regard to traditional foundation methods. A second study regards the development of strip foundations and also of specialities. Also optimising the prefabricated reinforcement will be further developed.

It is expected that the shape of all three-dimensional forms will be adjusted by the outcome of these studies. Next aluminium moulds shall be developed to enable large-scale manufacturing of

EPS-shell and edge form. After that more practical test can be performed to study new possibilities of this foundation method.

5. Conclusions

The practical serviceability of a new foundation method for housing is demonstrated by a small pilot project resulting in savings of concrete (some 30%) and less labour on site (some 50%). All requisites are standard elements manufactured beforehand (so this foundation method is prepared for prospective mass-production) and assembled as prefabricated formwork based on specific project requirements (so also irregular lay-outs can be realised). On site all activities can be carried out in running actions by a team of two persons (excavation worker and excavator machinist). This enables foundation work to be contracted out. The result is a more efficient organisation of foundation work.

Using the ground floor as buffer when pouring concrete mortar makes progress of work easier. Furthermore this enables simultaneous pouring of foundation beam and ground floor.

The pilot project shows promising applicability of the foundation method. Yet further study and practical tests are required.

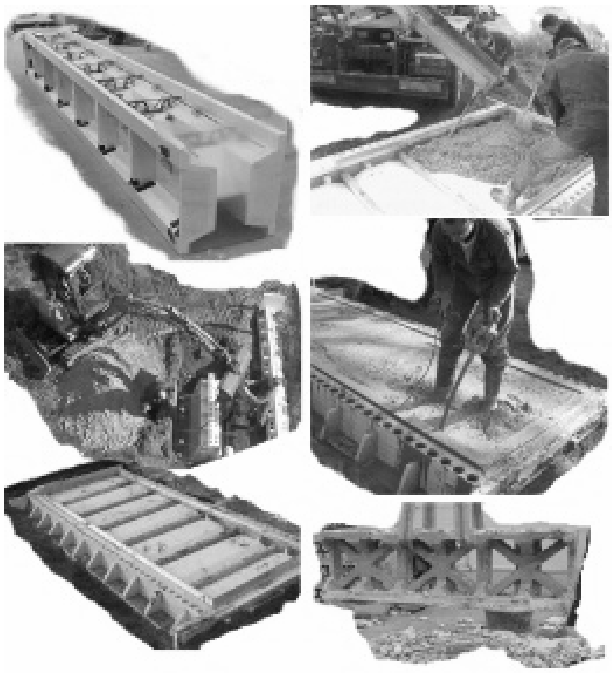

Figure 12: impression of pilot project. left-top: prefab form with reinforcement before applying edge form; left-middle: excavator prepares, levels, digs, shifts, positions and refills; left-bottom: ground floor and formwork ready for concrete; right-top: pouring of concrete (foundation + ground floor); right-middle: compacting; right-bottom: dismantled foundation.

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Section III

Productivity and Performance Improvement

Is Performance-Based Procurement a Solution to Construction Performance?

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Abstract

There are two ways to analyze the problem of construction nonperformance (not on time, not meeting the quality expectations of the owner, and not having cost increase change orders). The first is a project-specific approach, which assumes that the problems are being caused by the uniqueness of each project. This approach stresses: finding solutions in better trained personnel and craftspeople, more standards, construction management, and inspection. The other is a process approach, which assumes that the problems are being caused by the process. Performance-based procurement uses the process approach. It hypothesizes that the current price-based design-bid-build procurement process is inefficient, supports an adversarial environment, is devoid of performance information, is highly inefficient, maximizes management and inspection instead of quality control, and treats highly differential construction products and services as commodities. The Performance Information Procurement System (PIPS) was created to resolve these issues causing construction nonperformance. The results of 380 tests of construction procurement will be assessed in terms of performance. Using case studies from a variety of large clients, the results of performance will be analyzed in terms of on-time, on budget, and meeting customer expectations. Lessons will be drawn on the cost of performance, the minimization of client management and inspection, and the creation of a "win-win" relationship of best value for the owner while concurrently maximizing the contractor profit.

Keywords: Performance results, performance based procurement, construction delivery process, Six Sigma process application

1. Introduction - Construction Industry Performance

For the past twenty years, the construction industry has attempted to improve its construction performance (finishing on-time, minimizing change orders, and meeting customer's expectations). In both the United States and in the United Kingdom, overall performance has hovered between the 60% - 70% range for owner satisfaction [5, 16, 20]. The performance issues can be summarized by the following numbers:

1. 33% of projects in the US end over budget.
2. 53% of clients in the US do not want to have a relationship with the contractor at the end of construction.
3. Only 68% of clients in the UK would give a 8/10 rating or better on satisfaction.
4. Only 45% of clients in the UK stated that the costs were on target
5. Only 62% of clients in the UK stated that the projects were completed on time.

The construction industry has tried various solutions to improve construction performance. These have included continuous improvement, partnering, business process re-engineering, just-in-time construction, lean construction, prefabricated systems, and long-term partnerships. Although each solution may have improved construction operations, the general problems of nonperformance have persisted.

1.1 Influence of the Worldwide Competitive Price Pressures

The construction industry is guided by two major factors: competition and performance (Figure 1) [11]. In Figure 1, Quadrant III represents the construction industry structure before the advent of the worldwide, highly competitive marketplace. Clients or building owners selected performing designers and contractors. Terms were negotiated, and the construction was completed. Hiring was based on performance before price. These designers and contractors had highly skilled personnel and craftspeople that did their own quality control.

With the worldwide competitive marketplace, clients sought to procure a better value. The intention was to keep high quality, but increase the competition (moving from Quadrant III to II). However, the inability to identify and measure the difference of performance resulted in the awards being price based. Instead of moving from Quadrant III to II, the majority of clients moved to Quadrant I.

Quadrant I is a price-based, commodity environment. A price-based environment is only optimal when the products and services are true commodities. Commodities are described using minimum standards and requirements. The best value is the lowest price. Procuring construction as a commodity forces the contractors to provide the given acceptable performance at the lowest price. The client's representative (architect/engineer) uses minimum standards to reduce the risk of receiving a lower quality product. Figure 2 shows an example of four contractors, each with different levels of performance ability for a particular project. The specifications (input based specs (USA), not output based specifications as are common in the UK) put forward in the contract documents dictate a specific level of performance quality. To reduce costs and the chance of a successful bid, the contractors with a greater level of ability for the given project (quality, speed, expertise) lower their performance to the level of the specification. Thus, the contractors (and manufacturers providing the construction products/materials) use the minimum expectation as a maximum level (in order to maximize their profits and likelihood of a successful bid). By awarding to the lowest bidder, performance is guaranteed at only the lowest possible level, which maximizes the client's risk of nonperformance by a contractor. The resulting difference commonly causes an adversarial relationship (Figure 3) where the owner see the stated specifications as a minimum level of quality while contractors (and suppliers, manufacturers, etc.) see it as a maximum level of quality [9].

Figure 1. Construction Industry Stability

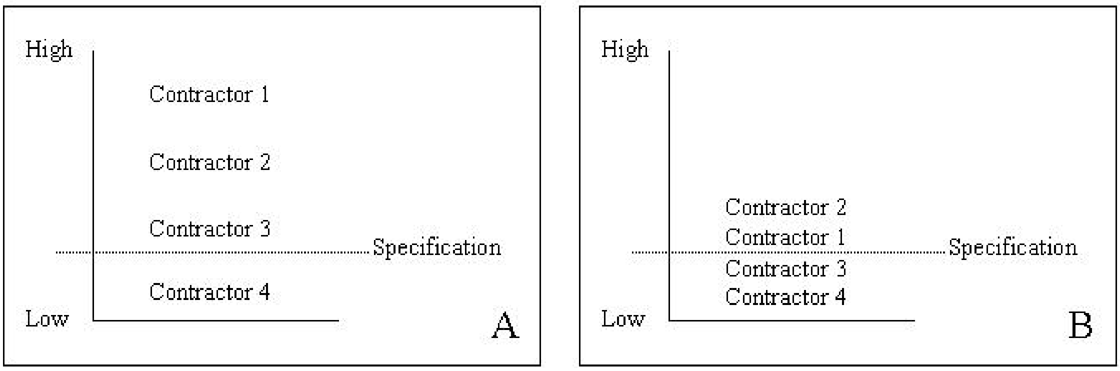

Figure 2. Impact of Minimum Standards on Performance

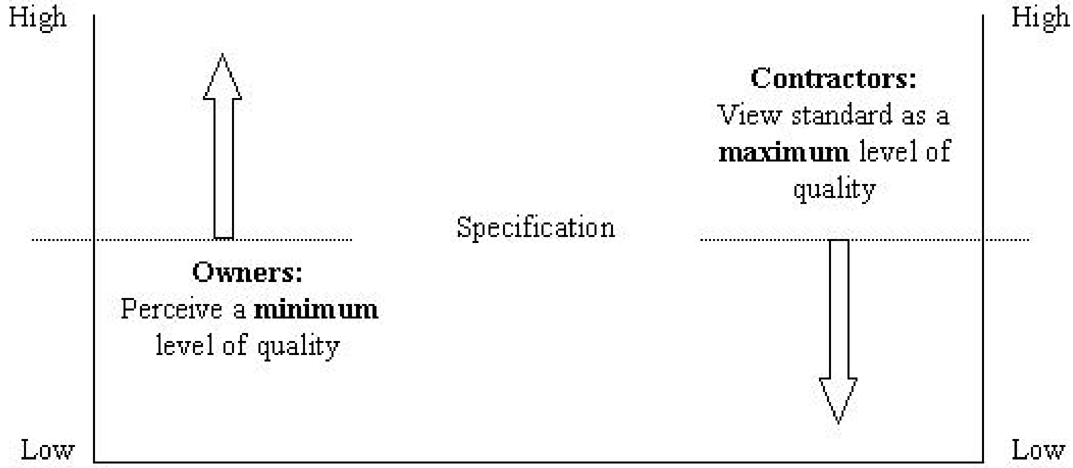

Figure 3. Owners vs Contractors: Difference in Objectives

1.2 Project Specific Approach: Construction Management and Expertise

The industry has tried to solve the adversarial, high risk environment by hiring experts who uses their expertise to differentiate every type of construction, set technical standards in each specialty; create means, methods, and material specifications; prequalify contractors; and manage, control, and inspect the contractor using technical expertise, thereby theoretically eliminating as must risk as possible. Ironically, their chief weapon, the minimum standards are a major source of risk [11]. Offering a higher performance (in a price based, Quadrant I environment) is a noncompetitive practice. This concept helps explain some of the bankruptcies of experienced construction businesses that have been in the industry for over ten years [3].

When standards are used, it forces the client to inspect in terms of means, methods, and materials (MMM). Minimum standards have no correlation to performance [2, 6, 13, 14, 21]. Standards and specifications also allow contractors who do not have experience to bid the project. The award to the low bidding, inexperienced low bidder may actually result in a higher project cost. This environment, with it poor performance results, threatens the sustainability of low-bid construction. The risk can also be identified by the high costs to sureties in both the bonding and insurance payouts [18, 15, 3]. Due to these factors, the authors hypothesize that performance has no direct correlation with awarded price. Therefore, if price does not affect specified performance, high performing contractors do not require external management and inspection. High performance contractors will quality control their own work. They minimize the performance risk with expertise and quality control.

The authors propose that by moving to a Quadrant II, performance based environment, the efficiency of the construction process will increase, minimizing performance issues. By hiring experienced personnel and contractors (which need less control, less management, and less inspection), the contractors will maximize their profit, and the owner will get best value. The authors are proposing that the effort to minimize construction performance issues using a project specific approach (Quadrant I) has proven to be inefficient and ineffective. A process based solution (Quadrant II) is required.

2. Process Based Solution: PIPS

To investigate process based performance procurement in comparison to current low-bid practices, the Performance Information Procurement System (PIPS) was designed in 1991 and has since been tested, modified, and retested 380 times over the past ten years. It is a Six Sigma based process that defines the process, measures the critical elements and the level of risk, analyzes the process using fuzzy logic, forces improvement, and controls deviation through process control (fundamentally Six Sigma's DMAIC (Define, Measure, Analyze, Improve, Control)).

The ten year, $4.2M research effort has involved the procurement of $230M of construction, and has resulted in over 80-refereed conference and journal papers. The fundamental hypothesis (construction nonperformance is a process based problem) has not been altered over the ten years, even though steps in the process has been improved through trial and error.

2.1 Research Hypothesis

Research Hypothesis:

1. Construction performance is mainly a process issue.
2. The critical element is identifying and competing performing contractors.
3. Management/control by the owner should be minimized [4].
4. An efficient environment will lower cost, deliver best value for the owner, and maximize the contractor's profit.
5. Risk should be minimized by contractors rather than clients.
6. Prequalification is only used when the process is price based.

Under the above hypothesis, PIPS was formed and is composed of five major filters of procurement (contractor selection) that seek to test the hypothesis. These major components or filters of performance based procurement are:

1. *Identification of past performance*. Past performance includes frequency of on time completion, minimal change orders, and high customer satisfaction of critical project performance elements (general contractor, site superintendent, project manager, and mechanical, electrical, waterproofing and other critical subcontractors).

2. *Project specific capability*. This is defined as the capability to identify, prioritize, and minimize the risk of the project in the non-technical terms of cost, time, and quality expectation.

3. *Competition based on performance (past performance and ability to minimize risk) and price*. The prioritization is done using a multi-criteria decision making model, which minimizes risk of nonperformance by giving credit to the identified critical past performance elements (recorded values of filters one and two). This model does not penalize values which are near the mode, but penalizes values that are below the mode. The processing of values forces contractors to provide their best value, and compete with every other best value, resulting in a two step best value process.

4. *Pre-award phase*. The best value contractor (as identified by the multi-criteria decision making model) must minimize the risks identified by all competitors. They must coordinate the requirements between critical elements, clarify or seek clarification on the project. The contractor will then sign a contract that includes their risk minimization plan, the intent of the owner, and all clarifications.

5. *Construction*. The contractor is forced to manage the project in terms of risk. The contractor passes risk information (affecting cost, time, and quality expectation) to the client's representative.

6. *Measurement of performance*. The project will be rated after completion. All critical elements of the general contractor's team will receive the same performance rating. The rating becomes up to 50% of the critical element's future performance rating.

3. Testing – Application of PIPS

Testing of PIPS was accomplished via its application on real projects for contractor procurement. Testing has been conducted over a ten year period in the public and private sectors for the following clients: Intel, Motorola, Boeing, Burr-Brown, International Rectifier, Honeywell, State of Wyoming, US Army Medical Command, Federal Aviation Administration, State of Utah, United Airlines, State of Hawaii, University of Hawaii, State of Georgia, Wyoming National Guard, Dallas Independent School District, Denver Hospital Group, Harvard University, and the US Coast Guard.

Over 380 tests and $230M of construction projects were procured using the PIPS system. The overall performance results of PIPS tests were:

1. No evidence that the first cost of the performance-based awards was more expensive than the costs of the low bid award. The Civil Engineering Unit of Oakland, CA of the US Coast Guard (USCG) concluded, via a cost analysis of PIPS awarded projects and non-PIPS awarded projects for the USCG, that PIPS represents a savings as large as 19% for a project's life cycle costs compared to low-bid or non-PIPS procurement [17].

2. PIPS showed 98% performance, where performance is given as projects that were delivered on time, with no contractor generated cost change orders after the pre-award phase, and

high customer satisfaction. This is in comparison to the documented performance of 60 – 70 percent performance of construction in both the United States and the United Kingdom.

3. Increased performance of contractors over time or in comparison with their performance in the low bid environment.

4. Contractors performing to a higher level in the PIPS environment than in the low bid environment. This includes perceived higher performance of the same contractors in the PIPS environment than in the low bid environment.

5. Construction management minimized up to 80%.

6. Minimized means, methods, and material details in design specifications.

7. Risk of designers was minimized due to the two levels of constructability review (business level review in the risk identification filter and detailed constructability review in the pre-award phase by the best value contractor).

The first repeat user of PIPS was the FAA Western Region (50 storm damage repair projects ($4M)) and the FAA provided no technical specification to the contractor. PIPS allowed the FAA engineering requirements group to increase the amount of work procured by 300 percent. Projects included building repairs, road repairs, and electrical and mechanical systems repairs. All the projects were finished on time, without change orders, while satisfying the clients.

United Airlines (UAL) was the next repeat user of PIPS (results shown in Table 1, where the owner rated certain items on a scale of 1-10 with 10 being the highest (most favorable)). As in the FAA projects, technical specifications were minimized. The process was tested on roofing, painting, waterproofing, flooring, abatement, and renovation/remodeling projects. The speed, efficiency, and minimized effort of PIPS decreased the overhead of construction delivery allowing more of the funding to go into construction.

Table 1: United Airlines Performance Based Results

NO	Criteria	Results
1	Total number of projects	32
2	Award Cost	$ 12,750,000
3	Low-Bid System of contracting. (Owner scale rated 1-10, 10 is max)	3
4	Performance Based System of contracting. (Owner scale rated 1-10, 10 is max)	9
5	Percent satisfied with PIPS	100%
6	Overall quality of construction using PIPS (Owner scale rated 1-10, 10 is max)	9
7	Percent of users that would hire the contractor again	100%
8	Percent of projects that finished on time	100%
9	Percent of projects that finished within budget	100%
10	Percent of projects with no change orders	100%

The State of Utah projects were the first large multi-million dollar projects (6 projects, $80M budget, the largest being $53M Olympic Village, Phase II). Due to the State's requirements, the projects had to be run without the most critical component of PIPS, the pre-award phase. Even though the capability of the process was limited, PBSRG ran the modified process to determine if PIPS could be used successfully on large projects with multiple subcontractors. The results were the best results (Table 2) at the State of Utah in ten years [1]. Without the pre-award phase, the contractors were not forced to find mistakes in the design documents before construction award. In the only project that was not completed on time or without change orders, the user stated that architect missed too many items for the contractor to cover [7]. The results reinforced the importance of the pre-award phase. The largest project, the $53M 2002 Olympic Village Housing project was awarded to the low bidder.

Table 2: State of Utah Project Results

NO	Criteria	Results
1	Total number of projects	5
2	Award Cost	$ 80,506,376
3	Budget	$ 85,770,000
4	Percent <u>Under</u> Budget	7% Under Budget
5	Low-Bid System of contracting. (Owner scale rated 1-10, 10 is max)	4
6	Performance Based System of contracting. (Owner scale rated 1-10, 10 is max)	9
7	Percent satisfied with PIPS	90%
8	Overall quality of construction using PIPS	9.2
9	Percent of users that would hire the contractor again	100%
10	Percent of projects that finished on time	80%
11	Percent of projects that finished within budget	80%
12	Percent of projects with no change orders	100%
13	Number of companies that were surveyed on past performance	357

The State of Hawaii ran the most projects (over 150) for the longest period of time (4 years) of the ten year test cycle. The test results were captured in the State's internal audit. The process eventually ended due to a change in political party and the appointment of a new comptroller who wanted to return to the traditional, technical based project approach. It is interesting to note that the State has been unsuccessful in finding a process that duplicates the results of PIPS. Their current inability to identify or use performance information, and the inability to document the performance of construction projects supports the authors' hypothesis that the owner does not know the value of construction in the priced based environment. The analysis of performance in the Hawaii tests were done in several ways:

1. Of the 55 roofing clients, 100% stated that the PIPS contractors' performance was excellent, 100% stated that they preferred PIPS over low-bid award, and 96% were satisfied with the quality of work [19].

2. Out of 20 inspectors, 100% were satisfied with the PIPS work, 94% stated that the PIPS contractors were more willing to perform, and 95% stated that PIPS required less work for their staff [12].

3. A transaction cost analysis was performed on the roofing PIPS projects and low-bid projects. The analysis concluded that PIPS resulted in over 13% savings in the first cost in comparison to low bid [19]. This did not take into account the increase in quality.

4. A comparison of 96 PIPS roofing projects documented that [19]: 98% of the roofs were completed on time, the contractors produced approximately twice as much work per day, and stopped the practice of the State repairing its roofs during the warranty period.

A project run at the State of Georgia was very significant since it allowed a clear comparison of the first cost of running PIPS versus the cost of low-bid on the exact same project. The procurement of the $45M construction of an environmental wet laboratory was bid twice using both processes [8]. The first round of bids was done using the PIPS process. The bid was rejected due to the perceived high cost. It was later identified that the project was over-designed. The project was redesigned cutting $4.5M from the project. It was re-bid and awarded using the low-bid process. The project was still over budget ($46.6M) and completed at $48.8M and late by 50% of the initial construction time. The project was finally completed with over $2.2 Million in change orders and approximately one year behind schedule. The State of Georgia ran a second, similar project using PIPS. After awarding to the best performer, they proceeded to manage and control the contractor as though it was a low bid contract. The client was impressed with the contractor but discouraged by the bureaucratic control by the State.

The Dallas Independent School District (DISD) implemented PIPS on nine roofing projects. The implementation illustrated several key concepts, including:

1. Contractors that DISD thought were very low performing (due to past low-bid work), were capable of performing very highly under PIPS.

2. Contractors and manufacturers did not know the performance of their roofs.

3. Contractors and manufacturers immediately began responding to problems that DISD had been requesting to be fixed for over two years.

Table 3 summarizes the results of the PIPS implementation at DISD [10]. The projects were completed on time, and 13 percent under budget. Once again, the first costs were lower for higher performance than the low bid prices.

Table 3: Dallas Independent School District Project Results

NO	Criteria	Results
1	Total number of projects	9
2	Award Cost	$ 4,205,208
3	Budget	$ 4,824,357
4	Percent Under Budget	-13%
5	Percent satisfied with PIPS	100%
6	Percent of projects that finished on time	100%
7	Percent of project that finished within budget	100%
8	Average user rating of low bid (Owner scale rated 1-10, 10 is max)	1
9	Average user rating of PIPS (Owner scale rated 1-10, 10 is max)	10

4. Conclusion and Recommendation

The process based approach of PIPS, based upon the nearly 400 projects run using the performance based system, seems to be far more effective in minimizing construction performance issues than the project specific, low-bid approach. The success of the PIPS system shows that the Quadrant I, technically oriented, price based construction delivery process may be the primary cause of construction nonperformance. PIPS is fundamentally a Six Sigma application that defines the process, measures performance at the right time by the right party, automated the analysis process using fuzzy logic, forced continuous improvement without management and control, and minimized deviation through the process control (DMAIC.)

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What do Construction Workers do? Direct Observations in Housing Projects

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Abstract

Industrialization is currently seen as one of the most important developments in the Swedish construction. All large construction companies have initiated processes for more prefabrication, especially in housing. The reason is to develop more lean processes as a way to increase the productivity and the profitability. In order to learn more about how productive and efficient their production processes really are, the Swedish construction company Peab has introduced short studies on how the time of construction workers is used on site. Full-time observers follow different work activities in housing projects and register what randomly chosen workers do every second minute. The purpose of this paper is to illustrate one aspect on how efficient the production is, by presenting how construction workers' time is used on construction sites. The results from the case project, which is presented in this paper, indicate that less than 20% of the workers time is spent on direct value adding activities for specific activities and that approximately 20% of the time is direct waste of time.

Keywords: Industrialization, productivity, construction workers, housing, work sampling

1. Introduction

The Swedish construction industry is often viewed as conservative and producing buildings on high costs. At the same time, the general opinion is that the industry is under hard competition and that the profit margins are low. In order to improve the productivity, the major construction companies make significant investments in developing the production towards more industrialized processes, especially in housing where repetition is obvious.

Peab is, next Skanska and NCC, the largest Scandinavian company in the field of construction and civil engineering. The group runs construction and civil engineering operations primarily in Sweden, but also in Norway and Finland. The group net sales are SEK 20 billion with about 10,000 employees. In order to learn more about how productive and efficient their production processes really are, Peab has introduced short studies on how the time of construction workers is used on site. Another reason for collecting empirical data from the construction sites is that Peab several times has realized that most employees don't accept improvement programs or specific projects aimed for improving certain processes. Empirical evidence would be helpful to initiate discussions about how to improve the processes.

The aim of this paper is to increase practitioners as well as researchers attention on the potentials to increase the productivity in construction. It is done by presenting empirical data from one housing project. The more specific aim is to identify what construction workers do in housing projects, especially (a) to identify the efficiency defined as the percentage of time spent on direct value adding work, but also (b) to identify the waste defined as the percentage of time lost.

The results indicate that the time spent on adding direct value into the building is surprisingly low. There are strong arguments for paying more attention on developing more industrialized processes in order to increase the efficiency and reduce the waste.

2. Labour Productivity

Construction workers in Sweden are, in an international perspective, well educated. Most of them have studied nine-year compulsory school and then three-year upper secondary school education. The workers have an open and fairly independent role on site. It's common that they get fairly much information about the project and that they take some part in planning and work preparations. There is a trend to include more managerial roles into the workers' tasks. Since the 1980's, most construction workers are employed with conditional tenure.

Considering construction workers, there has been a number of work sampling studies in the U.S. for the last 30 years. Allmon et al. [1] summarize the trends in U.S construction labor productivity for the period 1970-1998. A research group at University of Texas at Austin studied 72 projects during this period. The annual direct work mean values for these projects varied from 41 to 61%. This is in line with Oglesby et al. [2], who predict that direct work falls within 40-60% in most construction projects.

The activities of workers in these studies are typically divided into three categories, according to Allmon et al. [1]. Direct work includes productivity actions, picking up tools at the area where the work is taking place, measurement on the area where the work is taking place, holding materials in place, inspecting for proper fit, putting on safety equipment, and all cleanup. Supportive work includes supervision, planning or instruction, all travel, carrying or handling materials or tools, and walking empty-handed to get materials or tools. Delay includes waiting for another trade to finish work, standing, sitting or any non-action, personal time, and late starts or early quits. Inspired by popular literature and oral presentations about the Japanese car manufacturer Toyota, we believe that this structure is rather passive and must be developed further in order to strive for world-class productivity. Direct work should for example be divided in direct value adding work and indirect work.

Several authors discuss factors influencing the productivity. Allmon et al. [1] mention project uniqueness, technology, management, labor organization, real wage trends and construction training. Moselhi et al [3] study change orders impact on labor productivity. Ng et al. [4] take another approach and look at demotivating factors; rework, overcrowded work areas, crew interfacing, tool availability, inspection delays, material availability and foremen incompetence. According to Kaming et al. [5] bricklayers, carpenters and steel fixers in Nigeria rank lack of material, rework, absenteeism, interference and lack of tools as the major productivity problems.

3. Methodology

The approach we have chosen for the study, work sampling studies, could be criticized in several ways. Allmon et al [1] argues, for example, that work sampling only gives information about time spent on activities and therefore gives indirect information about productivity. However, they mean that direct work time does not necessarily correlate with unit rate productivity. The level of labor skill and the standard of equipment may for example influences the productivity without necessarily influence the volume of direct work. An advantage with the approach is that it is less controversial than other approaches such as output per time.

The study is limited to one housing project, which was used also for some other studies within Peab. Of that reason, the personnel on site were used to development work and various types of studies. However, an introductory discussion with the site managers and the construction workers were carried through in order to guarantee that they realized the aim with the study; to identify what the workers do as a consequence of the organization, the plans and the production systems, not how fast they work.

The data collection was performed as direct observations by one of the authors. Before the studies started he used a random table to systematically decide in which order the workers would be followed and for how many observations. During the observations he tried to stand and walk in such way that he influenced the work and the workers as little as possible. He experienced that they quickly accepted him as a part of a natural working situation.

The registrations were done exactly every second minute from 6.45 in the morning when the work started until 4.00 pm when the work finished. But if the work of some reasons began earlier in the morning or finished later in the afternoon he extended the observations to also include these periods.

Three building elements were chosen of practical reasons. These were studied during one week each during 2004.

The authors developed a code structure based on experiences from similar previous studies and on which activities were performed during the study, see Table 1. Every observation included six questions.

- Which date the observation was made, example yy-mm-dd.
- What time the observation was made, example hh-mm.

- Which construction worker to observ.
- Which building element the specific worker worked with. A detailed code structure was used.
- Which activity the specific worker performed. Six main groups of general activities were identified depending on if it was value adding work, preparations for value adding work or just lost time.
- Comments were made now and then in order to clarify what the workers did and also to note various reflections made during the study.

Microsoft Excel was used to analyze the data. A summary of the each week of study was presented for the workers followed by a discussion on what could be improved.

4. Results

4.1 Case: Area Folkparken

The case project is initiated and developed by Peab. The budget is SEK 64 million. The site is situated in Haninge, approximately 20 km south of Stockholm. The product is a house with external galleries and is designed to manage heavy traffic noise from one side. The gross floor area 5,159 m^2 and the gross building volume is 14,703 m^2. The project includes 82 tenant-owned flats with 1-2 rooms each. The building, which is divided in three parts with different numbers of storeys, has the form of an “S” in order to be experienced as more slender and better harmonize with the environment. The form of the building was one reason to that the distances on the site were quite long. The closest distance from the production site to the workers facilities was 70 m, to the site office 110 m, and to the stock of material 30 m. The distance between the north and south end of the building was 90 m. Peab’s site organization was in the beginning of the project one site manager, one site clerk, and one foreman.

Three elements of the building were studied:

- Load-bearing structure. The structure is in prefabricated concrete, which consists of a floor structure and load-bearing walls. The assembling of the structure was performed by six workers and supported by one manager.
- Roof. The roof is tin plated with low gradient. The roof trusses are wooden and prefabricated. The roof work, excluding tin plate, was done by Peab’s personnel. The number of workers varied from three to six. One manager supported the work.

- Exterial walls. The wall, which is not load-bearing, consists of a prefabricated wooden structure. It is internally covered by plaster and externally covered by mineral wool and plaster. The work was done by two to four workers and supported by one manager.

4.2 Results

In total, 4,979 observations were done during fifteen days of study, Table 1. However, the number of observations corresponds to almost 22 full working days, i.e. eight hours long days. The reason is that two teams of workers were studied in parallel for some days, and some working days were ten hours. Direct value adding work was on average less than 20% of the total time. Note that this group includes some corrections of defects. Indirect work, material handling and work planning is needed to be able to perform direct value adding work. These groups of activities corresponded to 45.4% of the workers time. 25.5% were spent on indirect work, which includes all kind of preparations in a few meters distance from the working spot. Indirect work included mainly handling of material and equipment, but also work with temporary constructions. 13.9% of the workers' time were spent on material handling, which includes transportation of material on the construction site. There are common that construction workers take part in the planning of the production on Swedish sites. In this case was 6.0% of the time spent on work planning. Waiting and unexploited time corresponded to as much as 33.4% of the workers' time. Almost 20% of the time was used to move between working spots and also moving before and after breaks.

Table 1: How construction workers use their time in load-bearing structure, roof and facade.

Activity / Element of building	*Load-bearing structure*	*Roof*	*Façade*	*All*
Number of observations	*2185*	*1843*	*951*	*4979*
10 Direct value adding work	**23.9**	**18.0**	**12.2**	**19.5**
- "New" production	21.2	16.0	10.7	17.3
- Correcting defects	2.6	1.6	1.5	2.0
- Prefabrication on site	0.0	0.4	0.0	0.2
20 Indirect work	**27.1**	**29.1**	**15.0**	**25.5**
- Studying drawings	0.5	0.5	0.1	0.4
- Discussing the work	1.6	2.9	1.2	2.0
- Handling construction material	4.8	7.9	2.1	5.4
- Handling equipment	8.8	5.8	4.3	6.8
- Measuring for prefabrication on site	2.0	6.8	1.5	3.7
- Cleaning on site	0.5	1.1	0.2	0.7
- Temporary constructions	8.6	4.1	5.7	6.4
- Other	0.3	0.0	0.0	0.1
30 Material handling	**11.8**	**13.1**	**20.2**	**13.9**
- Handling material	4.0	6.6	8.7	5.9
- Handling equipment	7.7	6.5	11.5	8.0
- Other	0.1	0.0	0.0	0.0
40 Work planning	**4.9**	**5.6**	**9.6**	**6.0**
- Work preparation	2.7	2.6	6.0	3.3
- Coordination	0.9	0.9	2.6	1.2
- Other	1.2	2.1	0.9	1.5
50 Waiting etc.	**23.2**	**18.1**	**32.2**	**23.0**
- Waiting because of lack of coordination	1.7	0.3	1.7	1.2
- Waiting because of lack of material	0.5	0.0	0.1	0.2
- Waiting because of lack of machine or equipment	1.0	0.1	3.6	1.1
- Waiting because of lack of work/instructions	1.7	0.9	4.6	2.0
- Waiting because other people were late	0.1	0.5	0.4	0.3
- Moving between working spots	16.1	15.5	18.2	16.3
- Other	1.9	0.9	3.7	1.8
60 Unexploited time	**6.3**	**15.1**	**10.7**	**10.4**
- Accidents, absence due to illness	0.0	0.0	0.0	0.0
- Moving in connection to breaks	3.8	2.8	3.8	3.4
- Too late start	0.5	1.5	0.7	0.9
- Too long break	0.0	0.0	2.0	0.4
- Too early finish	0.0	2.5	3.3	1.6
- Other	2.0	8.4	0.9	4.1
90 Other activities	**2.9**	**1.0**	**0.0**	**1.7**
Total	100.0	100.0	100.0	100.0

5. Discussion of Results

We found that the direct value adding work was 19.5% of the construction workers time in this case. However, 2.0% of their time was spent on corrections of defects. Of that reason, the direct value adding work would be 17.5% of the time. This is surprisingly low percentage compared to the American studies, which reported 40 to 60% [1,2]. On the other hand, in this case we have followed the definitions of value adding work fairly hard. For example, if the worker picked up nails from the floor exactly when the registration was made we registered losses, even if it only took a few seconds to do it.

Looking at these figures we could argue that the efficiency was very low in this case. But we could also take the discussion a few steps further in order to carry the matters to an extreme for the company. During the time of the study approximately 6% of the employed workers were on sick-leave. If we include these workers we could argue that the direct value adding work for the company's construction workers are 16.4%! In the next step we could include the managers, who supported the workers. For the three building elements, there was approximately 1.0 manager per 4.5 workers. If we also include the managers on site we could argue that the efficiency is as little as 13.4% of the total time spent on site, Table 2.

Table 2: Direct value adding work from three perspectives

Direct value adding work	*(% of total time)*
Construction workers on the site	17.5
All construction workers employed by the company	16.4
All construction workers employed by the company + supporting managers on site	13.4

The wasted time is at least 19.1%, Table 3. Then we include correction of defects, all waiting except moving between working spots, and all unexploited time. The major areas of waste were moving in connections to breaks, waiting because of lack of work or instructions and correcting defects. The volume of wasted time is significantly higher than what has been reported in defects studies [e.g. 6]. Still, the volume could be higher if we analyze the reasons for moving between working spots, which corresponded to 16.3% of the workers time. Some of the preparations, i.e. indirect work, material handling and work planning, could also be consequences of problems occurred.

Table 3: Activities performed by construction workers divided into direct value adding work, preparations, moving between working spots and waste.

Activity	*% of total time*
Direct value adding work, excluding corrections	17.5
Preparations	45.4
Moving between working spots	16.3
Waste	19.1
Other	1.7
All	100.0

A great number of studies claim that a typical day for managers in general and also for site managers include numerous interruptions and change of activities [e.g. 6,7]. This study indicates that also construction workers seem to have very divided days. Figure 1 shows a typical eight-hour day at the site for a construction worker, excluding breaks for coffee and lunch. In this case the worker have changed activity at least 156 times during the day.

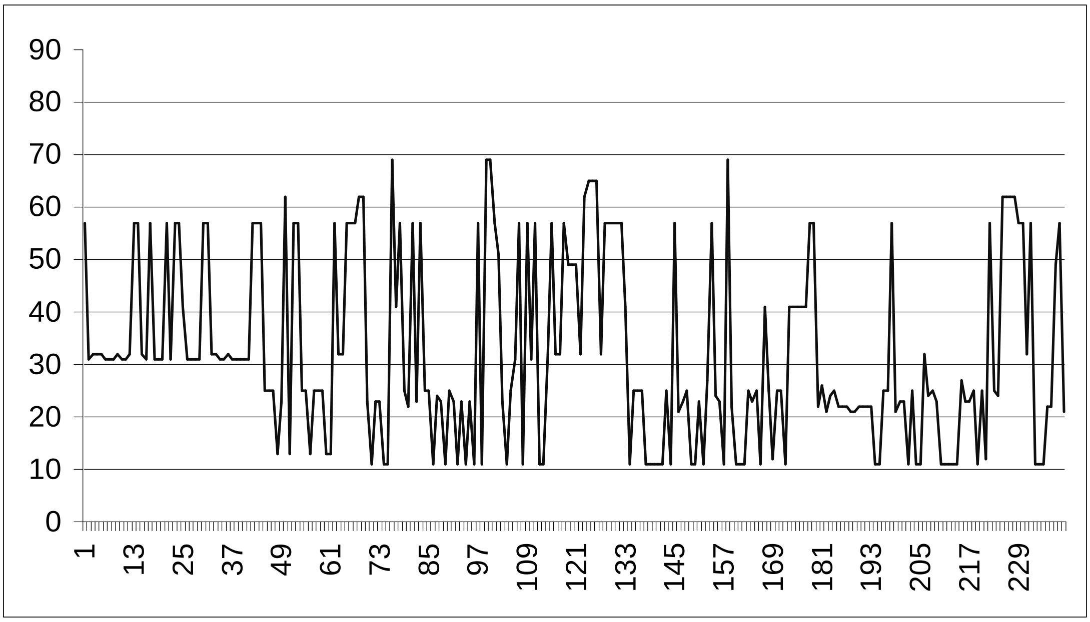

Figure 1: A typical eight-hour day at the site for a construction worker. The horizontal scale presents the number of minutes from start. The vertical scale presents the code for activities (see Table 1).

6. Conclusions and Recommendations

The aim of this paper is to identify how construction workers' time is used on construction sites, by making direct observations on site. The results form a strong argument for managers to pay far more attention on production processes than what is common today.

We have found that the efficiency is surprisingly low. Less than 20% of the workers time is spent on direct value adding activities. The obvious wasted time is approximately 20%, but will probably increase if we look closer at the indirect work and the handling of material and equipment. The typical day at work is divided and includes many different activities. The case considers a single housing project. However, the personnel within the project perceive it as quite normal. The results presented here should of that reason be considered as a typical example. There is a risk that the observer has influenced the team during the studies. We believe, however, that this influence is minimal. The main reason is that the study has been for such a long time that the individuals get used to people around.

The definitions of what is direct value adding activity, indirect work etc, has been quite hard in order to get as true picture as possible. We have experienced that practitioners tend to perceive indirect work and material handling as value adding. With influences from popular literature and a number of oral presentations about companies with more industrialized processes, especially Toyota, we have, however, decided to adhere to our original definitions.

The results indicate that further empirical data is needed in this area, as well as further analysis of the data, in order to better understand how much is wasted time, what kind of waste it is and what waste can be reduced or eliminated with existing production system as well as with other production systems.

The results have been an alarm for Peab. They have decided to also in future projects use the tool they have developed for work sampling studies about what construction workers really do. The approach is to make observations for a week and then analyze the data and go back to the site and discuss the results with the workers. On project level, the aim is to get the workers aware of the current situation and to get them create ideas of how to improve the situation. On firm level, the aim is to learn more about existing waste and how it can reduced.

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Variable Labor Productivity Unit Rate: Evaluation by Professionals

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Abstract

To forecast labor productivity indexes is a very important task to be performed, by the construction managers, in order to compose reliable building construction budgets and schedules. To do so, the main information sources have been the estimating manuals. These type of manuals are normally available in several countries, both developed and developing ones. The data, in such manuals, usually represent mean values for regional contractors performance. Although very easy to use, this approach, in the opinion of the authors, cannot be considered appropriate to the present context of Construction; the very competitive environment demands more accurate indexes to support managers' decisions.

Some recently developed researches, in Brazil, demonstrate the importance of considering a range of values to represent labor productivity unit rates instead of adopting a mean value for a broad scope of situations. The choice of a value from the proposed range would be based on the job's features.

Keywords: Labor productivity, productivity forecast, formwork, estimating manuals.

1. Introduction

The construction companies seldom measure the real productivity in their sites. So it is a current practice in Brazil to utilize productivity indexes gathered from estimating manuals to make budgets and schedules (Figure 1 shows the steps of a traditional budgeting process). These budgets and schedules are based on the physical resources consumption, which is composed by the labor, material and equipment consumption. This paper focus on labor consumption forecast for formwork job. Labor is the physical resource more difficult to manage and which demand have the highest variability. On the other hand, formwork is a labor-intensive task and often represents an event in the critical step of the project [1].

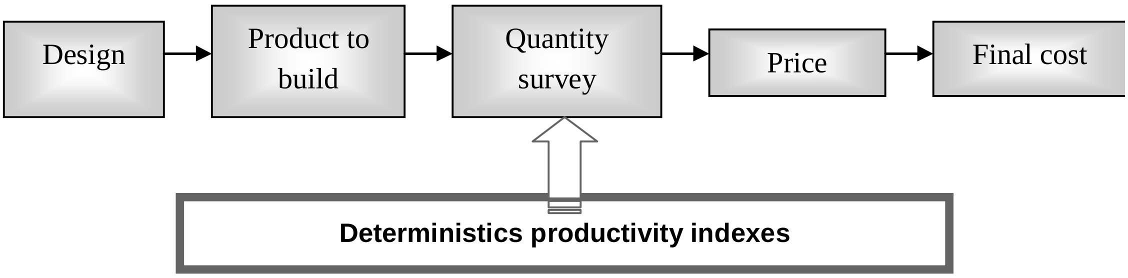

Figure 1: Traditional budgeting process

Two of the more important Brazilian estimating manuals, TCPO 2000 [2] and SBC [3], consider deterministic productivity indexes, as showed by the example in the Table 1.

Table 1: Productivity values formwork job taken from the main Brazilian estimating manuals for

Unit Rate (UR)	TCPO 2000	SBC		
	For whole formwork job	*For slabs*	*For beams*	*For columns*
Carpenter	1,35 Mh/m²	0,928 Wh/m²	1,268 Wh/m²	1,361 Wh/m²
Helper	1,35 Wh/m²	1,443 Wh/m²	1,773 Wh/m²	1,907 Wh/m²

*Wh/m² - Workhour per square meter of formwork

Authors as [4], do not indicate deterministic values on productivity forecasting. [5] emphasize that the simplicity on using deterministic approaches can be associate to a lost of precision on predicted productivities. [6] say that the costumers are not satisfied with the manuals values once they do not expose the job contend and context involved.

The high variability on productivity figures find representative of Brazilian building sites - that can reach 100%, according [7] e [8] - associated with the habit of using deterministic values and with an environment highly competitive generate a big insecurity on construction companies to forecast production costs. So, this paper intends to explore ideas linked to improve productivity forecasts to help the decision makers in the construction companies.

2. New Approaches to Forecast Productivity in Use in Brazil

The new approaches to forecast productivity discussed in this paper are based in the models prescribed on the literature (mainly on the Factors Model [9]) and on a productivity data base that have been collected since 1996 by the researches of the Department of Construction of University of São Paulo. The researches have been working on several different ways to of organizing productivity data to help the forecasting process. This paper discusses two of them: parametric equations developed by means of regression analysis and productivity range values associated to a list of factors that influence them.

The use of parametric equations was presented on [1]. Other research, as [11], added confidence to the statistical analysis. This paper deals with more recent parametric equations, as showed in 2.1 and productivity ranges on 2.2.

2.1 Parametric Equations

The unit rate for column, beam, slab and stair can be calculated by the following expression:

- ***bUR forecast - column***

$$bUR_{column} = 1.885 + 0.131BLE - (4.67SAR + 0.274BPL + 0.11TIE + 0.27LTI) + STR_{column} \quad (1)$$

Where:
UR = Productivity Unit Rate
bUR = Baseline for the skilled team
BLE = 0 when column leveling is based on each panel leveling; and =1 when column leveling is based on template leveling;
SAR: median cross-section area (in m^2);
BPL = 1 when column plumbing is based on studs plumbing; and =0 when column plumbing is based on whole panel plumbing;
TIE = 0 for removable ties; and = 1 for incorporated ties;
LTI = 1 for predominantly external ties; = 0 for predominantly internal ties;
STRcolumn = part of bUR referring to the column forms stripping. The proposed values for "STR" vary as showed by Table 2. One should choose higher whenever expects more difficulties in stripping the panels.

Table 2– "STRcolum" values variation range.

Minimum (wh/m^2)	Median (wh/m^2)	Maximum (wh/m^2)
0.13	0.14	0.30

- ***bUR forecast - beam***

The unit rate can be calculated by the following expression:

$$bUR_{beam} = 2.43 - 0.558BL + 0.267TU + STR_{beam} \quad (2)$$

Where:
BL = median beams length;
TU = 0 for when no tie is used; and = 1 for ties utilization;
STRbeam = part of bUR referring to disassemble beam forms. The proposed values for "STR" vary as showed by Table 2. One should choose higher whenever expects more difficulties in stripping the panels. The proposed values for "STR" vary as showed by Table 3. One should choose higher whenever expects more difficulties in stripping the panels.

Table 3– "STRbeam" values variation range.

Minimum (wh/m^2)	Median (wh/m^2)	Maximum (wh/m^2)
0.10	1.18	2.60

- ***bUR forecast - slab***

Floor structures with close slabs and beams raise difficulties in pulling down the formwork, inducing poor productivities (higher UR's). Table 4 presents some bUR values for slab formwork in conventional structures, where slabs rely on beams, and in plain slab structures, where slabs rely directly on columns.

Table 4 – bURslab values variation range.

Floors	**bUR_{slab}** (wh/m^2)	
Conventional structure (slabs with beams)	Minimum	0.40
	Maximum	0.96
	Median	0.69
Plain slab	Median	0.33

- ***bUR forecast – stairs***

bUR_{stairs} forecast can be based on the Table 5 information.

Table 5 – bURstair values variation range.

Stairs formwork	**bUR_{stair}** (wh/m^2)	
During the floor production	Minimum	1.78
	Maximum	2.64
	Median	1.93
After the floor production	Median	1.00

- ***bUR forecast – whole structure***

The $bUR_{whole\ structure}$ is calculated by the expression 3:

$$bUR = \frac{(bUR_{column} xA_{column} + bUR_{beam} xA_{beam} + bUR_{slab} xA_{slab} + bUR_{stair} xA_{stair})}{A_{column} + A_{beam} + A_{slab} + A_{stair}} \quad (3)$$

Where:

bUR= baseline for the skilled team
A= area (m^2 of structure).

2.2 Productivity Range

Labor productivity figures are presented by mean of a “ruler”, having the minimum and maximum values of the database at the extremes and the medium value pointed out in the between. The “ruler” comes with the indication of the factors driving the expected rate towards right (unfavorable ones) or left (favorable ones), as shows the Figure 2.

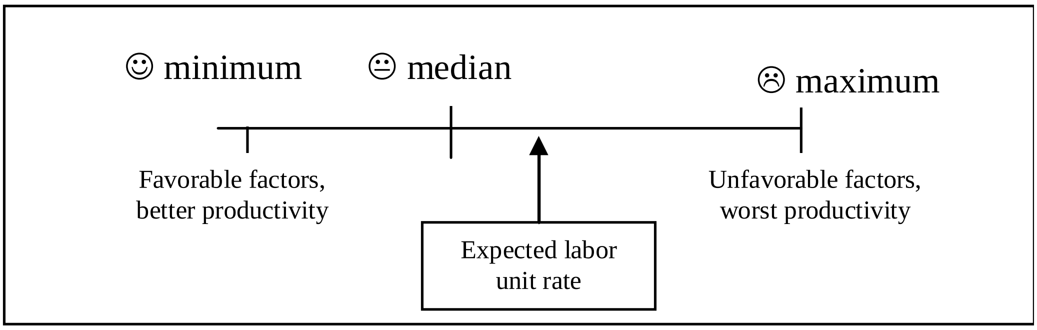

Figure 2: Concept of variable productivity range, Fonte: SOUZA et al.(2003)

In the Figures from 3 to 6 are presented labor productivity indexes range to carpenters of formwork job. The job envolves 4 tasks: column formwork (Figure 3), beam formwork (Figure 4), slab formwork (Figure 5) and stair formwork (Figure 6).

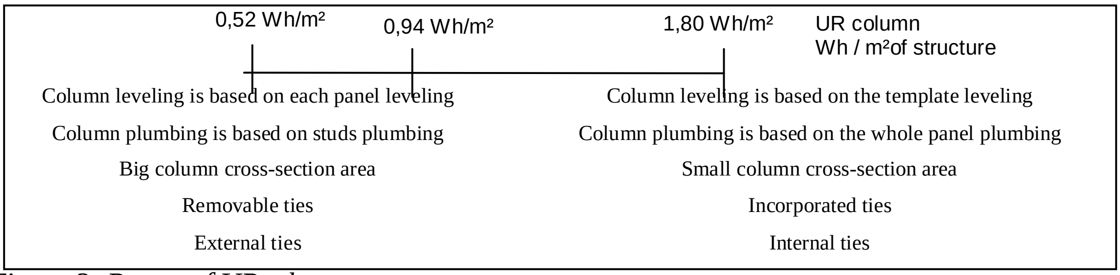

Figure 3: Range of URcolumn

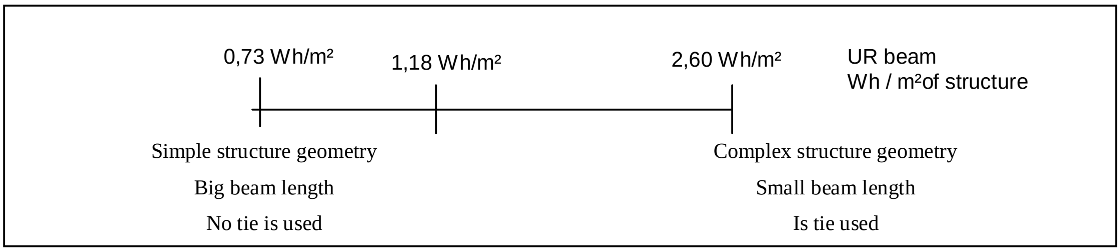

Figure 4: Range of URbeam

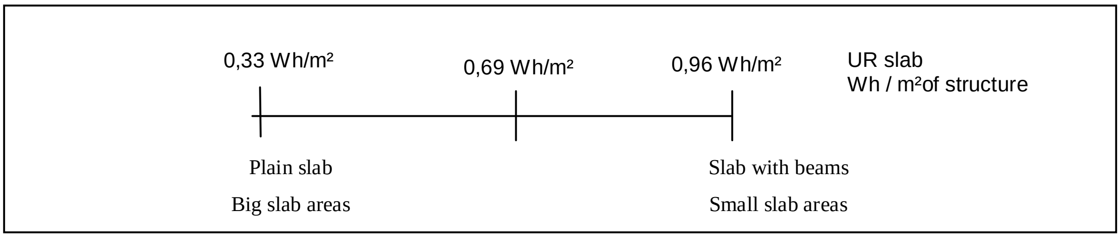

Figure 5: Range of URslab

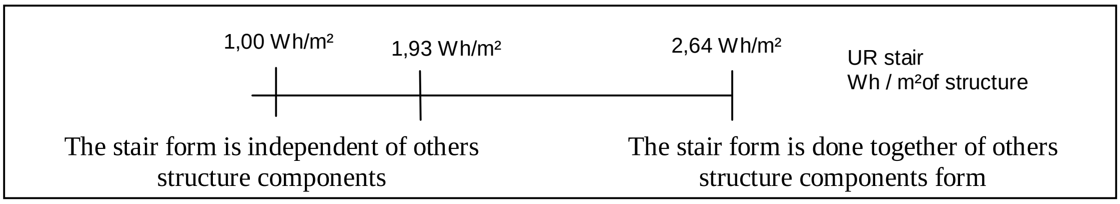

Figure 6: Range of URstair

Observe on Figure 3 that the median value is 80% superior to minimum and the maximum value is about 90% superior that median; this demonstrates the fault that we can do when the median value is chosen in situations in which one of the extremes were expected.

Any value within the range is accepted as possible value for productivity, although the expectations for the best or worst results involve other subjective factors.

In order to know the UR for all structure formwork, it should be done using the Equation 3. It will be necessary to chose on ranges what productivity better adequate to your build (minimum, median or maximum) and to know the dates of quantity extracted from projects.

3. Evaluating the Applicability of New Forecasting Approaches

The new approaches were tested following the steps of Figure 7.

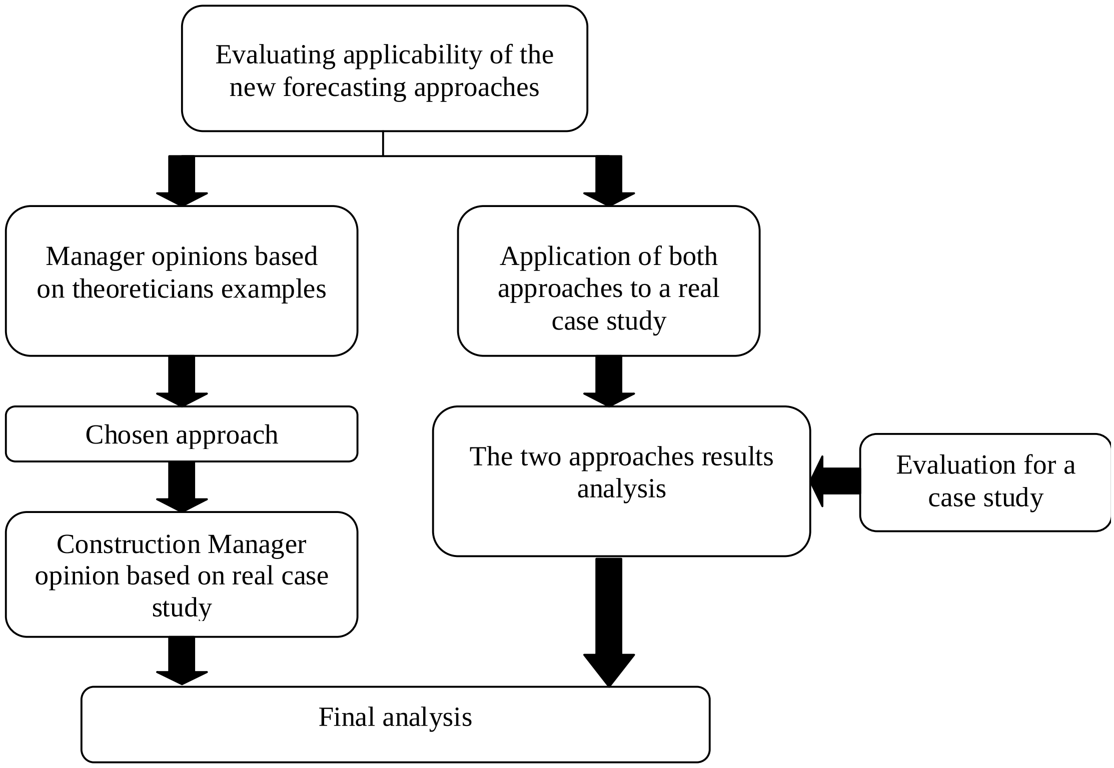

Figure 7: Methodology used to test the applicability of new forecasting approaches.

The test of applicability of two forecast approaches were has two ways:

a) First step - the approaches were submitted to construction managers to see what of them they feel more promising. These professionals were participating of a course about productivity concepts. They appreciate both approaches because they can have more dominion above the forecasts. Although they can apply the equations, they choose the ranges because they feel more comfortable on using it. After that, the ranges were presented to a construction manager that have never been in contact with productivity concepts or forecast. It was observed that he not feel secure as well in relation to factors relevancy as to analyze the productivity separately per components (column, beam, slab and stair). The manager have the feeling about total productivity that is necessary to get per type floor, this is due the labor contract model, which considers a fixed price per floor.

b) Second step – the authors did a forecast to a real build (that one in which the manager was questioned in the first step) utilizing as the range as the equation.

<u>Productivity Range Forecast</u>

It was chosen the follow values for the productivity:

- URcolumn: 0,94 Wh/m² (median value)
- URbeam: 0,73Wh/m² (minimum value)
- URslab: 0,69 Wh/m² (median value)
- URstair: 2,64 Wh/m² (maximum value)

The build had more favorable factors than unfavorable, however, to get more security on forecast, the median was chosen to column and slab. Only in the case of stair that the worst situation was chosen to be coherent with the factor, that was unfavorable. Based in these values and on survey of project quantities, applied on Equation 3, it were obtained the productivity forecast (0,80 Wh/m²).

<u>Parametric Equation Forecast</u>

It was given heights to the characteristics of build as indicated on 2.1 heading. The heights are presented on 3rd column on Table 6. Utilizing these heights into the Equations 1 and 2 plus the values chosen on Table 4 and 5, referent to structure components, it were obtained the results for column, beam slab and stair, which are presented on column 4th. These values were applied on Equation 3 to get the total productivity for whole structure, whose the result is presented on 7th column. The 5th column present the values chosen in the productivity range approach. The Table 6 shows yet, the Brazilian estimating manuals (SBC e TCPO 2000) values, on columns 6, 9 and 10.

In order to know the real productivity involved on formwork job in the floor, it were collected the quantity of hours worked for de formwork crew, which were composed only by carpenters (583 Wh/type floor; UR = 0,84 Wh/m²). This value is presented on 11th column on Table 6.

Table 6– Productivity dates for the real build.

<table>
<tr><th rowspan="2">Structure component</th><th rowspan="2" colspan="2">Build characteristics</th><th colspan="3">Forecasted UR for the structure components (Wh/m²)</th><th colspan="4">Forecasted total UR (Wh/m²)</th><th rowspan="2">Real UR (Wh/m²)</th></tr>
<tr><th>Equation</th><th>Range</th><th>SBC</th><th>Equation</th><th>Range</th><th>SBC</th><th>Tcpo 2000</th></tr>
<tr><td rowspan="6">Column (200,5 m²)</td><td>BLE</td><td>0</td><td rowspan="6">1,16</td><td rowspan="6">0,94</td><td rowspan="6">1,36</td><td rowspan="11">0,79</td><td rowspan="11">0,80</td><td rowspan="11">1,13</td><td rowspan="11">1,35</td><td rowspan="11">0,84</td></tr>
<tr><td>SAR</td><td>0,12</td></tr>
<tr><td>BPL</td><td>1</td></tr>
<tr><td>TIE</td><td>0</td></tr>
<tr><td>LTI</td><td>0</td></tr>
<tr><td>STR</td><td>0,14</td></tr>
<tr><td rowspan="3">Beam (153,3 m²)</td><td>BL</td><td>3.81</td><td rowspan="3">0,40</td><td rowspan="3">0,73</td><td rowspan="3">1,27</td></tr>
<tr><td>TU</td><td>0</td></tr>
<tr><td>STR</td><td>0,10</td></tr>
<tr><td>Laje (328,5 m²)</td><td></td><td></td><td>0,69 (mediana)</td><td>0,69</td><td>0,93</td></tr>
<tr><td>Escada (9 m²)</td><td></td><td></td><td>1,93 (mediana)</td><td>2,64</td><td>0,93</td></tr>
<tr><td>1st</td><td>2nd</td><td>3rd</td><td>4th</td><td>5th</td><td>6th</td><td>7th</td><td>8th</td><td>9th</td><td>10th</td><td>11th</td></tr>
</table>

Observes, therefore, that the forecasted productivity values obtained as for the equation as for the range (about 0,80 Wh/m²) got a great forecast, because they are near to the real productivity (0,84 Wh/m²) reached by the crew on the site building, while the estimate manual values are more distant to real productivity.

4. Final Considerations

The research with construction manager opinions not shows resistance on using of range. On the other hand, the position of construction manager interviewed presented critical, probably justified by the lost of training or sensitization about the subject and due to a form of labor contraction.

In the results analysis, although of, theoretically, the range presents a minor precision on forecast, because is a simplification on equations, it provides to a bigger easiness of application and the value gotten in this in case were satisfactory due to be near to the really it happened in the site build. On the other hand, the range eliminates some cited problems related to the traditional position (only presenting the average value).

Recently, one of the most important Brazilian estimating manuals included, beyond the traditional approach, the alternative approach of productivity ranges. The responsible believes that it can provide a better understanding for both, construction managers and designers, about the factors that influence productivity labor.

Once providing better understanding of labor productivity, the authors believe the "productivity range approach" can help improving cost and schedule forecasting in the Construction Industry.

Acknowledgements

The authors want to acknowledge the construction managers from São Paulo Construction Companies that are participating of productivity courses promoted by Department of Construction of University of São Paulo. In special way, the company Tarjab Ltda., that allowed visits in its site building to perform this research.

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Evidence-based Improvement on the Royal Bank of Scotland, Gogarburn Construction Project

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Abstract

Numerous independent studies have shown that there is significant room for improvement on construction sites, particularly in relation to productivity, quality, health and safety, and innovation. At the new Royal Bank of Scotland (RBS) headquarters in Edinburgh, the client and the construction management team set out to produce a construction project that would be considered an example of best practice in the above categories, and create a stimulating and rewarding working environment for the whole construction team. BSRIA, an independent construction consultancy, helped achieve these objectives by delivering comprehensive and interactive training, monitoring and analysing key activities of the construction process, and compiling an evolving and evidence-based lessons-learned database for feeding back valuable knowledge into the project. The outcome was a construction project that has generated construction cost savings of 9.33% and a construction time reduction of 33.3% when compared to projects performing at conventional UK construction industry levels. This success was complemented by an outstanding health and safety record.

Keywords: Costs, Health and Safety, Performance, Productivity, Site Management

1. Introduction

1.1 The Construction Industry

The construction industry is the largest industrial cluster in the world. In the European Union (EU-15) construction accounts for an annual turnover of € 955 billion[1] and direct employment of 11.8 million people[2], or 11% of the total gross domestic product (GDP)[1,3] and 10.4% of all employment[2], respectively.

In addition to its importance as an industrial sector, the construction industry profoundly affects the overheads of all other industrial, commercial, educational, healthcare, recreational, communication and transport activities and makes a huge contribution to the quality of professional and private life across the world. It is evident, therefore, that business performance and the daily lives of the world's population can be improved with better health and safety, quality, environmental, social and productivity performance within the construction industry.

Although the construction industry does produce some very accomplished work, independent research (and various performance statistics) conclusively shows that there is significant room for improvement in project performance. Some of these areas for improvement are summarised below:

- Over the last ten years, BSRIA has conducted detailed research into site processes and construction productivity in some EU countries and in North America. The research has shown that approximately 50% of all site labour resource is wasted due to a combination of delays and variability in installation performance [4].

- In the UK, widely-used Key Performance Indicator (KPI) data showed that, in 2004, only 60% of UK construction projects were delivered on time, only 49% of UK construction projects were delivered on budget, and only 68% of UK construction projects scored 8/10 for defects at handover [5].

- Health and Safety Executive statistics for 2004 reveal that there were 4,001 major injuries and 8,162 over-three-day injuries on UK construction sites [6]. Seventy people were killed on UK construction projects in 2004 (30% of all worker fatalities occurred in the construction industry), which is equivalent to a rate of 3.55 deaths per 100,000 workers [6].

- Recent statistical data has indicated that average worker fatality rates for EU-15 countries are approximately 1.6 times higher than the UK figures [7]. In addition, the deaths-per-100,000 workers rate for construction in the USA is 11.4, which is more than triple the UK rate [8].

1.2 The RBS Gogarburn Construction Project

The RBS Gogarburn project involves the construction of a new worldwide headquarters for the Royal Bank of Scotland (RBS) in Edinburgh, Scotland. It has been designed to accommodate 3,250 people, with parking for 1,650 cars. The main part of the project comprises the construction of seven, three-storey office buildings and a 500-seat staff restaurant. These are linked by a 300 metre-long enclosed street, which contains assorted retail outlets and informal social spaces. A basement runs the full length of the development. It provides parking for cars and bays for bicycles, and contains storage, kitchen, mailroom and plantroom areas. In total, the main development, shown in Figure 1 below, extends to around 65,300m^2.

Figure 1: The main building at RBS Gogarburn

The site also features separate conference, nursery, leisure and sport facilities on site, which account for an additional 8,000m^2 of floor space to the project.

The total development budget for the project is £335 million. The construction costs are £229 million, of which around 10.5% has been spent on site organisation and 12.1% has been spent on preliminaries. Groundworks commenced in November 2002 and practical completion is scheduled in February 2005, creating a construction programme of approximately 27 months.

In line with the high ambitions for a headquarters project, the project team was also looking to create a construction project that demonstrated best practice in productivity, quality, and health and safety performance.

2. Delivering Performance Improvement at RBS Gogarburn

At RBS Gogarburn, the project team acknowledged that the creation of a stable, highly productive, safe and quality-focused environment would require an investment in both the development of the people who would work on the project, and in an initiative that employed evidence as a key mechanism for delivering performance improvement. BSRIA was invited by the project management company Mace and the client Royal Bank of Scotland to assist with the delivery of these two elements.

2.1 The “Moving Forward” Training Course

A key objective of the RBS Gogarburn project team was to create an effective and efficient workforce capable of safely delivering best practice levels of construction site productivity and an excellent finished product. In order to achieve this objective, the traditional, high quality building skills that the workforce possessed, needed to be complemented with improved competence in areas such as work preparation, meeting the needs of others, housekeeping, innovative ways of working and learning from experience.

In order to embed these new areas of competence in the project workforce, BSRIA designed, in close collaboration with the rest of the project team, a five-module, half-day, interactive, site-based training course called: “Moving Forward”. A colour, pocket-sized project handbook contained key project health and safety information and a two-page summary of each course module, together with tear-out pages featuring work preparation checklists and feedback forms that could be used by the project team.

The five, 25-minute modules were designed for delivery to everyone working on the project, from director through to apprentice and from architect through to scaffold erector. The content of the five course modules is summarised below.

- Module 1: Knowledge and Learning – *Outlined the key objectives of the project team, provided an overview of a simple review and improvement methodology, highlighted the role of the individual in making improvement happen and showed examples of where evidence-based review and improvement had been successful.*
- Module 2: The Changing Construction Site – *Contrasted the relatively unchanged, 5,000 year-old, construction methodology based upon lots of people taking lots of time to put lots of components together on site, with industries that have introduced paradigm shifts in their production processes. Introduced the concept of the modern construction process, which blends the best of traditional practices with new products and innovative ways of working. Provided examples of construction project teams that have made this change*
- Module 3: The Working Day – *Examined how the build process on site is typically composed, together with the inputs, resources and outputs that are required for successful task delivery. Showed how a typical working day is composed through the concept of productive and non-productive time.*
- Module 4: Work Area Control – *Introduced 14 characteristics of work area control, which together enable the workforce to build high quality products in a safe and highly productive manner.*
- Module 5: Tools you can use – *Reviewed the key elements of the four preceding modules in conjunction with the accompanying project handbook. Provided an*

overview of the continuous improvement activities taking place on the project, together with the lessons-learned database in operation on the project.

2.2 Evidence-based Review and Improvement

Clear evidence in the form of performance statistics and independently-configured lessons-learned were selected as key drivers for the continuous improvement process at RBS Gogarburn. In order to collect this evidence, BSRIA conducted detailed monitoring exercises on activities that were either principal consumers of time and cost, or that dominated the critical path of project delivery.

A crucial component of the activity monitoring was the measurement of what percentage of the working day was lost to delays across all key work packages. BSRIA used its 10 years of expertise in this field to pre-define the 14 delay types employed in this process.

In conjunction with this performance measurement, good practice or areas for improvement were identified during the monitoring activity, and a process of root-cause analysis was undertaken to identify the causal reasons and appropriate corrective actions. In addition to conventional written representation of this information, digital video clips and digital photographs were also extensively employed.

The evidence produced by the above activities was fed into a wide range of performance improvement mechanisms, such as a single-page feedback forms with embedded charts or photographs, multimedia de-brief sessions for specific elements of the project team, input to project meetings, and content for plasma screens and notice boards located around the site. In addition, all the evidence produced was stored in a lessons-learned database located on the project intranet, which was structured by work package and by file type.

3. Results

3.1 Knowledge and Learning

During a 21-month period, 976 people from 85 different companies have attended the BSRIA “Moving Forward” training course. This is the largest initiative of this kind ever undertaken on a UK construction project.

A project lessons-learned database, structured according the work package descriptions already in use on the project, has been populated with the following evidence:

- 221 single-page, colour feedback forms on a diverse range of issues, such as site logistics, interface details, housekeeping, installation productivity, delays, health and safety and quality management
- 407 video clips of key activities on site
- 2,220 high resolution photographs that capture the construction process and show key project details

All the above files have been named using a standard protocol based upon the use of a primary and secondary keyword, the work package number and name to which it relates, a date and a identifier for the file type. *E.g. Protection-curtain wall-3200-external cladding-10 Nov 04-V.* This approach has facilitated easy storage and retrieval of the evidence.

3.2 Cost and Time Performance

At the time of writing of this report, the RBS Gogarburn project is 96% complete and one month away from practical completion. The project will be delivered below the original budget and four weeks ahead of the original completion date.

A key contributory factor to this impressive cost and time performance has been that the project team has managed to increase the amount of productive time during each working day, when compared to conventional UK performance. Over a 21-month study period, each person working within the observed construction teams at RBS Gogarburn lost an average of 20% of each working day to delays. Although there is room for improvement in this level of performance, this figure is significantly lower than the average UK construction industry benchmark of 40%, which was established by BSRIA during its detailed research between 1994 and 2002 [4,10]

Site personnel costs on the RBS Gogarburn project were an average of 28% of the total construction costs. This figure corresponds closely with other reference sources that have examined the configuration of costs on construction projects [9].

The effect that the improvements in productive time have had on time and cost certainty on the project is illustrated in Figure 2 and Figure 3 below. The analysis shows that if the project had experienced delays at conventional UK construction industry levels of 40% of the working day:

- The construction cost would have increased from £229 million to £250.4 million, or by 9.33%
- The construction programme would have increased from 27 months to 36 months, or by 33.3%

Actual construction cost performance on the RBS Gogarburn project with productive time equal to 80% of the working day	
Construction cost	**£229**
Non-labour cost at 72% of the construction cost	£164.9
Labour cost at 28% of the construction cost	£64.1
The amount of the labour cost converted into productive time (*80% of the working day)* This figure is therefore the cost of the actual manpower required to build the project.	£51.3
The amount of the labour cost consumed by delays (*20% of the working day)* This figure is represents the cost of the manpower that was paid for, but which did not contribute to the building of the project.	£12.8

Theoretical construction cost performance on the RBS Gogarburn project with productive time equal to 60% of the working day	
The cost of the manpower, or productive time, required to build the project. *(This figure is the same as in the table above because the quantity of built product is the same)*	£51.3
The amount of the labour cost consumed by delays*. (40% of the working day)* This figure is represents the cost of the manpower that was paid for, but which did not contribute to the building of the project. *(The cost of this element is significantly higher than the corresponding figure in the above table. This is because the productive time component of £51.3 in this table represents only 60% of the working day, as opposed to 80% of the working day in the calculation used in the above table)*	£34.2
Labour cost required for the delivery of the project.	£85.5
Non-labour cost required for the delivery of the project. *(This figure is the same as in the table above because the quantity of built product is the same)*	£164.9
Construction cost	**£250.4**

Figure 2: An analysis of construction cost performance on the RBS Gogarburn project (All figures are in £ millions)

Actual construction time performance on the RBS Gogarburn project with productive time equal to 80% of the working day	
Construction programme duration	**27 months**
The amount of the construction programme converted into productive time (*80% of the working day)* This figure represents the actual productive time required to build the project.	21.6 months
The amount of the construction programme consumed by delays (*20% of the working day)*	5.4 months

Theoretical construction time performance on the RBS Gogarburn project with productive time equal to 60% of the working day	
The amount of the construction programme required to build the project. *(This figure is the same as in the table above because the quantity of built product is the same)*	21.6 months
The amount of the construction programme consumed by delays. *(This element is significantly higher than the corresponding figure in the above table. This is because the productive time component of 21.6 months in this table represents only 60% of the time required, as opposed to 80% of the time required in the calculation used in the above table)*	14.4 months
Construction programme duration	**36 months**

Figure 3: An analysis of construction time performance on the RBS Gogarburn project

3.3 Health and Safety

Over five million man-hours have been worked on the RBS Gogarburn project since construction activity commenced. Three reportable injuries have occurred during this period. This level of health and safety performance is more than ten times better than the current average level of performance for the UK construction industry [6,11].

The level of health and safety performance generated on the RBS Gogarburn construction project demonstrates that the combination of a well-trained, motivated and responsible workforce, excellent site organisation and the provision of appropriate plant, tools and equipment does generate a reduced incidence rate of reportable injuries.

The achievement of the project team was recognised in January 2005 when a film crew, commissioned by the Health and Safety Executive, interviewed 20 workers at the RBS Gogarburn construction project. These individuals were asked to provide feedback about working on a project where a great emphasis had been put on best practice health and safety performance. The edited version of the video was shown at the Construction Health and Safety Summit 2005 – a major conference on health and safety in construction held in London in February 2005, which was attended by senior executives and trade union officials from the construction industry, as well as senior representatives from UK governmental departments.

3.4 Quality

A study of the causes of defects recorded on the project prior to practical completion revealed that 54% of all defects on the project were attributable to outstanding works, 20% were attributable to the quality of workmanship, 13% were attributable to the precision workmanship, 12% were attributable to damage of finished work, and 1% was attributable to either material or functional faults.

A analysis of the time taken for the clearance of individual defects from the project management system employed on the project also highlighted that there was not enough commitment from the specialist trade contractors to providing dedicated teams who assumed responsibility for finishing the project in a defect-free manner.

The above evidence was fed back to the organisations working on the project and this helped the project focus on the key factors that were inhibiting the delivery of a defect-free project at handover to the client. Consequently, the project team has been able to work towards project completion in a much more controlled manner than normal UK construction projects that have not had this level of understanding.

4. Conclusions

- The global construction industry has significant room for improvement in its cost, time, quality, and health and safety performance.

- If properly trained and motivated, the construction workforce is capable of delivering improvements in cost, time, quality, health and safety performance. Site-based training of the workforce should be more widely adopted by construction project teams. It should focus on complementing workers' traditional technical skills with improved competence in work preparation, meeting the needs of others, housekeeping, innovative ways of working and learning from experience.

- Evidence-based review and improvement is an effective mechanism for improving performance on construction projects. This approach enables teams to identify, review and improve the things that really matter, and should be more widely adopted by construction project teams.

- Performance improvement on construction sites generates significant economic benefits for all parties involved. Improved working conditions also create considerable social benefits for the workforce.

- Performance improvement in the construction industry will generate benefits for all other industrial, commercial, educational, healthcare, recreational communication and transport businesses.

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Definition defects at handover: Some defects with no significant impact on the client

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Definition reportable injuries: In the UK, injuries during work activity are reportable to the HSE when they are fatal, major (e.g. fractures), or cause absence from work for more than three days

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Scientific Benchmarking of Building Projects – Model and Preliminary Result

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Abstract

The Norwegian construction industry needs a benchmarking tool suitable for both common and individual use. The R&D project “Productivity in Norwegian construction industry” uses a scientific method, the Data Envelopment Analysis (DEA), for this purpose. The challenge has been to identify and collect data and supplementary facts for the analysis. The study is carried out at the project level. The data collection tool, i. e. a questionnaire with guidelines, has been designed with focus on the project as a whole. Likewise, much effort must be put on identification of the most important parameters. The contractor’s point of view is chosen and the sampling for the investigation must consist of fairly similar types of projects. A pilot study on the production of blocks of flats is carried out. The preliminary benchmarking result is suggestive and encourages the R&D project team in the commissioning of the pilot study and start of new investigations.

Keywords: Productivity analyses, efficiency analyses, benchmarking, statistics in construction, cost control

1. The R&D Project

1.1 Overview

Productivity in Norwegian construction industry is a five-year (October 2001- September 2006) research project with an estimated effort of 200 person-months. The main goal is to develop a tool for scientific benchmarking of building projects. The project is based on cooperation between two research environments; the Department of building process studies of NBI and the Frisch centre / Department of Economics at the University of Oslo. The economists support the project with know-how of applying benchmarking using the non-parametric, multivariate method for efficiency analysis referred to as DEA (Data envelopment analysis [2]). Further development of this method is a separate part of the project; see paper by Dag Fjeld Edvardsen, NBI [1].

1.2 Background

In the period 1995 – 2000 the Norwegian construction industry experienced a severe decline in productivity. Observing this in the context of similar figures for the average of all industries in Norway leaves an alarming impression. See figure 1.

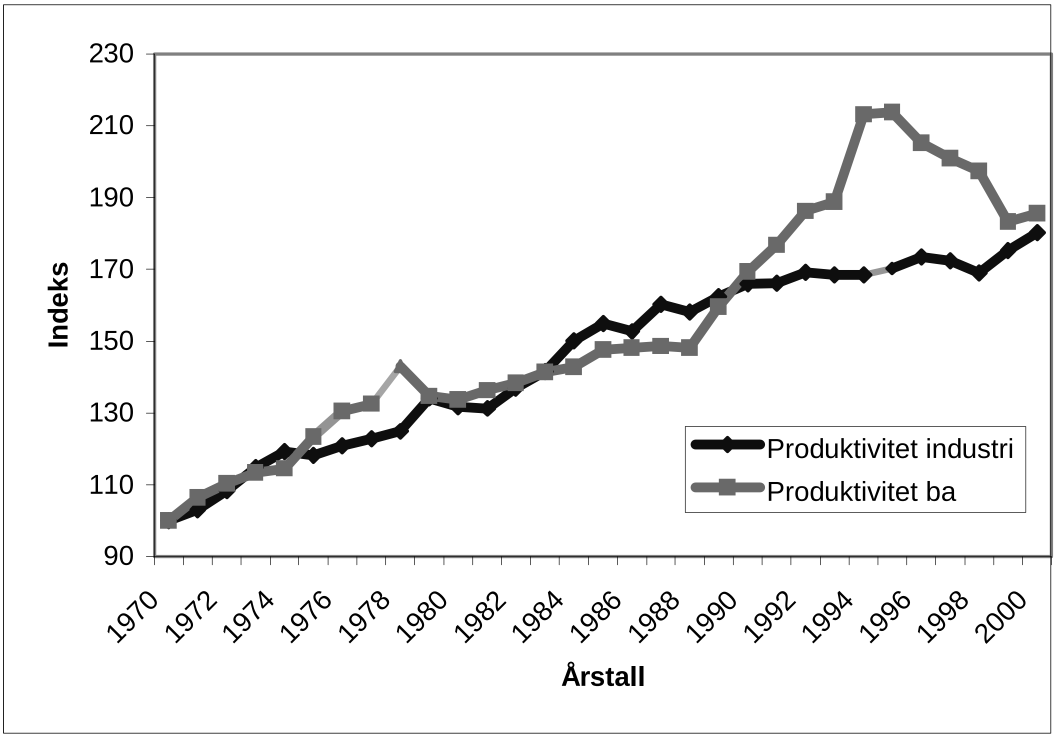

Figure 1: Development in labour productivity (grey) in construction industry vs. all industry (black) 1970-2000. Index 1970=100. Source: Norwegian national accounts

The dramatic (right) part of the curve has been given de-dramatizing explanations like

- the construction industry is very sensitive for change in business cycles

- the labor productivity figure, from national account, is not suitable as a basis for discussion of the productive efficiency in an industry like construction.

Nevertheless, the unpleasant development of productivity and the recognition of national account figures as non-suitable for productivity studies in construction industry, gave birth to the R&D project presented here.

1.3 Industrial Need

The construction industry is important for any industrialized nation. In most European countries it has a 5 – 15% share of the gross national product (GNP). The importance is strengthened by the fact that the construction industry has a strong impact on all other sectors in the economy.

To keep their "competitive edge", construction companies, as all other companies, has to establish and support their individual, continuously running improvement programs. The *ideal* concept for improvement work is an systematic, scientific approach, including productivity measurement and statistic analyses, as recommended in the ISO 9001:1994 Quality systems. In the Norwegian construction industry this is not very often observed. It is more usual, if there is any improvement program at all, that it is a "gut-feeling"-based approach with low attention to data and statistics.

Few productivity studies have been carried out in the past in the construction industry. The main experience is that data collection is difficult and that low quantity of data causes low quality of the results. Consequently the industry does not know much about itself through statistics. A few national account based studies indicate that the efficiency fluctuates with the business cycles. That is about all. There is a lack of knowledge about how to measure productivity/efficiency and how to identify influencing factors. The aim of the ongoing R&D project is to change this unsatisfying state of art.

2. Productivity and Efficiency in Construction Projects

2.1 Measuring Productivity

This paper gives a summary of the early phase work of the R&D project. The aim was (is) to develop a model for measuring productivity of building projects, on which a final benchmarking can be carried out. Productivity is defined as the ratio

$$\textbf{Productivity} = \frac{\textbf{Product} \text{ (e. g. figure(s) giving precise quantitative measures of the delivered product)}}{\textbf{Resources} \text{ (e. g. figure(s) giving precise quantitative measures of resources used)}}$$

In construction industry, the tradition has been – and still is – to pay the workers ("blue collars") based on *labour productivity* (piece work contracts). Between the worker's union(s) and the contractors' trade union federation(s) normative references are established for all types of operations in the construction process. For given parts of a project, e.g. the floor construction, one can calculate the labour productivity as:

$$\textbf{Productivity of floor production} = \frac{\textbf{Floor area}\text{ (f.ex. 1000 m}^2\text{)}}{\textbf{Hours}\text{ (f.ex. 500 hrs.)}}$$

For sub-contractors with floor constructions produced on-site as the main product, this number will be of high interest for every contract they carry out. (In the denser parts of Norway, such organizing/specializing of the building process is normal). Even for this type of company, the floor production differs from project to project. Span and thickness of the floor construction differs, and so does the specification of the concrete, the required finish, the number of block-outs, embeddings, etc.

When it comes to production of a complete building, the challenge of measuring productivity is increased: First of all, not all activities in the building process are as easy to single out as the production of floor slabs. Normally 10 – 30% of the tasks will be handled in other ways than through a piece work contract. Furthermore, most buildings are one-of-a-kind projects, making systemizing and use of productivity data resource consuming and difficult. With the increased number of sub-contractors in an ordinary project, the productivity data will be spread on different companies. Finally, the ability to produce a building with a minimum of resources (with highest possible efficiency), seems to depend on how much time is "leaking out" *between* all specified activities, different professions and/or contracts in the project.

Measuring productivity has different challenges. One of them is how to separate the productivity from the profit, see figure 2.

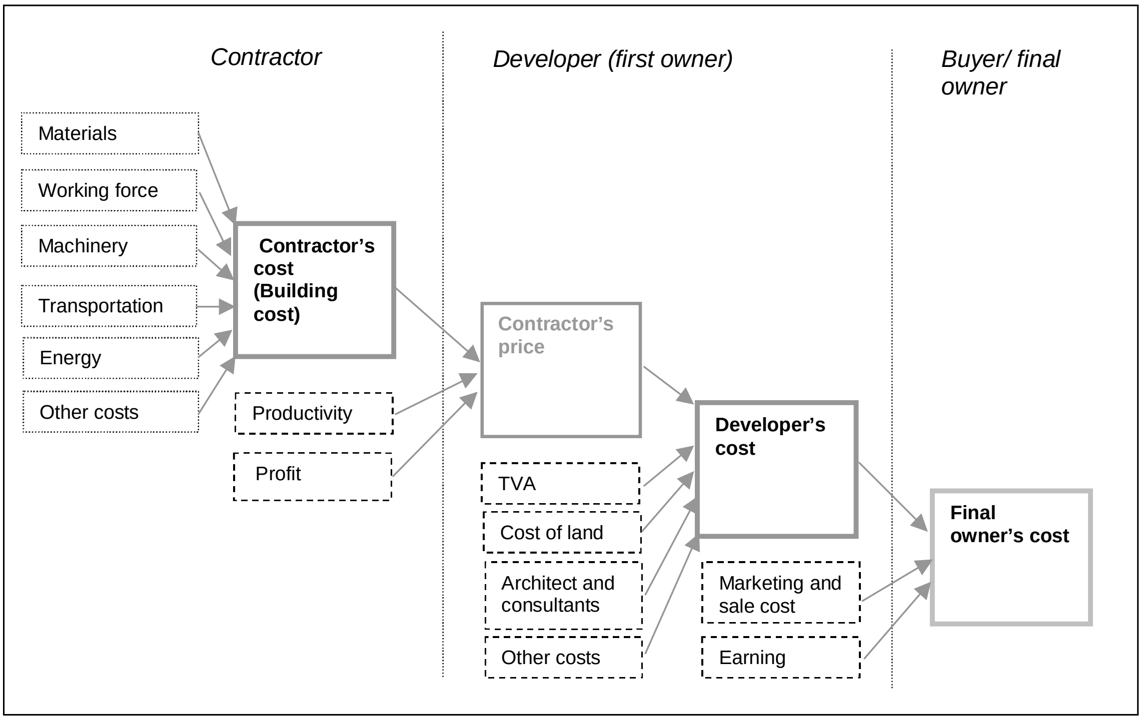

Figure 2: Building – the value chain. Source: Eurostat 1996

In figure 2, *productivity* is illustrated as an individual item, separate for the cost and the profit. In the contractors' books, the phenomena of productivity will show up as a part of the profit figure. If the productivity has been better than anticipated, this will become visible as a higher profit figure than calculated. If the productivity is lower than planned, the profit will become lower than calculated. (Other relations can also have a similar influence on profit. This makes the detection of "through productivity" even more difficult. - *The productivity box* in figure 2 can be read as an emphasizing of the fact that productivity is a specific aspect of the production that should be identified).

2.2 Comparing Productivity

From improvement point of view the productivity number has limited interest. The interesting part is to learn how well one producing unit is performing compared to other units, to it's own earlier performance(s) or to some normative number. When comparing productivity, each producing organization in a sample will come out with it's own "E-score" (the efficiency score), see figure 3.

$$E_n = \frac{P_n}{P_{Ref}}$$

Figure 3: Efficiency ("relatively productivity") for a unit (n) with reference to the unit (Ref)

The DEA method uses economic theory to rank a group of producing units from the most efficient one(s) (E-score 1.0) to the least efficient ones with scores from 1.0 and downwards. The main principle of the method is that each unit in the master sample is compared to the one(s) with highest E-score (1.0), i.e. the units that have demonstrated *best practice.* The theory is complex and can be studied in relevant literature, see for instance [2]. The basic condition for carrying out a proper benchmarking by this method is that the products are comparable ("Apples compared with apples"). Crucial is also that collected data are consistent and of satisfactory quality. Discussion of these aspects of the research process is presented in 3.1.

An interesting part of the early phase work was the discussion of details with respect to *point of view*, i.e. if we should establish our investigation with the owner's point of view or the contractor's point of view. The contractor's point of view was chosen, mostly because the fact that the word *productivity* in a historic perspective is connected to *physical production*. (See also figure 2, where the "productivity box" is connected to the contractor. On the other hand, the owners also conduct their business with different skill and success, and it would be of great interest to study the productivity based on the cost figures of the owner).

To reduce “market disturbances” we asked the contractors for their cost *without* profit. The fact that the contractors’ cost numbers contain the profit of their *sub-contractors* can produce “noise of second order”, but we regarded this as a minor problem.

Conclusion of the preparatory activities:

1) A tool for productivity measurement in the construction industry has to focus on *the project as a whole*.
2) The challenge is to identify the most important parameters for the nominator (product) and the denominator (resources) in the productivity formula, see above.
3) The resource data shall be collected from the *contractors’ project accounts*
4) The main sample must consist of fairly similar types of projects

2.3 The Pilot Study

To succeed with the modeling work, it was necessary to focus on one certain type of construction project. It was, for several reasons, natural to choose blocks of flats for the pilot study.

One of the benefits of DEA is the fact that the analysis is not dependent on a representative (large) number of items in the sampling [1]. Traditionally, a homogenous set of approximately one hundred items is regarded as satisfactory for a qualifying analysis. Based on this, we planned a data collection operation with the goal of getting 120 units, thus keeping the necessary number of qualified projects after excluding “bad data” items.

Blocks of flats-projects were defined as

- buildings with at least three floors
- buildings that can, but does not need to, have cellars (lower ground floor)
- projects that include common stair(s) and lift(s)
- buildings where the area of flats exceed 50% of total main function area. This means that part of the project can host other functions, like stores, institutional service function etc.
- projects that are one single block of flats or more than one (many)

Preferred type was defined as blocks with apartments of two, three, four or more rooms, principally planned for sale in the market. But other types, like studios, student housing, buildings with a share of social service department, were also accepted.

As many contractors as possible, situated all over Norway, should be invited to participate with information. Each reported project would have to be completed, physically and with respect to the project accounts.

A questionnaire was prepared to the collection of data and other project information. It was divided into four parts, one for each type of information, see figure 4.

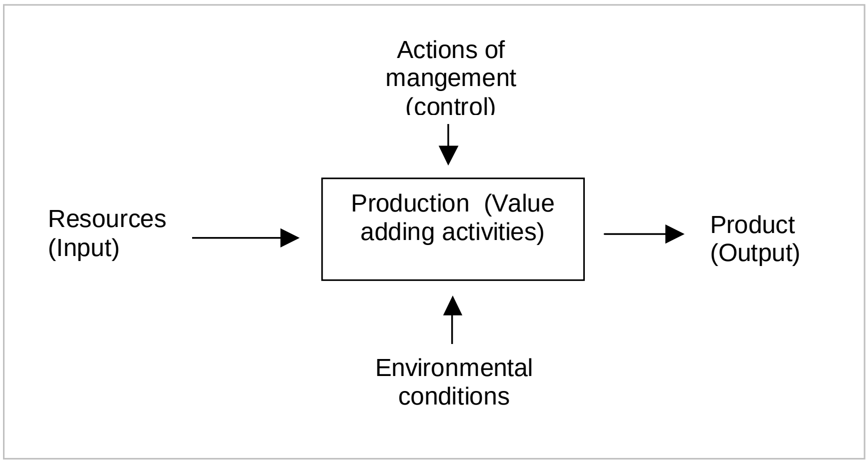

Figure 4: Efficiency analysis – the four main groups of information

The efficiency ranking of the group of building projects is based on calculations of data from the two groups Resources and Product See discussion of the productivity ratio in 2.1 (above). The other two groups of information are the *explanatory variables*, which are used in step two of the analysis, where regression technique is carried out to identify correlations between efficiency and the different variables. The Resources and Product parts of the questionnaire are commented in the following two chapters. The two parts covering explanatory variables are discussed (shortly) in 3.3. (An additional part asks for ID of the project and some rough characteristics. This firs page of the questionnaire is not given further comments in this paper).

The questionnaire is prepared for communication between the R&D project and each actual building project's manager. The ideal way of data collection, i.e. to invite the participants so enter the R&D project's homepage (www.byggforsk.no/productivity) and fill out the questionnaire, was abandoned after testing the probability of broad response this way. Conclusion was to open different ways of answering, giving each project manager the freedom to use the one preferred by him – or her. (The main sampling includes approx. 3 % female project mangers, unfortunately too few to test hypothesis "Efficiency and *female management*"). Approx. 40 % returned the questionnaire as attachment to e-mail. Another 30 % answered by post after having filled in information by pen. The last 30 % was also a paper copy, filled in by the R&D project representative during meetings with the building project manager that wished "1:1-information" before doing the answering job, which was estimated to take 3 – 6 hours. For more about data collection experience see section 3.1.

2.4 Resources

In productivity measurement theory [2] resources normally are grouped as follows:

Working time; f. ex. man hours. (B15 + B16 + B23 + B24)

Materials; raw materials and manufactured components for enclosure. (B22)

Energy; heating, enlightening, running of producing machinery, etc. (B13)

Capital; rent of machinery and equipment supporting the production) (B11)

To carry out the efficiency study, we needed these types of data for each building project. The Norwegian Standard NS 3453 *Project cost structure* (chart of account for building projects), includes all four of these resource groups. This gave input to the design of the part B of the questionnaire. See figure 5 and the numbering in brackets above. Unfortunately the NS 3453 structure does not correspond directly with the contractors' calculation sheets and charts of accounts. Each company has it's own structure, mainly following the construction process from ground work and concrete structure to technical installation and interior finishing work. (Curiously enough, the difference between the different charts of accounts is small. It seems mostly to be a result of habit and traditions. It should ease future data collection, if all companies and projects had taken the same charts of account into use).

As long as the contributors' charts of accounts were different, the R&D project was in a state of (strong) uncertainty regarding how good each project's information about use of resources could match any structure in the questionnaire. Consequently we designed the questionnaire to take care of both a "worst case" and "best case" responding situation.

Worst case: Low degree of detailing in many project accounts. The anticipation was that even if this would be the situation, all of the project managers most certainly would know the *B-40 figure* for his own project and give the R&D project this minimum of information necessary to feed the DEA model, see figure 4.

Best case: Highly detailed account in most every project. The expectation was that all cells in the break-down-column (Level 2) would be filled with the actual cost figure for each project, thus giving us high freedom to develop the optimal model.

B- Resources (Inputs)

To get updated on the principles of this study, take a quick look at the first chapter of the Guidelines

		Level of information 1 Main figures (in 1000 NOK)	*Level of information 2* Brake down costs	*Level of information 3*
B-10	**Common costs (establ. + running the site)…..**			
B-11	Rent of machinery, production tools etc.			
B-12	Waste; rent of containers, transportation etc.			
B-13	Cost of el. energy for running the site			
B-14	*Salary, production mangement/staff*			Number of workin hours
B-15	*Wages + worked houres, own empoyees*			
B16	*Cost of workers hired through personell support companies*			
B-17	Other costs (reg. establishing and running the site)			
B-20	**The building**			
B-21	Sub-contractors			
B-22	Costs of materials (for own producton)			Number of workin hours
B-23	*Wages + worked houres, own empoyees*			
B-24	*Cost of workers hired through personell support companies*			
B-25	Other costs (if any)			
B-30	**Technical installations……**			
B-31	HVAC			
B-32	Electricity			
B-33	Low voltage installations (Theleph., ….)			
B-34	Lifts			
B-35	Other installations (if any)			
B-40	**Acc. Cost of building, see Norw. Stand. 3453 …..**			
B-51	*Outdoor works (green surroundings, etc.)*			
B-50	*Acc. Cost of enterprise, see Norw. Stand. 3453 ……*			
B-61	*Costs of detailed planning (after general permission)*			
B-60	*Turn key cost", see Norw. Stand. 3453 ……*			

B-70 Check of the quality of the filling in: Mark a positive answer (Yes) with a X

1 All figures are cost figures, i.e. NOT including our own gross margin and profit

2 The figures are NOT including VTA

In 1000 NOK

3 B-40 includes following costs regarding non-conformancy work, either already paid out or expected to be paid during the "warranty period"

Figure 5: Questionnaire – Part 2 Resources used in the building process

We also had a “Very best case”, which was all “man hours-cells” filled in with figures for each project (Level 3 in figure 5). This information would improve our platform even more, as we then would reduce the need for deflating the costs (index problem).

2.4 The Product

The most common way to quantify the product (the result of a building process) is by the gross floor area. Through this simplified way of quantifying the product, and with cost as quantification of the resources, the productivity factor of a project will be

$$\textbf{Productivity of floor production} = \frac{\textbf{Floor area} \text{ (f.ex. 1000 m}^2\text{)}}{\textbf{Hours} \text{ (f.ex. 500 hrs.)}}$$

In Norway this ratio is often used as an indicator of productivity or cost efficiency (Square meters/NOK - or more usual the inverse; NOK/square meter). As an indicator it might be suitable, at least among experienced builders. As measurement unit it is too rough, since important aspects of the product, like differences in standard ("quality"), important environmental conditions like ground, etc. is disregarded.

The great benefit of the DEA is the ability to take more than two aspects into consideration when measuring productivity. In short, the method, and the high computer capacity of today, gives us the opportunity to carry out numeric calculations of productivity with many independent variables, that is 4 - 8 when the data set consists of approx. one hundred items.

Part C in the questionnaire was designed in a similar way as shown in figure 5, though consisting of two A4 pages, due to the many aspects needed to define and quantify the actual product. Table 1 contains the factors asked for in the part C of the questionnaire.

Table 1: Product definition factors for blocks of flats

Quantifying factors for blocks of flats	Comments
1 The block(s) in general	
- number of blocks	
- number of floors (total, incl. basement(s))	
- number of basement(s)	
- number of lifts	
- number of indoor stairs/staircases	
- number of flats with open fireplaces	for gas or wood
2 The Block(s) – areas	
- gros area (BTA)	
- open air area (OPA)	galleries, balconies, terraces
- total areas of flats	(BOA and/or "BRA-Sale")
- heated area for other main function than living	F. ex. stores at ground floor
- area for parking and tchn. func. in basement(s)	Data control question
3 Standard of construction ("qualities")	
- standard of specified parts of the flats	7 different parts are quantified
- standard of the exterior and common areas	4 different parts are quantified
4 Non conformance to specification	
- degree of non-conformance at hand over	Degree of remarks in the protocols
- cost of repair during the guarantee period	In Norway this is 5 years by law
5 Energy for heating	
type of energy delivered	main source of heating
type of heating systems in the flats	main system of heating

3. Efficiency Analysis

3.1 The Data Set

During the period from June 2003 to January 2005 data from 138 completed blocks of flats projects were collected. The collecting process lasted longer than expected. Different circumstances can explain this, but it should be stressed that the R&D project is a model development project and not an ordinary collection of data for statistically processing in an existing tool.

The many projects were all built in the period 2000 – 2005. Based on the filtration criteria, see 2.3, nine projects were excluded, thus leaving an early main sampling of 129 projects. Suppliers were 37 contractors/ 65 profit centers (regional offices, departments) throughout Norway. The size of the projects varied from 7 mnok to 450 mnok with arithmetic middle of 77 mnok, respectively 6 to 618 dwelling units with arithmetic middle of 75 units.

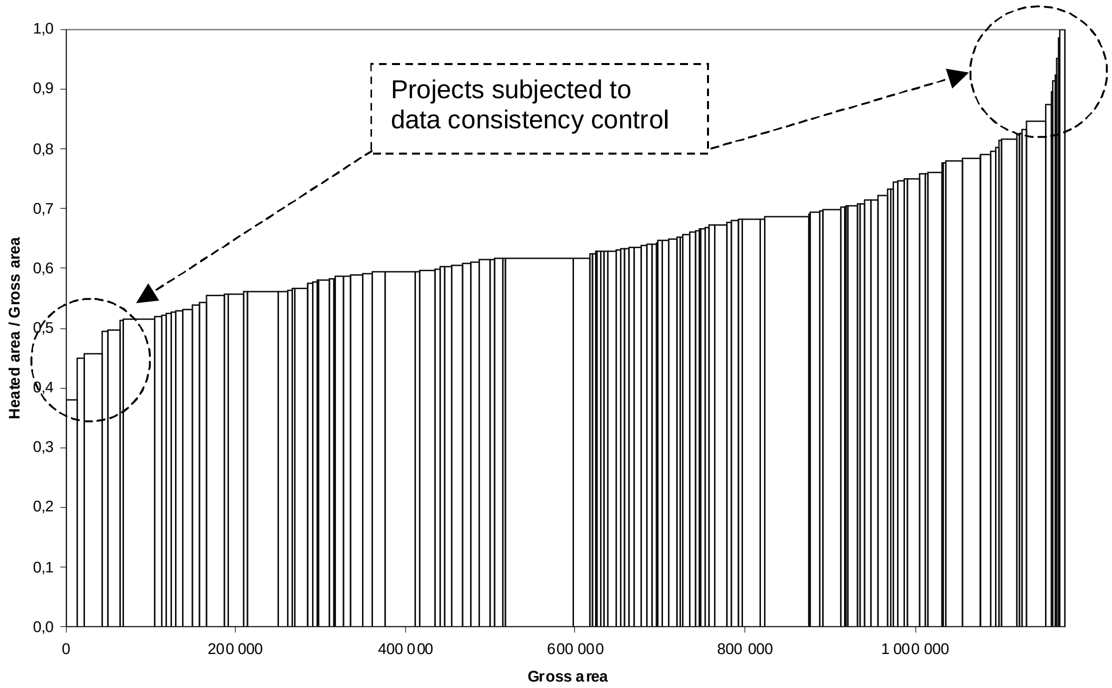

Figure 6: Example of data consistency control.

The quality of the present set of data differs, even if much effort has been put into control of data during the collecting phase. Checking the data set is still an ongoing activity. At the time of writing, 12 different data consistency controls have been carried out, and a similar number will follow. Figure 6 shows the ratio “Heated area”/Gross area. The “tails” (see dotted circles) of the diagram calls for special attention. The values (area numbers) behind the extreme low, respective high, columns are hopefully correct, but by controlling these once again we can discover miscopies, slips or errors or have even higher confidence to the data set.

3.2 Preliminary Efficiency Benchmarking Result

Based on the partly checked data set a preliminary result of the efficiency analysis can be presented, see Figure 7. The result is based on a DEA model with seven variables, operated by project colleague Dag Fjeld Edvardsen of NBI.

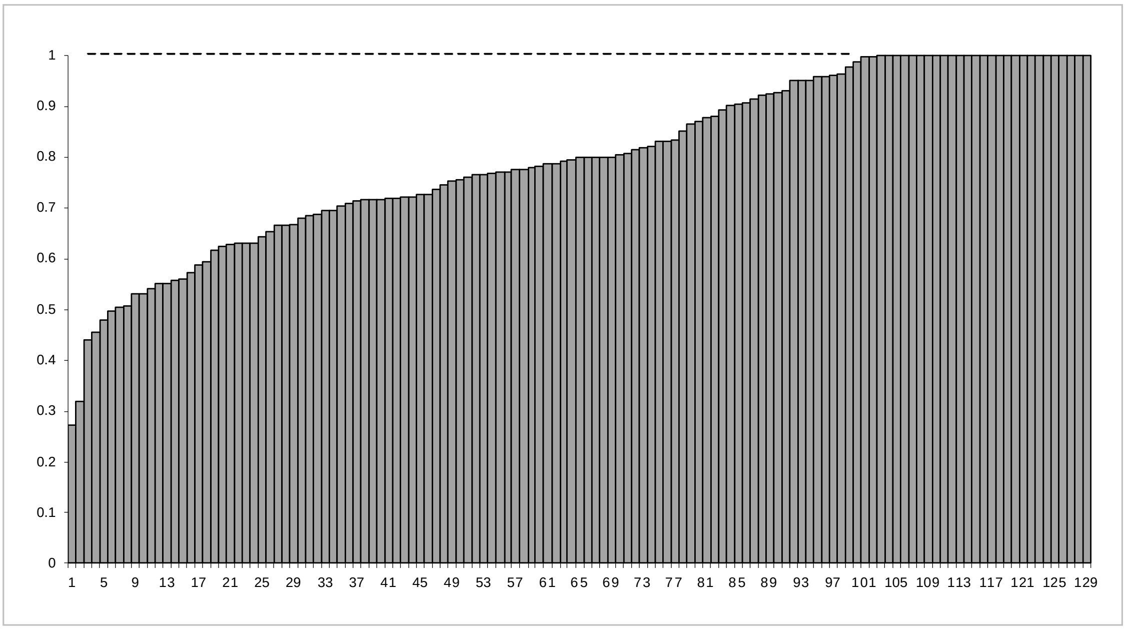

Figure 7: Preliminary efficiency scores for 129 projects (blocks of flats)

Each column in figure 7 represents one project. (In the final version each column will be given a width corresponding to the project's size (cost of construction, B-40). The figure shows considerable differences in efficiency. To the right is 27 projects with E-score = 1,0. These represent *best practice*. The rest of the projects are compared to a convex combination of these. The total improvement potential is indicated by the integral over the curve (the white triangle between curve and dotted line at level 1.0).

It is interesting to observe the improvement potential, especially if the 129 projects are part of the same economy. In our case there are 37 different companies behind the result. A group of five major companies have contributed with more than 10 projects each. For these, and in fact for all with more than a few project in the lot, the results are of specific value. The identities of the projects are anonymous, but each company can know the ranking of their own projects. Based on this a company will have valuable information of own performance and a basis for individual improvement initiatives.

3.3 Why are the Most Efficient Projects Most Efficient?

The projects representing best practice is of course of specific value. Together with data regarding resources and product, the questionnaire was used to collect information of *Environmental condition* and *Actions of the project management*, see figure 4. Approximately 500 questions about the two types of *explanatory factors* are answered by the project mangers and prepared for the step 2 of the efficiency analysis. By regression technique we are searching for explanatory factors that correlates with high efficiency, respectively with low efficiency. – After this huge numeric operation, and after having assured the quality of the research results by case studies of a few projects from the two extreme categories, we hopefully will have identified certain Environmental condition and Actions of the project manger that characterize each of the two groups. In he near future we hope to report also these Step 2 results.

4. Conclusions

The construction industry needs adequate tools to carry out benchmarking as basis for organizational learning and company development. Based on the DEA method and statistical analysis, NBI has carried out a pilot study where the main challenge has been identification and collection of necessary data and supplying facts. A questionnaire has been designed and answered by 138 project managers of assumed comparable projects of blocks of flats. The data consistency check and preliminary efficiency analysis make us believe that the method can be taken into use for continuously benchmarking of production of blocks of flats. We also believe that the model can be adjusted to suite other types of construction project. A simplified and refined questionnaire is the aim of the R&D project, used on a new set of data during 2005-06.

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The Motivation of Masons in the Sri Lankan Construction Industry

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Abstract

This research is an empirical study of human resource management (HRM) for the motivation of masons in the Sri Lankan construction industry (SLCI). The structured interview was chosen as a main research instrument for data collection. 90 masons and 30 supervisors were randomly selected from 10 construction sites within the SLCI.

The study's findings show that the supervisors and masons in the construction industry (CI) in Sri Lanka are aware of the supposed advantages of staffing, employee development and the rewards of a HRM approach. However, these characteristics have yet to play a significant role in the motivation of Sri Lankan supervisors and masons. A contextually sensitive application of these three strategies has the potential to improve motivation of the Sri Lankan construction workforce.

Keywords: Motivation of Masons, human resource management, Sri Lanka

1. Introduction

The management of present day construction projects is becoming increasingly complex and challenging due to many factors. To meet this challenge it is of the utmost importance to provide efficient management throughout projects. This research is an empirical study of human resource management (HRM) in the Sri Lankan Construction Industry (SLCI). The research focuses on the particular roles that staffing, employee development and rewards have in the motivation of masons in the SLCI. The study as a whole contributes to the wider debate on worker motivation.

2. Statement of the Problem and Significance of the Study

The construction industry (CI) is one of the most important industries in almost every country [1]. The crucial importance of the CI to a sustained development effort in a developing country cannot be overemphasised. Although construction is not an end in itself, it is the means for the achievement of the desired end, which is the development of new production capacity in the economy. In developing countries, productivity in construction has remained at a relatively low level compared to other major industries [2]. Therefore the effect of productivity on a nation's economy is highly significant. Improved productivity in the CI can have an important role in promoting national competitiveness and a satisfactory growth rate.

The Sri Lanka State Engineering Corporation, Sri Lanka Building Department, Sri Lanka Port Authority (SLPA) and Sri Lanka Labour Department have experienced that most of their projects are affected by low productivity and motivation [3, 4]. Most projects have also suffered from serious setbacks and even termination of contracts. In the SLCI, it is believed that productivity is low when compared to other developing countries and to the Asian sub-continent in particular [5]. One of the factors contributing to such low productivity is that of employees' motivation [6, 7, 8, 9]. However, in the ancient and colonial eras, the SLCI was properly organised, well motivated and highly productive [10, 11], although no evidence of the methods they used to manage and motivate construction employees still exists. It could be argued that without sufficient motivation of employees, such success could never have been achieved. Therefore motivation of Sri Lankan workers is one of the appropriate approaches to achieve higher productivity in SLCI. There is a large body of conceptual and empirical evidence concerned with the application of motivation theory to the CI [12, 13, 14, 6, 15, 16, 8, 9]. Unfortunately, there has not been so much empirical research on applying HRM strategies to the CI. No research about motivation was conducted for SLCI. The literature on motivational studies has flaws and weaknesses and is outdated [17, 18].

3. Motivational Theories vs. HRM Concepts

Motivational theories are also based on the functionalist paradigm, are not multi focused and do not give a real representation of how workers in construction are motivated. Most of them deal with intrinsic properties which are not sufficiently socially constructive for any credence to be given to them. The motivational theories, which take a functionalist view, offer only one perspective on the social construct. What is needed, therefore, are other methods of researching motivation in construction which embrace some of the salient points mentioned in social research theories [19]. Both the social as well as the scientific nature must be included in any study of construction worker motivation.

HRM is a socially constructed concept as opposed to the functionalist and traditionalist views of the motivational theories. Therefore, future studies of motivation of construction workers, in particular Sri Lankan construction workers, should embrace these modern, more pragmatic views of the social construct that are found within human resource management [20, 21, 22].

However, the traditional motivational theories used by previous researchers are dated: the researchers still talk in terms of managerial issues and personnel administration. These theories do not incorporate the different facets of human complexity and the evolving dynamic construction environment. They do not in any way play a significant role in shaping the self-identity of workers even though they have existed for a very long time. The main theme of this research is that motivation of workers cannot be separated from the context of the socio-economic environment. The extent to which perception of the workplace can be changed by HRM discourse is questionable in the case of construction employees' motivation. However, from this perspective, HRM plays an active role in understanding and constructing the social reality of the workplace and motivation of employees.

More crucial is the need to be aware of the strong links between the conceptual literature that has sprung up on HRM and the outdated empirical research that has been carried out on motivation. Themes such as staffing processes, employee development processes and rewards systems have to be understood. On the other hand, in Sri Lanka, Western management and HRM approaches have been employed in construction projects over the past few decades, without an assessment of the appropriateness of such approaches.

This has raised some crucial problems. The workers in the CI in Sri Lanka are aware of the supposed advantages of the HRM approach. The discourse of HRM in the SLCI has played a role in the motivation of the Sri Lankan workers. Effective and efficient application of HRM to Sri Lankan workers would improve their motivation.

4. Methodology

Research data were collected by means of a survey of masons in 10 construction sites in Sri Lanka. The data-gathering techniques were:

Interviews (one-to-one)
Interview sessions were the main research instrument in the study. 120 structured interview sessions were conducted and fully tape recorded. The interviews were conducted in Sinhala, which is the lingua franca of the Sri Lankan operatives.

Observation
10 observation sessions were conducted in 10 work sites within the SLCI. Structured observation schedule was used for each observation session. The findings of the observations were triangulated with finding from the interview sessions. Both techniques were pilot tested prior to the main research work.

5. Research Results and Discussion

5.1 Staffing Processes

Staffing encompasses the human resource activities designed to secure the right employees in the right place at the right time [23]. Management professionals in the construction industries making a decision to recruit employees must consider whether to rely on the external or internal labour market [24]. Among Sri Lankan construction firms, those with outstanding and average performance seem to be less informed about recruitment and selection processes.

5.1.1 Existing Staffing Processes in the SLCI

This research shows that the most common staffing procedures for supervisors and masons in the SLCI are as follows: advertising the vacancy, calling job applicants, conducting interviews, direct recruitment through personal contacts, friendship or any other form of relationship. Advertising the vacancy is more prevalent than other existing staffing procedures.

Direct recruitment through personal contacts, friendship or any other relationship sometimes causes favouritism and employment of unsuitable workers. However, there are some advantages to this system. Recommendations from a reliable source can guarantee the trustworthiness of employees.

Other methods for recruiting employees are not common in the SLCI. These include: direct recruitment, conducting a practical test of applicants' knowledge, conducting a theory test of applicants' knowledge, giving effective pre-work training, and using a registered list or recruitment agency. Although direct recruitment as a result of political influence is not common in the SLCI as a whole, it does play some part in direct labour recruitment. Direct recruitment due to political influence is detrimental to the company and results in similar difficulties to those discussed earlier in relation to direct recruitment through personal contacts, friendship or any other relationship.

The theory test of an applicant's knowledge is not especially suitable for masons and not prevalent in the SLCI. One reason is that most masons are not taught the rudiments of masonry theoretically. They start off as an apprentice to another mason, or as labourer who shows some interest in masonry work. Only 7% of supervisors and none of the masons mentioned the theory test method. In general, masons are not as well educated as supervisors – thus some Sri Lankan masons cannot understand the theory test. The practical test is more suitable for the recruitment of masons, because their job is completely practical, unlike that of supervisors. 62% of masons and none of the supervisors specified a practical test. Recruiting employees through an agency system does not exist in the SLCI. This is due to the availability of cheap labour. An employment agency system has not taken root in Sri Lanka.

5.1.2 Characteristics of Staffing Processes in the SLCI

The research results show that the existing characteristics of staffing processes in the SLCI, which have a response rate of more than 50%, are as follows:

- There are appropriate and adequate job design and analysis procedures (mainly concerned with how to recruit, how to select, how to train, how to develop, how to downsize, how to administer wages etc.)
- The organisation has clear staffing procedures
- There are recruitment plans to avoid unexpected staff (labour) shortages
- Staffing is designed to secure the right employee at the right place and at the right time

- The recruitment and selection processes are concerned with identifying, attracting and choosing suitable people to meet an organisation's HR requirements.

The above characteristics are perceived as being very important to the SLCI. There is a general willingness to include them in company practices. Unfortunately, only the first characteristic is currently functional. The reasons for the malfunction of the other characteristics can be identified as follows: financial and facility problems, the difficulty of introducing new methods, the difficulty of giving up old procedures, insufficient time because of a busy schedule, the difficulty of changing how the institution is perceived, management deficiencies and superiors' lack of interest in management procedures. A small number of employees cited other influences (e.g. political). However, effective management can help to prevent the above problems from arising.

5.2 Employee Development Processes

Employee development processes have become an integral part of most construction industries (25, 26). In general, both new and existing workers will require more training and employee development, especially in developing countries. The findings show that the employee development and training process is a highly valued function, but not adequately distributed amongst supervisors and masons in the SLCI. Only 12% of the respondents stated that they had satisfactory access to employee development processes. This is the result of the reluctance of employers to invest in employees due to uncertainties in the SLCI.

5.2.1 Existing Employee Development Processes in the SLCI

The survey results regarding employee development processes in the SLCI reveal that the following processes are both widespread and popular:

- On the job training by specially appointed people
- On the job training provided by senior employees
- Induction training at the beginning of employment
- A short duration training programme.

Most construction firms in the private sector offer only introduction training as an employee development process. Some private firms do not even offer this limited option due to their busy day-to-day schedule. This means some employees are starting work without any induction being offered by their employer. This can obviously result in poor quality work and low productivity, because company procedures are not well understood. On the job training by senior employees can sometimes prove detrimental to a company because of favouritism, or the passing down of work-related weaknesses from senior employees to trainees. On the job training by specialists can overcome the above disadvantages.

There are other methods (e.g. a firm's own training programme, frequent conferences) which are not common in the SLCI. Although uncommon when considered as a whole, considerable variation in response can be seen if the responses of the various groups are considered separately (e.g. masons only or supervisors only).

Most employee development processes in the SLCI are available to supervisors to a much greater extent than they are to masons. The supervisor's role involves more responsibility and is thus of more importance to the firm. Consequently, only 36% of masons but all of the supervisors have short introductory training programmes. Similarly, only 26% masons compared to 80% of supervisors experience their firm's own paid training sessions. It should be noted that some training sessions that are conducted for masons can prove to be very challenging due to the low literacy level of most masons within the SLCI.

5.2.2 Characteristics for Employee Development Processes in the SLCI

The characteristics of most employee development processes are that they are scanty and not fully functional. This can be clearly seen from the fact that in the survey, when asked to identify the existing and functional characteristics of employee development in the SLCI, the respondents only cited one characteristic with a response rate of more than 50%:

The management may decide to orient their training and development activities towards short-term or long-term objectives.

In reality, this characteristic cannot be said to be functioning adequately in the SLCI.

The findings show that all characteristics investigated in employee development processes in the SLCI are clearly perceived to be important but that there are significant obstacles to their successful implementation (e.g. financial and facility problems, lack of time due to a busy schedule).

5.3 Reward Systems

Another key feature of modern approaches to HRM, within the construction industry and elsewhere, is reward systems [26]. Generally, the structure of the reward package is related to the job, as well as to the expectations of the employee and the labour market. Reward packages consist of either a salary component or an incentive component, and can also be categorised as money related or non-money related [27, 24]. However, most Sri Lankan construction firms suffer from serious financial problems and are busy with day-to-day workloads. These firms still have poorly distributed reward systems. The superficial view is that most of the small private sector firms in Sri Lanka are often bankrupt and terminate contracts without having a chance to reap the benefits of reward systems. The study findings show that the majority of construction firms in Sri Lanka have some kind of reward system, but that these are inefficient.

5.3.1 Existing Reward Systems in the SLCI

Certain reward and incentive systems are currently in existence in the SLCI. The following are all being implemented with varying degrees of efficiency: a satisfactory salary is earned; a good reputation is achieved, good employer/employee relationships are achieved; satisfactory facilities are provided (e.g. housing, accommodation, etc.); satisfactory welfare facilities are provided; a satisfactory bonus is offered; overtime is offered; social activities are organised; appropriate quality training is offered; permanent jobs are offered; praise is given; rewards and certificates are given; performance appraisal programmes are conducted; and promotions are given. However, from the above list, only the following elicited a response rate of more than 50%:

- Overtime is offered
- A good reputation is achieved
- Praise is given
- Satisfactory facilities are provided (e.g. housing, accommodation, etc.)
- Social activities are organised
- Rewards and certificates are given
- A good employer/employee relationship is achieved
- A satisfactory salary is earned
- Permanent jobs are offered

Overtime is currently the most prevalent and popular reward system in the SLCI. Considering the high amount of absenteeism and the insufficient number of employees, management has to cover the day-to-day workload by giving overtime to existing workers. This explains the high incidence of overtime in the SLCI. However, management has to manage and plan the workload. It also has to take into account employees' work capacity and allocate overtime accordingly, otherwise productivity and motivation will be negatively affected.

Unemployment is a severe problem especially in developing countries and this situation is clearly true for SL. The opportunity to have a job is a significant motivation for Sri Lankan employees. It must also be remembered that the benefits and salary provided by employment within the SLCI are much higher than in other industries. Hence having a job in the SLCI is also a means of achieving a good personal reputation.

Expressing warm approval, respect and gratitude for high-quality work is also considered to be a reward system in SL. This reward can be easily provided and achieved. However, praise given to unsuitable employees can also negatively affect the motivation of others. Management has to be aware of this because the problem of favouritism is also widespread in the SLCI. Bearing in mind the economy and living conditions of the country, the provision of satisfactory facilities (e.g. housing, accommodation, etc.) is a reward valued highly by Sri Lankans.

Considering supervisors and masons separately, it can be seen that there are more beneficial reward systems available to supervisors than masons. 100% of supervisors and only 36% of masons have permanent jobs. 77% of supervisors and 53% of masons are satisfied with the social activities organised by their firms. Furthermore, the results show that there is only an 11% overall prospect of promotion in the SLCI. This is extremely low. The responses of supervisors and masons differ: 67% of supervisors and only 24% of masons stated that their firms have a clear promotion scheme. Offering training opportunities or facilities as a type of reward is more freely available to supervisors than masons.

Masons appear to be more satisfied with their salaries than supervisors, even though the supervisors' salaries are higher than those of the masons. According to the qualification, social status and comparison with other industries, masons are more satisfied with their salaries.

5.3.2 Characteristics of Reward Systems in the SLCI

The following characteristics are currently in existence within the reward system in the SLCI: the organisation has an efficient reward and incentive system; a reasonable performance appraisal programme exists in the organisation; money-related rewards are important; non-money-related rewards are important; group-related rewards are important; individual related rewards are important. There are incentives not linked to performance such as holiday pay, sick pay, long-service allowances, pension funds etc; there are incentives partially tied to performance such as profit sharing; incentives directly tied to performance; and the organisation keeps its payment structure up to date.

However, an examination of all the responses reveals that only a small number of characteristics can be said to be in existence to any significant degree. The following elicited a response rate of more than 50%:

- The organisation has an efficient reward and incentive system
- The organisation keeps its payment structure up to date
- Non-money related rewards are important
- Incentive is directly linked to performance
- Group-related rewards are important.

Although the respondents stated that all of the reward system characteristics were important to their firms and that they are willing to have them, the above characteristics are not functional due to financial problems as well as the inadequate resources and facilities available within the SLCI.

To summarise, the findings show that most supervisors and masons are aware of the supposed advantages of modern HRM approaches (i.e. staffing, employee development and rewards). They realise that these approaches can have significant positive effects on employee motivation, although they have yet to play a role in the motivation of the Sri Lankan supervisors and masons. Furthermore, supervisors and masons are aware of the motivation benefits, which can result from the implementation of the approaches. 95% of the respondents cited the motivational benefits (e.g. institutional and employee productivity is increased).

6. Conclusion

The study concludes that supervisors and masons in the construction industry in Sri Lanka are aware of the advantages of staffing, employee development and rewards in HRM; a contextual application of staffing, employee development and rewards for Sri Lankan masons would improve their motivation. The findings also show that the discourse of staffing, employee development and rewards in Sri Lankan construction industry have not played a role in their motivation.

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Measuring Productivity on Project Level

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Abstract

This paper presents a research project which developed a method and indicators for construction site productivity assessment as well as tested them on apartment-block sites. Productivity indicators were complemented by others representing explanatory factors, their purpose being to help identify best practices. Dependencies were studied, for instance, with the BayMiner data mining tool. The research is part of a joint venture of five Nordic countries implemented in 2001-2004.

Keywords: Productivity, efficiency, benchmarking, construction, data mining

1. Introduction

1.1 Overview

The Norwegian Building Research Institute, the Icelandic Research Institute, the Swedish National Testing and Research Institute, the Danish Building Research Institute and VTT have completed a three-year productivity study on the Nordic construction sector. Each country conducted a subproject focussing on itself. The findings were shared through the joint Nordic project. This paper describes the Finnish portion of the productivity study.

The main interest of a company in conducting productivity studies is to identify the factors which impact productivity. Knowing these factors makes it possible to improve internal processes. By collecting information from several projects, companies can identify the best practices for high productivity, and transfer them from one project to another. If the key factors for high productivity can be identified, productivity measurement can be an important development tool for a company.

The objective of this work has been to develop a methodology for measuring productivity on the project level and to conduct a benchmarking analysis.

1.2 Measuring Productivity in Construction

One focus of productivity research is the analysis of company-level productivity and analysis of the productivity development of various processes and work phases. Companies make use of productivity monitoring and indicators in developing their operations and technologies. Statistics Finland monitors productivity development on the national economic level, and the results are used in evaluating industries and their development needs.

In 1996 the construction industry and Statistics Finland conducted the *building construction productivity indicators* study. It defined productivity indicators for the entire building construction industry and its sectors. The study suggested measuring the productivity of the industry on three different levels. Annual development is monitored on the industry level by an index type indicator that does not depict the level of productivity but changes in it. Another level of measurement consists of value-added-based indicators for subsectors that show the absolute level of productivity. The third level involves monitoring labour productivity by product group- and building type-specific indicators which are by nature physical productivity indicators. [1] Statistics Finland launched the highest level monitoring suggested. However, sector organisations have not yet begun monitoring productivity on the other two suggested levels.

Companies are not in the habit of publishing their in-house productivity studies, but Helsinki University of Technology has persistently researched the performance of companies with them [2]. VTT has developed methods for determining the efficiency of the site process as part of the *Site process re-engineering in building construction* project in 2002-2004 [7]. The indicators of productivity measurement were studied in 1992-93 [13]. VTT has also examined the monitoring of productivity in infrastructure production. The project produced productivity indicators for the infrastructure sector and launched monitoring to test the developed indicators [12].

1.3 Implementation

The study investigated ongoing productivity research in construction in cooperation with Nordic research partners. In addition to Nordic research, it reviewed the English KPI (key performance indicators) method which was also tested by the Norwegians in an actual construction project. The Finnish subproject consisted of the following phases:

1. Definition of preliminary productivity indicators
2. Development of data collection models
3. Comprehensive data collection
4. Adjustment of productivity indicators and analysis of material
5. Reporting

Comprehensive data collection was implemented in the form of a questionnaire study targeted at the contact persons of participating companies using a multiple-choice Internet form. The response material was analysed by both the traditional normative statistical approach and so-called data mining based on the Bays Network. Reporting consisted of a public research report and a confidential report to each partner company.

2. Methodology

2.1 Approach

The evaluation of the performance of a complex process can be approached in two ways. One involves developing an indicator-type integrated gauge consisting of individual gauges that measure different features of the process as comprehensively as possible. The industry-specific overall productivity indicator can be considered one: it measures the combined performance of various subprocesses by a money-based indicator of added value and combines them into a single indicator.

Another approach to gauging a complex process is to use individual physical meters that provide the best possible description from the viewpoint of the performance of the entire process, while they actually only assess a single feature of the process. Gauges can also target the process preceding the process in question, the one following it, the use of process resources, or process control. For instance, process resource consumption can be used to evaluate also the performance of the process itself. This approach has been applied, for instance, to the assessment of the quality of the operations of a construction company.

The study approached productivity measurement by applying the principles of complex process measurement. Practical input-output parameters were defined in accordance with the concept of productivity: their ratio depicts productivity. To determine the factors that affect productivity, the impact of various control and environmental factors on productivity was analysed. (Fig. 1)

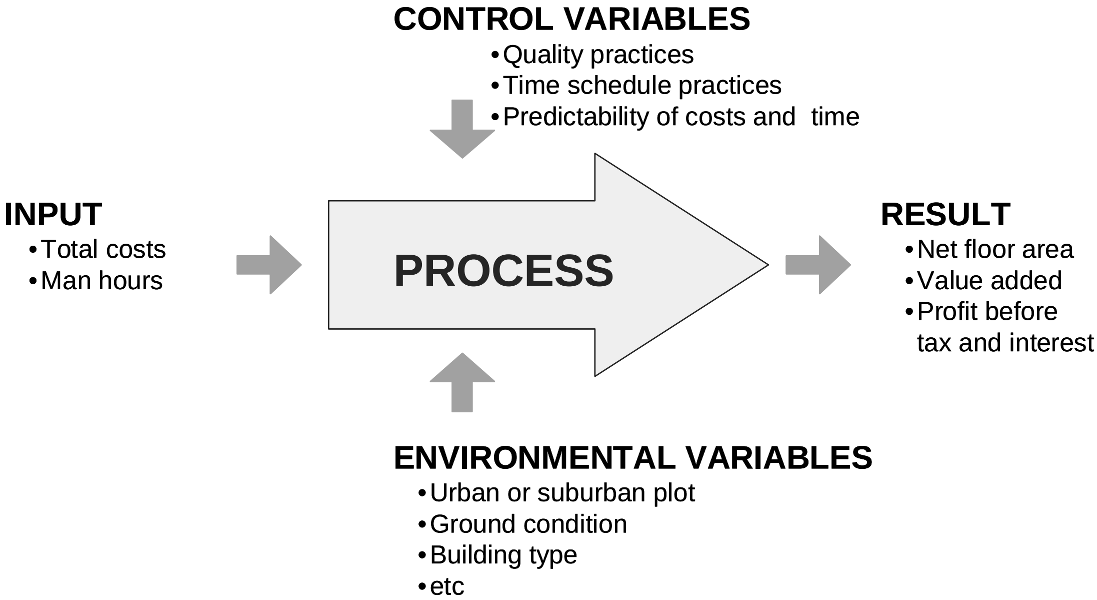

Figure 1. Productivity measurement by the input-output ratio. Control and environmental factors can help discover procedures and factors that explain good and poor productivity.

2.2 Explanatory Factors

For the purposes of this study explanatory factors were divided into control and environmental factors. Control factors are linked to things that the construction company itself can impact. The control factors examined in the study include, for instance, the quality procedures employed in the construction project, how intermediate scheduling goals were reached, what share of the costs had been realised at handover, and the degree of subcontracting.

The construction company cannot affect environmental factors itself. These include things like whether the building is located in an urban centre or a suburb and the foundation engineering conditions. Factors like the distribution of dwellings within the building and distribution of dwelling sizes were also considered environmental factors even though some of the projects were self-developed projects. It is naturally unthinkable that a builder would just construct large dwellings in a suburb pursuing higher productivity when demand focuses on small units in the central area.

2.3 The DEA Method

Data envelopment analysis (DEA) is used to rate the efficiency of organisational units against the best unit. Basically, the method tells what percentage of the inputs used by a unit would have been required for a certain output, had the unit operated as efficiently as the best compared units.

The method is suitable in instances where the evaluated organisational units produce a similar product. In Finland the construction products industry has tested the method at least in rating the productivity of facade element production. There the input was labour input in hours and the output the square metres area of produced elements. In other Nordic countries the method has also been applied to the measurement and comparison of the productivity of building construction. In building construction the benchmark project must be as comparable as possible.

In the DEA method the material is reviewed using a so-called Salter diagram or a so-called scatter diagram. In the scatter diagram resource consumption (input) is represented by the x-axis and the output produced by the organisational units by the y-axis. The surveyed organisational units are represented by dots in the diagram. A broken line drawn through the best organisational units indicates the realistic target level that all organisations could reach if their productivity was as high as that of the best units (Fig. 2).

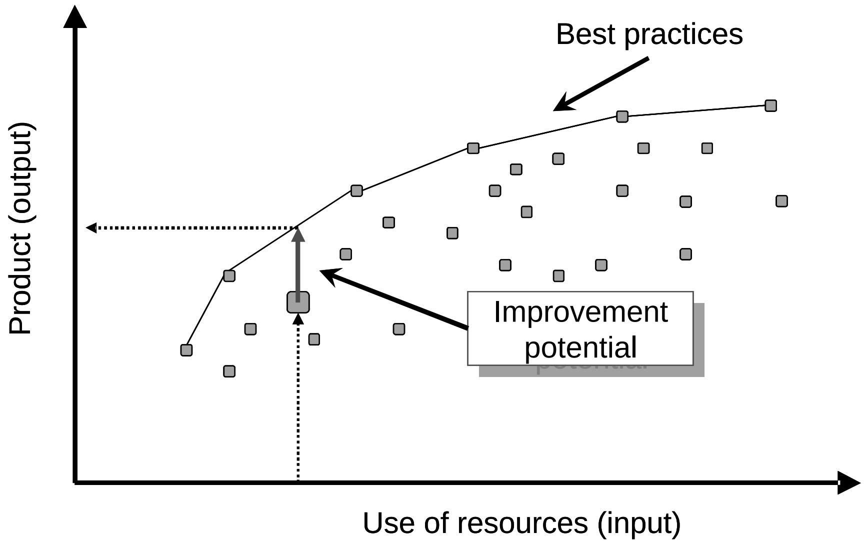

Figure 2. Scatter diagram. A broken line drawn through the best organisational units indicates the attainable improvement potential.

2.4 Bayes Network

The challenge of productivity research is to determine which practices actually are so-called best practices and place the project either in the good or bad category. Since we cannot tell beforehand which practices are good, it is worthwhile collecting as much data as possible on several potential explanatory factors. This leads to complicated analysis of causal relations.

In complicated reasoning tasks the lack of human knowledge can be replaced by calculation models, so-called computational intelligence, where part of the calculation model is based on collected measurement data on the subject. An expert may have a conception of the operation of the target process, but not enough knowledge about all causal relations. To produce a model capable of predicting the future, the missing parts are complemented by so-called computational intelligence [9].

Bayes Networks are decision-making systems based on probability calculation and, above all, so-called Bayesian decision-making. Probability distributions are assumed for all elements of modeling: the parameters applied to the model architecture and the data used for the purpose. The system then selects the most probable model and parameters considering the measured data.

Construction of a model based on the Bayes Network is possible using complex algorithms and requires high computing power. The advancement of IT has, however, made it possible to calculate efficient algorithms, and applications built on Bayes Networks have also seen commercial use.

Bayes Information Technology Oy has developed an efficient data mining tool based on the application of the Bayes Network for statistical processing of material. The BayMiner software is used via the Internet as a so-called ASP service. The BayMiner software is also suitable for analysing research problem setting, i.e. determining which control and environmental factors explain the construction project's ending up among good or bad ones (Fig. 3) [10].

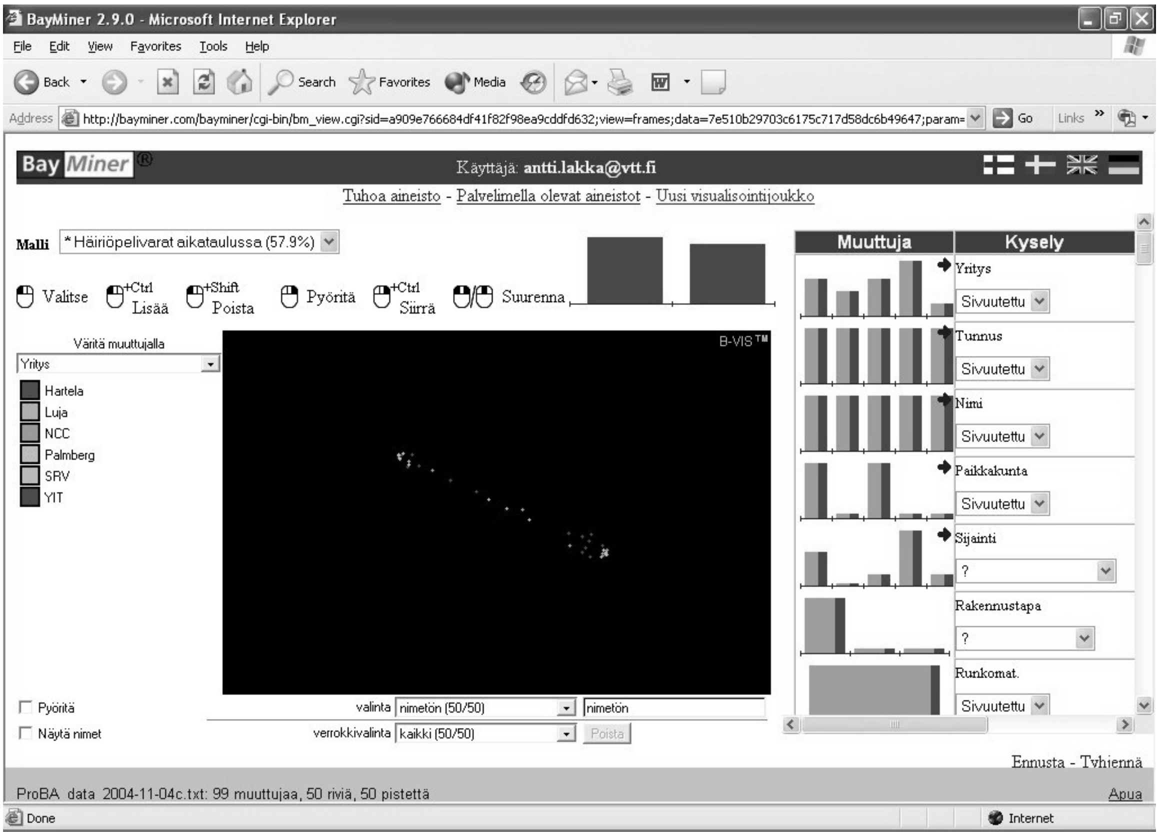

Figure 3. User interface of BayMiner data mining tool. The software was developed by Bayes Information Technology Oy.

3. Comparative Study

3.1 Sample

Apartment-block sites were selected as the subject of productivity comparison: they were thought to be sufficiently alike to allow site-level productivity comparison. The subject was limited to new construction, and comparison targeted the site phase of the project. Cost items external to the site were excluded such as the acquisition cost of the plot and profit margin. Confining the survey to realised costs limited usable productivity indicators to physical ones. For instance, a value-added-based productivity indicator based on the value added to the company per person-year was thus excluded.

Sample size was 50. Data on some was deficient and consequently comparisons were based on a reduced sample. The typical sample size for surveying explanatory factors was 43.

3.2 Productivity Comparison

A productivity indicator that treats different types of apartment-block construction as impartially as possible was sought to allow distinguishing "good" building projects from "bad". The goal was a practical gauge that provides a reliable indication of the productivity of compared projects for which input data is available from projects of various construction companies. The input of the selected productivity indicator consisted of the consumption of resources on site in monetary terms, i.e. realised site costs in euros. The selected output was the volume of site production in net floor area.

In Fig. 4 the sample of the comparative study is plotted in a so-called scatter diagram. A broken line was drawn to connect the points representing the best performing projects to indicate the highest attainable productivity. For instance, one building project used about €3.5 million in resources to produce a net floor area of 2,200 m^2. The best project, on the other hand, used the same amount of resources to produce nearly 3,500 m^2 of net floor area.

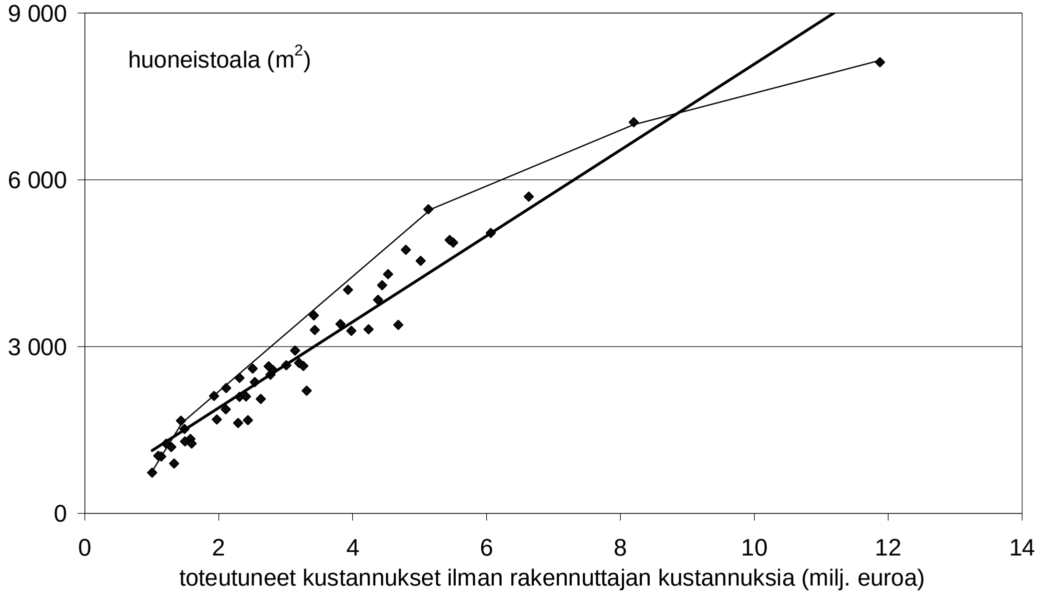

Fig. 4. Scatter diagram: output of building project [net floor area] in relation to used resources [realised construction costs]. Sample N=50 apartment-block projects.

In the comparison of projects special attention was given to the comparability of input data. For example, the content of different sets of area data in the sector has been defined quite well on the national level and can be considered comparable. On the other hand, the comparability of cost data is less certain.

In the study an attempt was made to secure the comparability of subjects by excluding the client's costs and by concentrating on site costs. The results of a productivity comparison are also impacted by the quality level of buildings since the quality level of units built wasting resources may be higher which also raises their sale price.

In addition to finding productivity indicators, the study also tried to define other key indicators which would allow dividing the sample projects into good and bad ones. Such an indicator is the predictability of costs represented by the ratio of realised costs to planned costs.

One indicator that proved good during the study is the ratio of realised profit margin to planned profit margin. The major advantage of that indicator is its neutrality towards different projects whose target margins may differ widely. The indicator based on a change in profit margin was not, however, tested in practice during this study.

3.3 Factors Affecting the Success of a Building Project

So-called best practices may underlie the success of good projects measured by different indicators. Indicators are also susceptible to various environmental factors which the site cannot impact even if they are known to have an advantageous or adverse effect on the result of the productivity indicator. The relationship between explanatory factors and productivity was studied using BayMiner data mining tools.

The explanatory factors used in the study could not, however, identify good procedures. The reason is that the selected explanatory factors were too common. For instance, using applied quality procedures as the explanatory factor could not provide additional information about good projects since nearly all apartment-block projects apply the same quality procedures. The situation would be different if quality procedures were just being launched and different projects applied different procedures. The scheduling practices used in the studied material were also in line with the prevailing good production practice, and there were no differences between projects in that area.

The analysis of environmental factors revealed that the best projects based on the selected productivity indicator were all outside the metropolitan area. The explanatory factors were the parking and foundation engineering solutions which increased costs per useful area. There may also be other factors that raise or lower costs which were not detected on the basis of the studied material.

4. Conclusions

4.1 Methodology

The developed research method was found to be, on the whole, usable in measuring site-level productivity. It is important that the productivity indicator is complemented with other performance indicators since it is difficult to establish a single site-level productivity indicator that is descriptive enough. It was also discovered that the data mining tool based on the Bayes Network is suitable for analysing explanatory factors in a site-level productivity survey.

The research found that indicators that explain and complement actual productivity indicators should be quite accurate – preferably ones that depict site processes. It would be good to select the measured processes serving as the explanatory factor from among recently launched site processes since differences still exist between them. In an ideal case someone has made an educated guess in advance about the impact of a certain factor on the project turning out good or bad. Then, the method used in the study could verify the accuracy of the prediction and thereby confirm the procedure as a good one.

4.2 Productivity Indicator

The productivity of a construction company or project can best be measured by a value-added-based productivity indicator. The indicator output is the monetary value added to the company or project. The indicator input consists of the labour input within the company or into the project, measured, for instance, in person-years.

Physical productivity indicators are most suitable site productivity indicators. The output may be produced useful area, and the input construction costs or own labour input on site in person-years. The problem with physical productivity indicators is that they are not comparable between highly different construction projects.

4.3 Suggestion for a Site Performance Indicator

It is suggested that site performance be assessed based on a profit-predictability figure indicating the ratio of realised profit to target profit. Profit predictability is a comprehensive indicator of the success of site operations. Its significant advantage is its neutrality vis-à-vis different projects whose target profits may vary widely.

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Section IV

Project Delivery Systems and Contractual Practices

Experience on a PPP-based High Speed Road Maintenance Project in Hong Kong

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Abstract

There is a growing trend for governments worldwide to explore new routes for procuring infrastructure facilities, such as various forms of Public-Private Partnerships (PPP), due to restricted fiscal budgets and an increasing demand for infrastructure facilities. Many practitioners and researchers believe that PPP can harness flexibility, encourage innovation, enhance productivity, allow better risk allocation, increase value–for-money, and improve cost-effectiveness by involving the private sector in the provision of public services. A Work Department of the HKSAR Government (the Department) has recently introduced the concept of PPP into their road maintenance programmes – the High Speed Road Maintenance Contract. The project is an interesting challenge to relevant public authority as the form of contract, project organisation, risk allocation and points of responsibility are totally novel. Most of the infrastructure projects using PPP approach are of much larger scale and are in the form of PFI so that the private sector is responsible for financing, constructing and maintaining the road network. The experience gained from this project, and especially its success would improve our understanding on whether PPP is suitable for similar road maintenance projects around the world. Before investigation of the success level of the new project, it is important to study the view and standpoint of the stakeholders on the issue of PPP as the human factor is believed to be a crucial contributor to the success of PPP. The paper begins by outlining the nature of the PPP high speed road maintenance project. As there is potential for the Department to extend the use of PPP approach to other road maintenance projects, a questionnaire survey conducted with other potential stakeholders of future PPP projects of a similar kind are presented to examine the effectiveness of the new PPP contract from their perspective.

Keywords: Public-private partnerships, high speed road maintenance, questionnaire survey

1. Introduction

Public-private partnership (PPP) is becoming an increasingly popular option of project delivery for governments. In view of the restricted fiscal budgets and the growing demand for infrastructure facilities, governments worldwide are striving to explore the use of private sectors' resources and particularly to involve private finance in the construction of facilities for the purpose of providing services. Many practitioners and researchers believe that PPP can harness flexibility, encourage innovation, enhance productivity, allow better risk allocation, increase value-for-money, and improve cost-effectiveness by involving the private sector in the provision of public services. It is also believed that PPP can improve project procurement environments and the relationship between project participants by changing the traditional adversarial scenario to cooperative partnerships [1].

The idea of PPP is not new to Hong Kong. Since the late 1960s, Hong Kong has gained valuable experiences from the successful development of five large-scale tunnel projects using the Build-Own-Transfer (BOT) arrangement [2]. In 2003, the HKSAR Government (the Government) has set up a clear goal in developing the city into a society with "big market, small government" [3]. This new principle of governance is supported by the idea that government should "steer more and row less" and that the role of government should be "proactive market enabler" [4]. In response to that, the Government has begun to explore different options of private sector participation. Several guidelines were published aiming to encourage the use of the private sector in serving the community. The Chief Secretary for Administration, Donald Tsang pointed out in the foreword of the guidelines that it is the responsibility of the Government to make the best use of both the public and private sectors so as to ensure that government activities do not dominate the market and would not absorb more of the gross domestic product than is optimal for economic success. With the help of the private sector, the Government can then focus its limited resources on identified priorities. [5]. In addition to new infrastructure projects, the Government is also being proactive in examining existing activities to determine whether they can be provided by the private sector, and the use of PPP would be explored for both traditional and innovative projects [6]. By moving tasks into the private sector, the Government believed that employment and business opportunities can be developed and expanded in ways that are simply not possible within the public sector [7]. In this paper, the effectiveness of PPP is examined through a pilot PPP maintenance project in Hong Kong.

2. Case Study in Hong Kong

Aligning with the government direction, a Work Department of the HKSAR Government (the Department) has introduced the concept of PPP into their maintenance contracts and a trial project, the High Speed Road Maintenance Contract was started last year based on the PPP approach. Being different from Private Finance Initiatives (PFI) – the most common form of PPP, this project involves no financial investment from the private sector. While many people equate PPP to PFI after its introduction by the British Conservative Government in 1992 [8], PPP actually has a much broader scope. It is defined as a cooperative venture between the public and private sectors for the delivery of a public service through appropriate allocation of resources, risks and rewards [9]. The ultimate objective of PPP is the joint realization of commercial and social benefits between the two parties [10].

2.1 Problems in Traditional Term Contract

The traditional high speed road maintenance project is in the form of a term contract. Staff from the Department are responsible for general road inspection to identify defects on the road which require work to be carried out. Work orders are then issued by the Department to the contractor for carrying out the corresponding maintenance work. There is full time supervision on the contractor to ensure the quality of work. Upon completion of the work order, the amount of work done by the contractor is measured and payment is given to the contractor according to the agreed rates stated in the contract. The traditional system of the maintenance project is considered as insufficient, since the amount of maintenance work to be carried out is budget driven instead of as-need. In addition, it is time consuming and tedious to deal with the large amount of work orders. A great amount of resources is also required for carrying out the measurement, estimation, accounting work as well as inspection and full time supervision. There is no room for innovation in the traditional term contract as the method of work is specified in the contract and little flexibility is allowed. Maintenance work is also considered to be inefficient in the traditional term contract. Long and complicated procedures are required to be gone through from the time of defect identification or receiving complaints to issuance of work order.

2.2 The MOM Contract

As a result of the deficiency in the traditional system of road maintenance and in response to the Government announced policy, the Department has taken a step towards PPP. It aims to improve the efficiency, performance and cost-effectiveness of high speed road maintenance project through involving private sector resources and enhancing cooperation between the two parties. To test the successfulness of PPP in high speed road maintenance project, a new project based on the PPP approach was started in 2004 by the Department using the western network of the high speed roads as a trial. By drawing upon the experience learnt from the trial project, other high speed road maintenance projects may also adopt a PPP approach on completion of its existing term contract.

The new high speed road PPP contract has taken the form of a Management, Operation and Maintenance (MOM) Contract and is a performance-based maintenance contract. In this project, the contractor is responsible for providing scheduled road maintenance services including road inspection, planning, design and supervision for repair and minor improvements of roads and highway structures, as well as for handling complaints from the public during the 4 years contract period. The management and maintenance works required to be carried out by the contractor are grouped under 3 main work orders which were issued at the beginning of the contract period. The major work items in the work orders are highlighted in Table 1 below.

Table 1: Major work items covered in the three work orders issued at the beginning of the contract

Work Order 1	Work Order 2	Work Order 3
1. Provide network manager 2. Maintain road markings and road studs 3. Maintain road drainage system 4. Conduct routine maintenance inspections for slope and undertake maintenance works	1. Conduct road safety inspection and undertake general road maintenance works 2. Conduct road detailed inspection and undertake general road maintenance works 3. Conduct structural inspection and undertake structural maintenance works	1. Maintain vegetation 2. Sweeping road by mechanical sweeper 3. Picking up litter 4. Cleansing traffic signs and the like 5. Cleansing carriageway 6. Maintain road network in hygienic condition 7. Operate calls receiving centre 8. Provide electronic maintenance management system

However, only 65% of routine maintenance works are covered under the PPP part. The rest of the non-scheduled, unplanned works are carried out according to the traditional work orders system. The contractor is entitled to a lump sum payment for the PPP component. Monthly audits would be carried out by the client's representative to determine the level of payment that the contractor can receive according to the predefined performance yardsticks. Samples are selected for audit is carried out on a random basis and 24 hours' notice would be given to the contractor before the audit. In addition to monthly audit, with no advance notice given to the contractor, the Department's staff would also continuously carry out road defects inspection on the road network. Default notice would be issued to the contractor on identification of any defects and a fixed sum of money would be deducted from the contractor. It is believed that the performance-based payment system can allow greater flexibility, encourage innovation, enhance efficiency and improve cost-effectiveness of work by allowing concurrent engineering of functions, use of new materials and techniques [11]. The performance standard of the contractor is measured by a set of benchmarks in different areas of works as specified in the contract. For example for road markings, a continuous road marking line with more than a certain percentage loss of paint in any given section length would be counted as a defect. The lump sum payment entitled by the contractor would be adjusted according to the number of defects discovered by the client's representative in the audits. Table 2 illustrates the differences between PPP and traditional approach in the high speed road maintenance contract.

Table 2: Comparison between PPP and traditional term contract

	Traditional	**PPP**
Form of contract	Maintenance term contract	Management, operation & maintenance contract
Terms of payment	Schedule of rates	Lump sum
Payment mechanism	Work-based (payment according to amount of work done)	Performance-based (reduction of monthly sum if performance standard not reached)
Specification	Method specification	Performance specification
Quality control	Full time supervision	Inspections & monthly audits
Road defects inspection	By staff of the Department	By the contractor
Time to carry out maintenance work	On receiving work order from the client	Immediately after identification of defects
Duties of client	Estimation, measurement, issuance of work orders, road inspections, full time supervision, programming of maintenance works	Audits and ad hoc Inspections
Duties of contractor	Maintenance work according to work orders	Road inspections, operation of call receiving center and electronic maintenance management center, planning and programming of works, general road maintenance
Documentation	Work orders (by client)	Work programme, report of finished work (by the contractor) Inspection records & site audit checklists (by client)
Types of work covered	All types of maintenance work	Routine & scheduled maintenance works
Relationship	Principal – agent	Peer – peer

2.3 A New Form of PPP

The new maintenance project is a great challenge for the Department as the form of contract, project organization, risk allocation and points of responsibility, etc. are all novel to the Department. No other similar project has ever been carried out before. Most of the overseas maintenance projects using PPP approach are of much larger scale and are in the form of PFI, which means the private sector is responsible for financing and constructing the new roads together with the subsequence maintenance of the road network. For example in Singapore, according to the PPP Handbook for public consultation [12], PPP is a form of "best sourcing" that mainly used in cooperation with the private sector to deliver services that require the development of new physical assets. Some of the staff in the Department also believed that the optimal and ideal form of PPP project should be one which starts from the capital works and continues with the maintenance works. This can encourage the contractor to uplift the construction quality so as to save its future maintenance cost. The contractor can then be paid on the "user pays" principle through the operation of toll roads. However, this kind of PPP in highways schemes may be difficult to be carried out in Hong Kong. It is because the road network in Hong Kong is almost fully developed, and very few new roads will be constructed in the near future. For the renovation of old roads or other road improvement works, it is difficult to convince the contractor to finance the work and be paid back through operating the toll roads without a good business case. Like other BOT-type projects, there would be practical, social and cultural difficulties as it is a radical policy change to charge on a user-pays basis for services that traditionally had been provided free of charge by the government [13].

3. Research Methodology

At the time of the research, the high speed road maintenance project using the PPP approach has only been implemented for less than a year. Therefore, not much data can be collected for evaluating the cost effectiveness of the project and the performance of the contractor under PPP. However, as there is potential for other road maintenance projects to migrate to PPP, views of other staff within the Department as well as other contractors should also be collected to uncover their views on the new PPP approach. It is believed that their opinion would be more objective and without bias as they have not been involved in the PPP project. In addition, since the human factor would also be a crucial criterion for the success of PPP, it is important to study the attitude and perspective of other stakeholders towards the new approach. This may be helpful in developing a PPP culture among the stakeholders within the organizations.

A questionnaire survey had been conducted with some potential stakeholders of future PPP projects to examine the effectiveness of the new PPP contract from their perspective. They include different levels of staff from the Department in various groups of maintenance projects (including both high speed road and local road) as well as contractors who have been involved in traditional term contract. A total of 33 respondents completed the questionnaire, of which 26 were from the Department and 7 were representing the maintenance contractors. The profile of the respondents is shown in Table 3.

Table 3: Designations of respondents

The Department	
Engineer or Technical Officer	12
Inspector of Works	6
Work Supervisor	8
Contractor	
Manager	2
Site Agent	5

The questionnaire consists of 17 statements regarding the cost and effectiveness of the PPP contract. To improve the understanding of the respondents, a brief introduction to the new PPP approach was provided to them as a preamble to the questionnaire. Depending on their level of understanding, questions were explained in greater detail and reasons for their answers were sought through face-to-face or telephone survey.

4. Questionnaire Findings

The results of the questionnaire show that the respondents from the contractor group generally have more positive views on the effectiveness of PPP while the responses from the Department's staff are more diverse. Many of them might have had some reservations in answering the questions. In this paper, only part of the questionnaire findings (in the aspects of time, cost and quality) are presented.

4.1 Effectiveness of Contractor-led Inspection

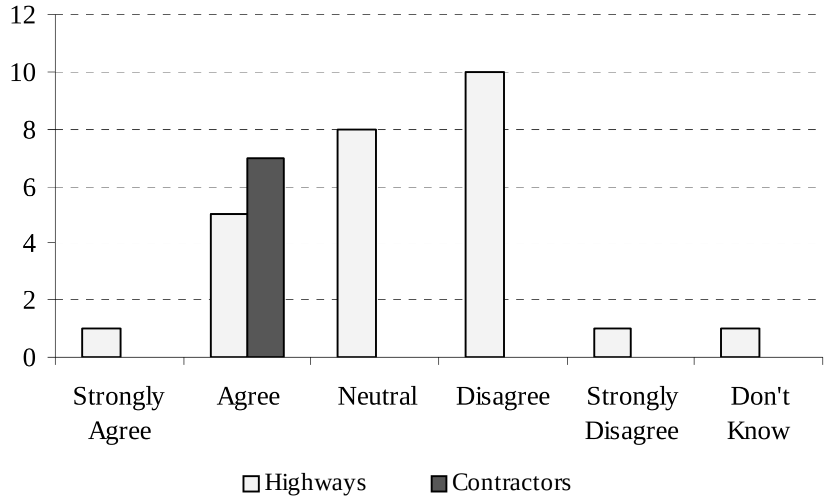

Figure 1: Effectiveness of contractor-led inspection in identifying defects

As shown in Figure 1, all respondents from the contractor group agreed that inspection carried out by the contractor is more effective in identifying defects than that carried out by the client representative. They claimed that the contractor can take the initiative to work and more resources can be devoted for full-time inspection. It was believed that payment reduction on defects discovered is also an important factor driving the contractor to more effective inspection. On the contrary, most respondents from the Department (11 out of 26) disagreed with the statement. They thought that the contractors in Hong Kong do not have self-discipline and supervision is required to monitor their work. There is also large percentage of the Department's staff (8 out of 26) expressing neutral view on the statement. They thought that the effectiveness of inspection depends on many factors including the tender cost, audit requirement, individual initiatives, human resources input, as well as qualification, training and experience of the inspectors. Some staff of the Department agreed that contractor-led inspection would be more effective. They believed that the contractor would have more resources and can have a dedicated team to take charge of inspection, whereas in a traditional term contract, there is not enough staff from the Department for the inspection work and the inspectors are always tied up with other duties at the same time. In addition, any unrectified defects would contribute to payment reduction. Thus the contractor would devote more effort in the inspection work.

4.2 Efficiency of Maintenance Work

Regarding the efficiency of maintenance work, nearly all respondents from the contractor group agreed that work carried out through PPP approach is more efficient than traditional term contracts. It is because work can be carried out directly without waiting for the issuance of work order. The majority of respondents from the Department also agreed with the improved efficiency due to the streamlined procedures and better programming of work. Time can be saved in preparing work orders which are tedious and time consuming to prepare. Some respondents had negative opinions on the efficiency of the work. They believed that the contractor would tend to leave the work until a later stage during Cyclic Lane Closure (CLC), while in the past, staff of the Department can issue work orders to instruct the contractor to finish the urgent work immediately. They thought that there is limited control on the contractor in the PPP contract.

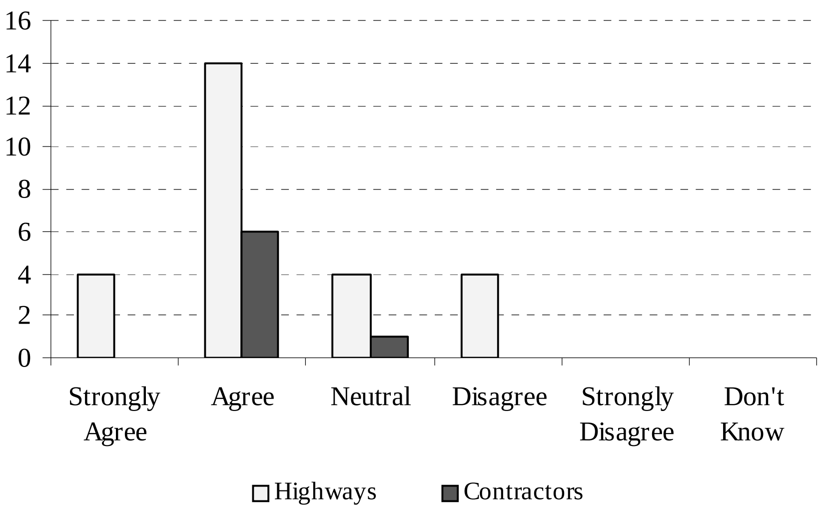

Figure 2: Efficiency of maintenance work carried out through PPP approach when compared with traditional term contracts

4.3 Amount of Documentation

For the amount of documentation, most respondents from the contractor group claimed that the amount of documents the contractor has to deal with has greatly increased. The contractor has to submit their programme and completion report to the client. On the contrary, most respondents from the Department (12 out of 26) agreed that the amount of documentation can be reduced in PPP contract due to the great reduction in amount of work orders. There would no longer be estimation, measurement and checking of work completion. However, some respondents argued that there would be additional documents like default notice, inspection report and audit report resulting in a similar overall amount of documentation.

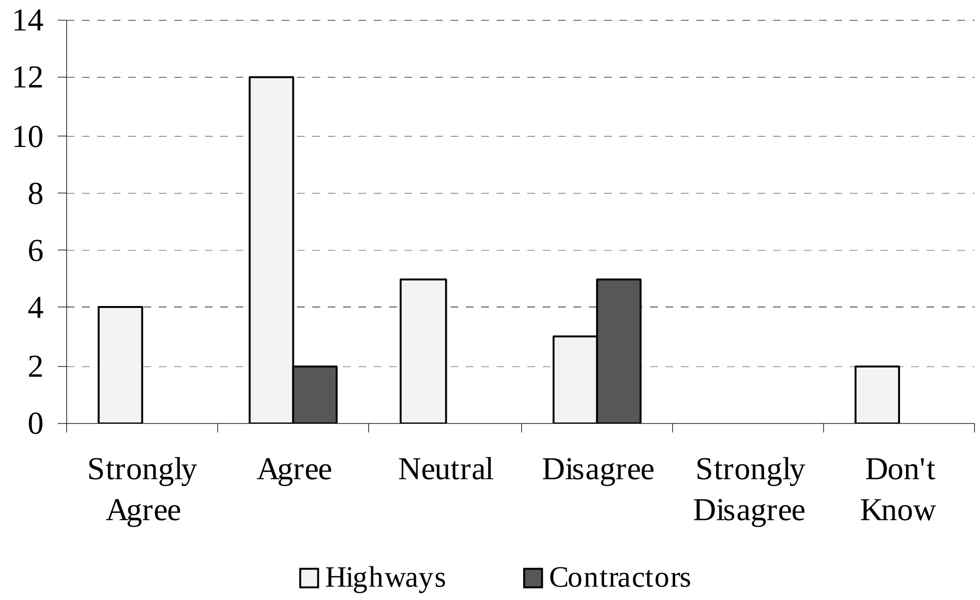

Figure 3: Potential of reducing the amount of documentation

4.4 Amount of Administrative Work

4 out of 7 respondents from the contractors believed that the amount of administrative work would be more than the past as the scope of work of the contractor has increased. Most respondents from the Department believed that the amount of administrative work can be reduced due to streamlined procedures and better communication. They no longer need to prepare or sign work orders for works under the scope of PPP.

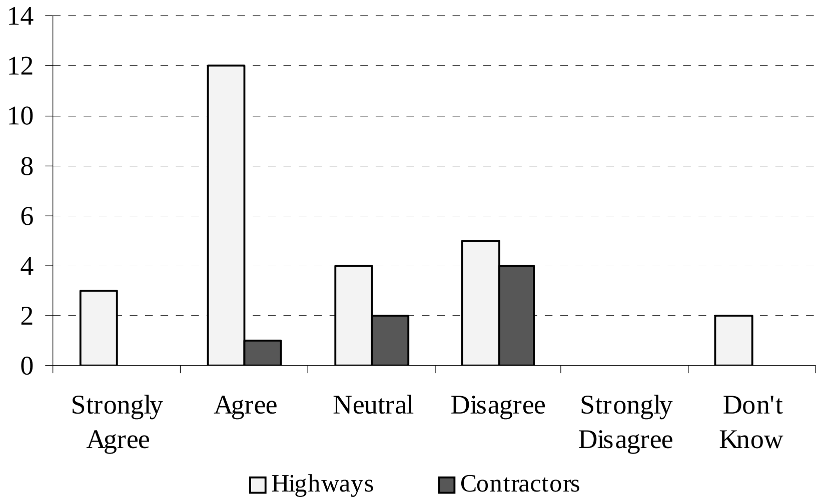

Figure 4: Potential of reducing the amount of administrative work

4.5 Staff Cost of the Department

As shown in Figure 5, most respondents from the two groups also agreed that staff cost of the Department can be reduced. It is because most of the work has been taken up by the contractor, including inspection, coordination and planning. There is no longer full-time supervision on the contractor and thus the number of supervisor can be reduced. Besides, preparation of work orders, estimation, measurement and accounting work can also be reduced. Some respondents argued that staff cost of Department depends on the contractor's performance. It would require more audits if the performance of the contractor is poor.

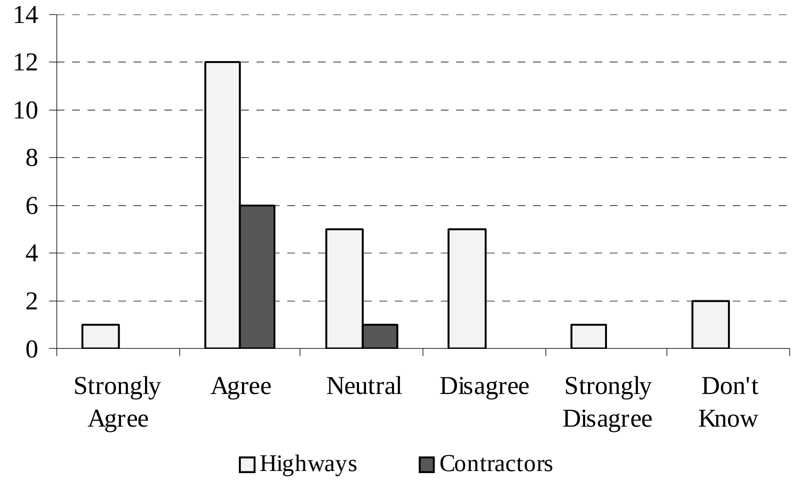

Figure 5: Potential of reducing the staff cost of the Department

4.6 Overall Cost Effectiveness

As shown in Figure 6, many respondents from the contractor group (5 out of 7) and the Department group (11 out of 26) believed that PPP would be more cost effective than a traditional term contract in the long run. Some staff of the Department surveyed postulated that the overall cost effectiveness depends on the tender price, the conditions of contract as well as the contractor's performance. More resources are required if the contractor is not good.

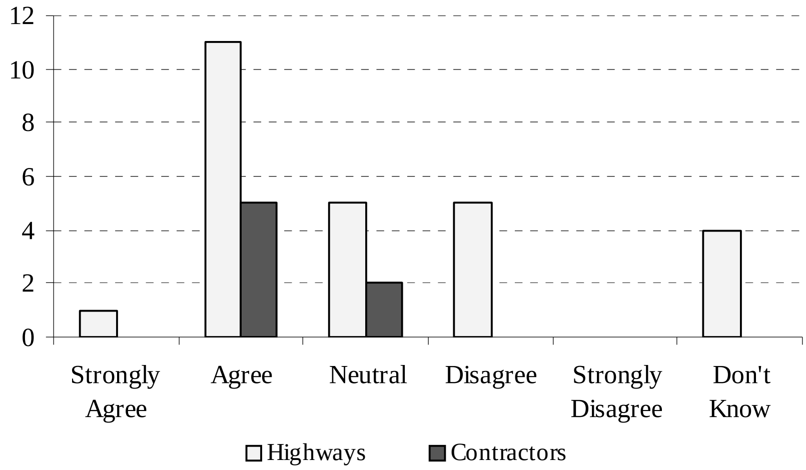

Figure 6: Overall effectiveness of PPP when compared with traditional term contract

5. Conclusion

The idea of PPP has been widely adopted in many countries over the world. It has mainly been used in large-scale capital or infrastructure projects in the form of PFI. The Department of Hong Kong has extended the use of PPP to their maintenance contracts. A new project, the high speed road maintenance contract was launched in 2004 using the PPP approach. It is a form of MOM contract with the contractor being responsible for the management and maintenance of the high speed road as well as operation of the call receiving centre throughout the four years contract period.

To study the potential for future development of PPP in other maintenance projects, a questionnaire survey was conducted to study the perspectives of potential stakeholders of future PPP projects on the effectiveness of the new PPP contract. The results from the survey indicate that most respondents supported the use of the PPP approach and agreed that it would be more cost-effective than the traditional term contract. They believed that the new approach can help by bringing in operational efficiencies, cost savings and better output performance.

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DBB, DB or DBM?
Performance of Road Project Delivery Methods

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Abstract

Internationally, road procurement is moving towards more integrated services. At the same time, the number of alternative project delivery methods has increased making selection of the best one difficult. The client must understand the features of the methods in order to select the most effective ones. That is why the presented study compared the performance of Design-Bid-Build (DBB), Construction Management (CM), Design-Build (DB) and Design-Build-Maintain (DBM). Based on the analysis of road procurement, more integrated services give better value for money and are of more help to the client in attaining his goals than more traditional methods. Yet, one should realise that each method has its typical applications, and all methods are not suitable for all purposes.

Keywords: Road procurement, project delivery, performance, comparison, life-cycle

1. Client's Changing Needs as Starting Point

Project delivery methods where the implementer offers more integrated service packages are increasingly used in infrastructure projects worldwide. The client no longer splits up the project to procure different types of services by different contracts. Besides construction, at least technical design and maintenance for a certain time period, often also financing, are covered by a single contract. The change in the modus operandi is the result of clients wanting to focus on their core businesses as managers of infrastructure networks as well as the overall aim of generating added value.

Generally, broader service packages have been assumed to allow optimising the product and implementation as a whole as well as to actuate sector development. Yet, contrary views in favour of traditional methods are also voiced: splitting up the project into small components is believed to increase competition in the markets and ensure the client's decision-making power concerning the details of the project. This together with other presented critique raises the issue of the usability and actual effectiveness of various delivery methods.

2. Performance Assessments as the Goal

The presented study charted the performance of different delivery methods in road procurement from the international viewpoint focussing especially on three areas:

- Examination of the operating principles and present performance level of various methods in actualized road projects.
- Assessment of the development means and potential of delivery methods and their resulting future performance.
- Anticipation of changes in the operating environment, and evaluation of their impact on the usability of different delivery methods.

Since there is special interest towards Design-Bid-Build (DBB), Design-Build (DB) and Design-Build-Maintain (DBM) in Finland, the study was to analyse the performance of these delivery methods and their applicability. As the municipal sector uses Construction Management (CM) it was also included in the comparison to some extent. Different financing solutions and costs as well as (indirect) social impacts were excluded from the study.

3. Charting of International Experiences

The study looked at the experiences gained from different project delivery methods in England, Australia, New Zealand and the United States in addition to Finland. An earlier study [3] found these countries the most innovative, which was presumed to mean that they were best poised to answer questions about new methods. Data were collected by interviewing over 60 persons representing different project parties in these countries and by charting and making use of studies conducted there and in other countries [1]. In the assessment of the merits of the delivery methods, the client's viewpoint was emphasised. The viewpoints of the contractor, designer and end user were also considered in order to ensure the support of all parties for the methods. Only that ascertains the positive future development of the sector.

In the studied countries there is a clear trend towards more integrated services and more risk borne by service providers. DB has gained ground on DBB and even replaced it completely in some countries. It is considered effective in procuring roads since it shortens project duration thereby improving cost certainty. Just about the only problem seen with it is the cooperation between the parties (especially designer/contractor) which various joint enterprise models seem to be able to address.

Various applications of DBM have also been used alongside DB since the 1990s to improve the life-cycle economy of roads. The applications have ranged from fully client-financed roads to pure toll roads. With the former, the enlarged responsibility of the private sector covers only 10-year maintenance whereas in the case of toll roads the project company collects revenue in the form of user fees over a contract period of 30-40 years. DBM has led to effective operation in terms of quality, schedules and costs. Yet, for instance, the used payment bases have also been criticised.

CM has been used hardly at all in road procurement. Finnish experiences of CM indicate some benefits from it although, at the same time, the fact that buying small work packages does not allow the industry to develop drew criticism.

4. Cost Savings through Integrated Services

Each phase of a project (procurement, design, construction and maintenance) involves a certain cost and duration. Costs may be incurred by the client's organisation (procurement, supervision) or industry (tender preparation, design, construction, maintenance, consulting). In the study, the interviewees indicated the actual phase-level, party-specific cost changes of various delivery methods compared to traditional procurement based on projects they have carried out. The costs for comparing different delivery methods were calculated on the basis of relative costs where the starting point was the cost structure of two reference projects. The chosen study period was 30 years, and delivery methods were compared on the basis of the present values of their costs.

The analysis [2] showed that DBB is the slowest and generally leads to the highest total costs in road procurement as shown by Fig. 1. CM speeds up project implementation, but costs about as much as DBB. The duration of a DB project may be slightly longer than in CM due to the longer procurement phase, but shorter than with DBB. On the other hand, the costs are clearly lower than with the CM and DBB. However, DBM is the one that yields the largest savings. In DBM the project takes a little longer than in DB and especially CM.

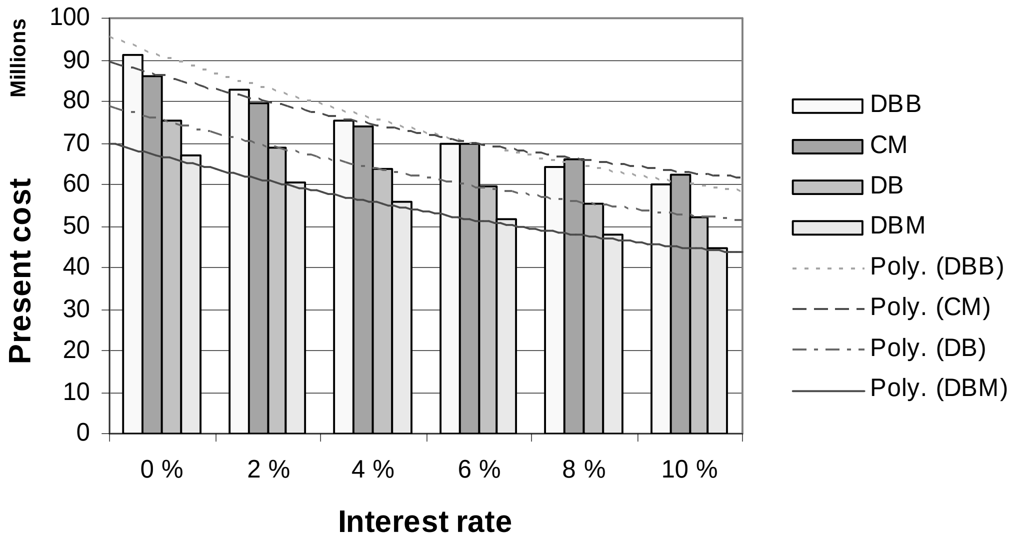

Figure 1. Costs of reference project by different delivery methods and at different discount rates.

The savings from DB and DBM depend on many factors; the most significant one appears to be savings in construction costs. Moreover, the methods also lower a project's supervision, project management and design costs. On the other hand, the savings in maintenance costs appear to have little effect on the present value of total project costs. The present cost is also affected by the discount rate, but – with the exception of relative position of DBB and CM – changes in it do not alter the ranking of the delivery methods. Subsequent assessments were made using relative costs based on a discount rate of 6 per cent.

5. Added Value through Integrated Services

Not only does the cost behaviour of procurement methods vary, their ability to generate value for the client and the other parties also varies. The value criteria generally used were grouped in the study into the value factors of Fig. 2: cost certainty, time certainty, short cycle times, good quality (aesthetics, travelling comfort, minor need of maintenance), safe and environment-friendly implementation, flexibility (ease by which client can effect changes), smooth delivery (effective communication, no disputes or claims), public inconvenience (road availability, minimum user disturbances). The interviewees assessed how well these goals were attained by different delivery methods compared to DBB. The viewpoint was mainly that of the client.

In general, the interviewees found that methods where the contractor is responsible for design (DB and DBM) generate more value. The broader the service package, the better the perceived value generation on average. DBB and CM, on the other hand, were believed to lead to an increased number of interfaces between the parties and possibly to problems, inefficiency and lower value generation. CM was, however, considered superior to DBB in some areas.

Different clients and projects may emphasise value factors quite differently. If flexibility becomes the determining criterion, DBB and CM are the best methods. On the other hand, if the weight of quality and flexibility trebles, the value generation of DBB exceeds that of DB. If again, the weights of flexibility and time certainty increase 2.5-fold, CM generates more value than DB. Yet, as the study focussed on a so-called average project, various value factors were assigned equal weight in drawing conclusions and the illustration of results.

When value generation was studied from the viewpoints of other project parties, contractors and designers were found to have noticed some problems also with the more integrated methods. Contractors perceived high tender costs and cooperation with the designer the biggest problems. Risk allocation and increasing project sizes also provoked discussion. Typically contractors did, however, find that broader service packages lead to efficiency and better possibilities of developing operations. Designers saw problems especially in the implementation of DB where they are often subordinated to the contractor as the limited economic resources of designers seldom give them an equal footing.

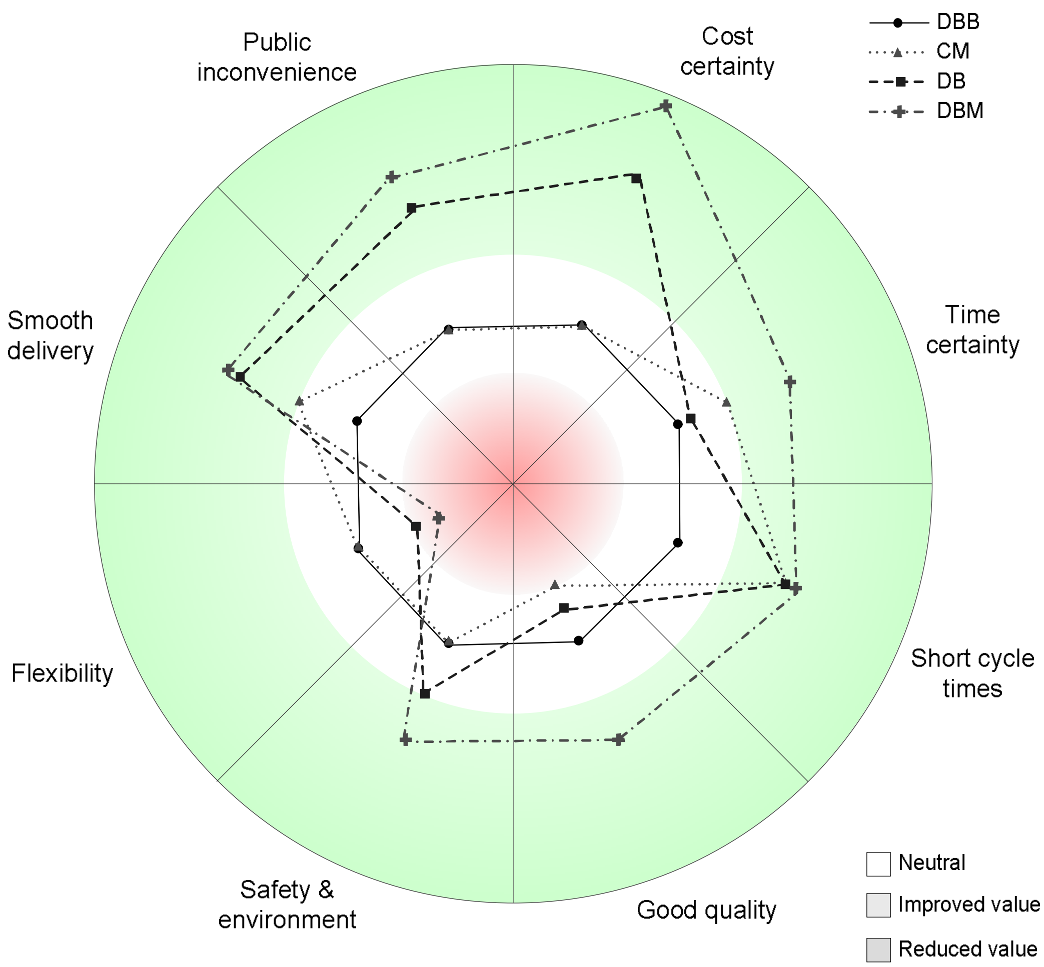

Figure 2. Value generation capacity of different procurement methods compared to DBB.

6. Economic Efficiency is the Key

There is a continuous demand on public clients to get more value for tax money. The accrual of costs or value generation in themselves do not prove the excellence of a delivery method in that context. The significant factor is the amount of value the method can generate in relation to its costs. That is why the concept of economic efficiency (EE) was introduced into the study. It indicates the normative ratio of generated value to costs in comparison to DBB.

The conducted analysis and Fig. 3 in the next chapter show that CM's economic efficiency is on a par with DBB. DB improves EE significantly: it generally allows generating more value for the client at lower costs. DBM as much as doubles the benefits of DB and thus gives the best value for money. The total differences are so large that moderate changes in the weights of value factors play no role in the ranking of delivery methods. The overall assessments requested of interviewees concerning the "value for money" of various methods were also in line with the above analysis. The general reasons perceived to contribute to the superiority of DB and DBM included transfer of risk to the private sector, the optimised delivery process and quality as well as utilisation of the management skills of the private sector.

7. Development is the Basis of Future Performance

The study also attempts to provide answers for the long term instead of just evaluating the "historical performance" of delivery methods. Therefore, the interviewees were asked to assess the development potential of different methods. Development potential was divided into more easily assessable sub-factors by main categories as follows: 1) adaptability/regeneration of process, 2) generation/utilisation of information, 3) project team coherence/capacity for cooperation, and 4) means and possibilities of improving workability of delivery method. The first three categories represent general preconditions for development of the activity over the long term. The fourth one covers the concrete means for improving the efficiency of delivery methods presented by interviewees and literature. Based on the assessments of the interviewees and on the critical analysis, it became evident that DBB and CM have little development potential whereas the potential of DB and DBM is significant. The relative development potentials of different delivery methods are indicated by the lengths of the arrows in Fig. 3. However, here the lengths of the arrows are meaningful only in relation to each other, not as exact numeric values.

Future performance is the sum of present performance and development potential. Thus, there are good grounds to assume that the performance gap between DBB and CM on the one hand, and the more integrated DB and DBM on the other, will only widen in the future.

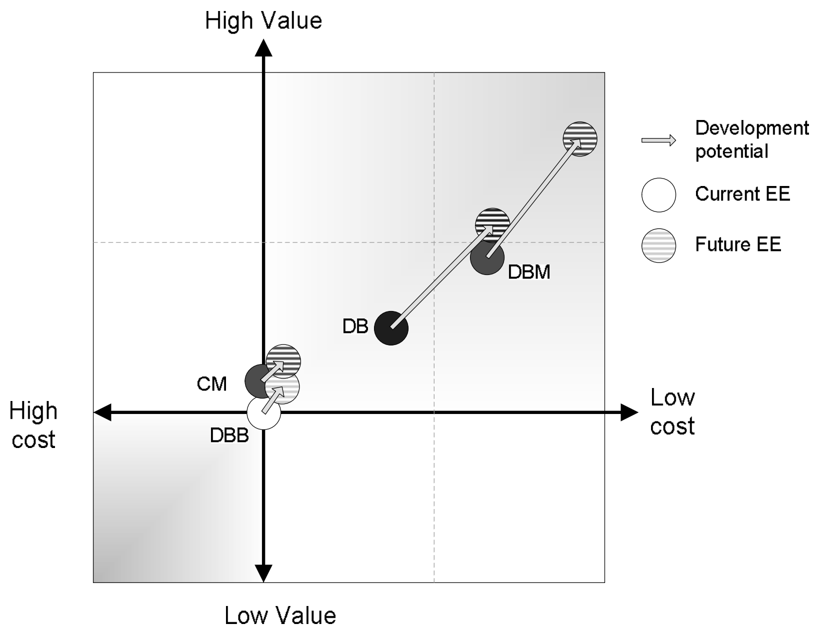

Figure 3. Current economic efficiency of delivery methods and its future development.

Attainment of the full performance capacity of delivery methods naturally requires elimination of the existing factors that limit efficiency. The research report [2] specified the improvement proposals already considered as development potential above. Their aim is to optimise the performance of delivery methods from the viewpoint of all parties (see [1]). In DBB, for instance, the constructability of designs and cost certainty can be improved. In CM, the overlapping of operations can be reduced thereby making project management more effective. In DB, tender costs can be cut, cooperation between suppliers improved, risk allocation optimised, opportunities to innovate increased and quality improved. In DBM, tender costs can be reduced, risk allocation optimised, innovation promoted and flexibility increased.

8. The Future Operating Environment

The future will bring changes also to the operating environment where roads are procured and built. Changes will affect factors guiding procurement (rules, financing, changing traffic environment) as well as the production process – even the end product. In light of the anticipated changes it would appear that more integrated delivery methods will allow us to adapt better to changes than more traditional methods. Yet, there would appear to be no serious hindrances to the use of any of the methods in the future.

9. Application Areas of Different Delivery Methods

The study would seem to indicate that more integrated delivery methods provide better value for money than traditional ones. Each delivery method does, however, have its distinct best applications outside of which its advantages cannot be realised in full. According to Fig. 4, DBB is still suitable for small and simple projects, which offer little room for innovation, or which involve many factors of uncertainty due to parties or issues external to the project. CM, again, is well suited for large and/or tight-scheduled projects involving many constraining factors where the client also must effect changes during implementation or the life cycle.

As project size and degree of freedom increase, DB and DBM become more preferable. Since DBM is suited for larger-than-average projects, DB can be considered appropriate for average projects. DB and DBM projects must not, however, involve factors of uncertainty due to third parties.

10. More Integrated Service Packages for Future Roads

The study clearly indicated that more integrated service packages can provide concrete benefits to all parties compared to DBB. Thus, further development of DB and its adoption as the standard alternative to DBB is recommended. The benefits of DBM are also apparent; it is generally the best solution for large projects.

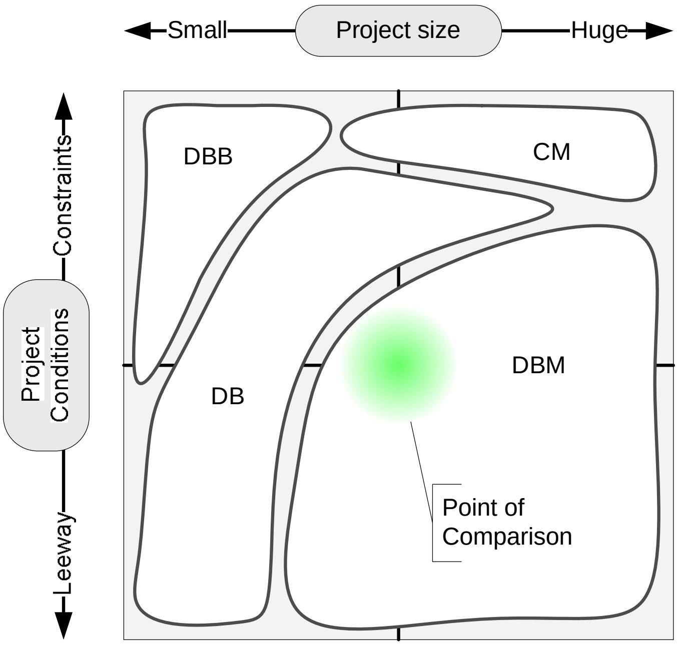

Figure 4. Optimal application areas of various delivery methods.

Changes in procurement must yet occur in steps in order to give industry time to adapt and to allow time for contract standardisation and development of appropriate specifications. Selected delivery methods must also be used continuously to motivate people to acquire the know-how required by new methods which will also make them better. The private sector must at the same time focus on relationship-building and developing cooperation models. Thereby road procurement and implementation can be raised to a new level which furthers the attainment of the client's goals, increases industry's productivity and profitability, and gives society the best possible value for tax money.

It should be kept in mind that the study targeted only road projects. Thus, the results cannot be assumed to be directly applicable to vertical, or even other infrastructure construction, since these often differ from road construction in many ways.

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Advanced Design Management as Part of Construction Management (CM)

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Abstract

Construction management (CM) contracts are increasingly used in large building projects in Finland. It is understandable that opinions on the relevance of CM forms of contracts vary widely. Finnish owners have had mainly positive but also some negative experiences with their CM projects. Typically, many owners are starting their building investments before users are known or users are not yet ready to determine their design requirements. CM contracts make it possible to start new buildings before even room layouts are designed. It has not been easy to change the traditional culture of the sequential design and construction to the concurrent CM culture. The greatest problems lie inherent in the delivery and the contents of the building design documents. The suggested design management model (FINSuke) enables true teamwork between project actors. The results of the initial tests suggest that there are many advantages in CM projects compared to fixed-price projects. For example, it is possible to arrange enough time for designers in the working drawing phase. Designers may now protect the visual and technical solutions without drawing and specifying all the details before the tendering of subcontracts. In addition, it is possible to utilize the solutions of product suppliers. Final designs can be developed in cooperation among a CM manager, designers, and suppliers before the assignment of subcontract agreements. The best performing contractor (or supplier) is then chosen in competitive terms.

Keywords: Buildings, construction management, design management, Finland, project delivery methods

1. Introduction

Herein, a new model (FinSUKE) for managing building design processes as part of construction management (CM) projects is introduced briefly. The FinSUKE model is being developed within the unit of Construction Economics and Management (TKK/CEM) at the Helsinki University of Technology. The FinSUKE study as a whole aims at developing **a new design management system** which will in part ensure the attainment of the project-specific (or building-specific) objectives in terms of performance, quality, costs, and schedule. In part, a few existing concepts such as the basic principles of open building [e.g. 1, 2] have been applied to this model design task.

The design management is herein approached in terms of **planning and controlling** the delivery of the design documents and the procurement concurrently as follows. In general, the two kinds of problems beset conventional engineering, i.e. weak process and weak co-operation [3, 4]. The separation of design and construction has long been presented as **the root problem of construction**. This separation threatens, in particular, the constructability of the building in question. Thus, it is no wonder that great expectations have been attached to the use of design-build contracts, where these two stages are integrated at the outset [3]. However, many empirical findings [5,6] have revealed that the design-build contract alone does not produce significantly better results than conventional procurement methods.

In the manufacturing management literature, push and pull are distinguished as the two primary techniques for managing work flows [7,8]. When the pull technique is used, a site will “shout for” design documents from designers. When the push technique is used, design documents are prepared and submitted to a site according to a design schedule. Herein, experiences have proved that no single model functions well alone. For example, a design schedule cannot be effectively derived from a procurement schedule. This is due to a fact that each of separate bidding packages is only a small, “wrong” piece from the point of view of the design process. In the FinSUKE model, the design management is perceived as **a combination of a push technique and a pull technique** (Figure 1). From the beginning, design management is a push technique until the inspections of the advancement of the design package take place. After each inspection, the remaining management of the work drawings and the specifications is a pull technique which utilized by management at a site.

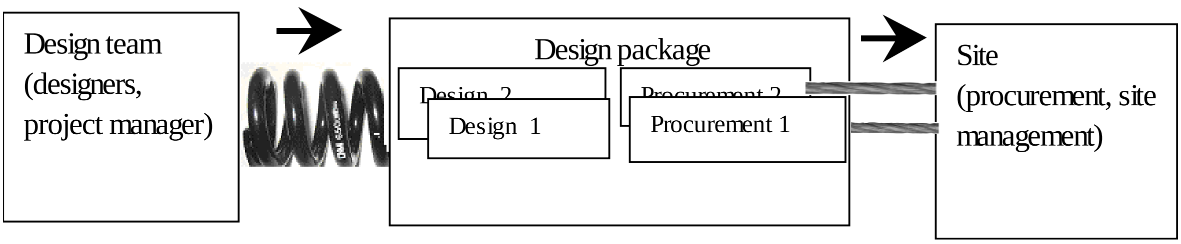

Figure 1: Building design management as a combination of the push and pull techniques.

In many countries, the dominant project delivery methods involve the ones where all the design documents are ready before construction works actually begin. Typically, these practices have been justified by such reasons as pre-managing the complete design process efficiently. On the contrary, the authors counter-argue herein that **the dependencies caused by contract forms and building design must be cut off**. Under CM contracts, the dependencies caused by the contract form are being readily eliminated. But a CM form as a delivery method does not alone guarantee flexible projects. The flexibility has to be carried into subcontracts, especially into building services (M&E) contracts.

From the design management view, **the principles of open building** offer one plausible way to produce highly flexible building (sub)solutions [1, 2]. The cutting of the dependencies not only enables the shortening of the total implementation period, but it has many other advantages. A design team is guided to approach the design of a permanent support with a long life span in a way that differs from the one adopted for the design of an infill part with a short life span. Flexible designs and technical solutions are being enhanced. The principle of cutting dependencies makes also the work of a structural engineer easier because the information such as the loads of the structures and the flues for building services (M&E) are produced on time.

The paper is structured as follows. Next, the founding differences in the use of the contract forms are emphasized in the case of Finland, the UK, and the USA. Thereafter, the three alternative process models of a CM project are introduced. The concept of design packages is introduced as the core of the advanced design management under CM projects.

2. Use of Contract Forms in Finland, the UK, and the US

In Finland, building projects have traditionally been executed under so called **main contract forms**, i.e. general lump sum contracts. A project can be delivered under one main general contract or multiple prime contracts for structural works as well as air conditioning, piping, electrical, automation, and IT installations. When **multiple prime contracts** are used, all the contracts are assigned to the main contractor for coordination only. It is much like the UK nomination system. In Finland, it is normal for owners to hire a professional construction manager (an agent or a representative), who will manage both the design process and the prime contracts. Thus, these main contracts with multiple assigned prime contracts are not considered to be a CM form of contract. In the USA and the UK, construction management with a single general contractor is one of CM forms [9]

In forms of general contracts or main contracts, owners (clients) receive fixed prices and schedules. However, their possibilities to influence processes or to make changes during construction stages are limited. Any change in design involves negotiations between a client and a contractor concerning costs and scheduling. The implied lack of competition infers that changes in the late stages can become expensive.

Chains of competition can be compared in the various forms of contracts as illustrated in Figure 2. In lump sum general contracts, chains of competition are very long. Each building-product purchase must pass 3-4 price competitions. It is very difficult to produce high quality through these kinds of elimination processes. An owner has his or her designers finalize the plans, drawings, and specifications that are used as a basis for arranging competitive bidding among interested general contractors. In turn, a general contractor arranges competitive bidding among second-tier subcontractors, and so on. All these competition stages are based on the cheapest products that meet an owner’s requirements. Designers try to avoid a decrease in quality in these competition chains by specifying increasingly detailed product requirements.

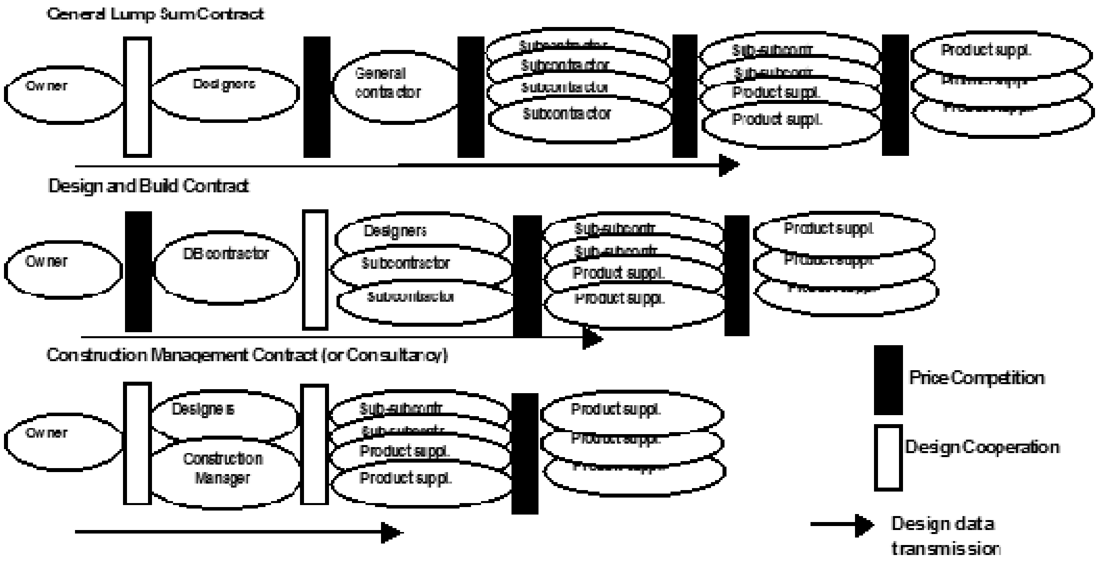

Figure 2: Chains of competition. A comparison of cooperation and price competition in general, design build, and CM forms of contracts [applying 10,11]

Thus, the number of eligible products is reduced and quality/price competition is restricted. All available suitable products and high operational performance cannot be obtained through this low bid chain. Instead, owners are left with many severe low bid problems such as weak quality, chained price competition, decisions made prematurely, and low flexibility for possible design changes [10, 12] When one of the CM forms of contracts is adopted, the improved performance can be part of the selection procedures. In addition, the freedom of suppliers to offer their solutions and assume the responsibility for same can be incorporated into contracts.

The Finnish forms of CM consist of two models as is the case in the USA and the UK, namely, CM consulting (Agency CM or CM for fee) and CM contracting (CM at risk). Construction management is characterized as a form where a professional CM organization leads a project in close cooperation with an owner (client). A construction manager suggests the schedules of the design development packages and those of the procurement packages as well as the related contracts. The relationship between an owner and a construction manager is based on **true cooperation** including open books (cost information). A construction manager acts as an owner’s right hand, i.e. their representative who sits at the same side of the table. An owner has the final decision-making power during the course of a project concerning design solutions, trades or works contracts, and suppliers. An owner may make decisions later at more suitable points in time.

The suggested FinSUKE model of design management can be incorporated both into a CM consulting form and a CM contracting form. Likewise, many of its principles are readily applicable to design management contexts where other project delivery methods are used.

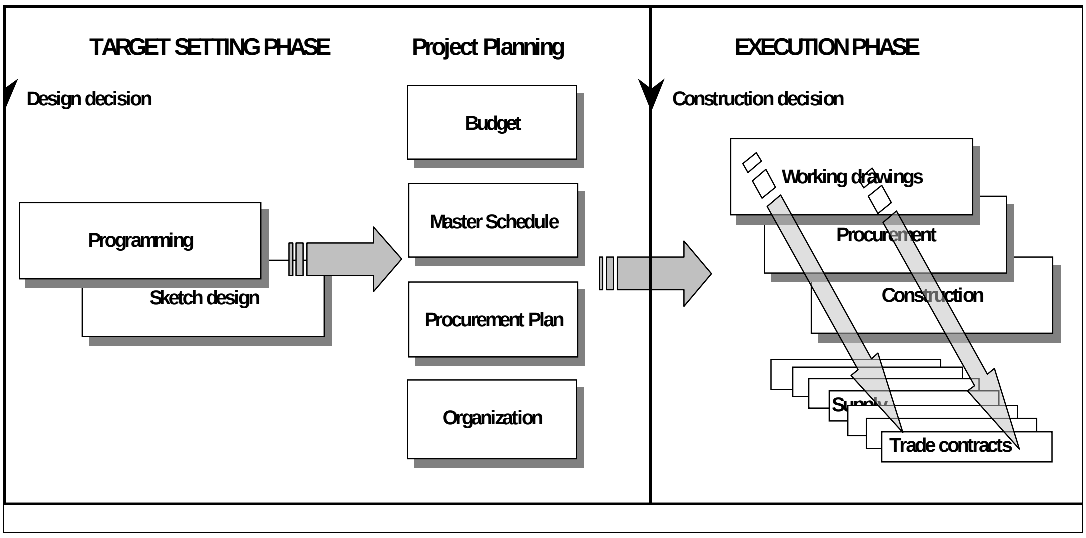

Figure 3: Two-phase model of a construction management (CM) project [12]

3. Three Basic Process Models of a CM Project

In general, a project process is defined to include building design, procurement, and construction works as well as to expose the overlapping of these phases. Herein, **the three alternative basic models** of a project process are illustrated in Figure 4. The critical paths are marked with the shadowed lines. The same (maximum) period of time can be allocated for the actual construction works. **The chain model** is underlying the traditional main contracts, i.e. each sub-process follows fully one another. **The concurrent CM model** involves the time compression based on the two start-ups with the shortest periods that are interrelated, i.e. (a) “Scaling WD1”, which is a period needed to make design documents before the first related procurement, and (b) “Scaling P1”, which is a period needed to make the first procurement before the related building work starts at the site.

The Finnish CM model is designed as a concurrent model, in which the building design, the procurement, and the construction works overlap and particular bidding packages are used as the tools for project management. The durations for making the last working drawings are fairly open to the end.

A physical segmentation adds value also in CM-projects. Using the segmentation it is possible to make design documents ready for one segment while the design of other blocks continues. A segment is usually a vertically sliced entity from a cellar to a roof in new buildings. In addition, the horizontal dimension is applicable in many renovation projects.

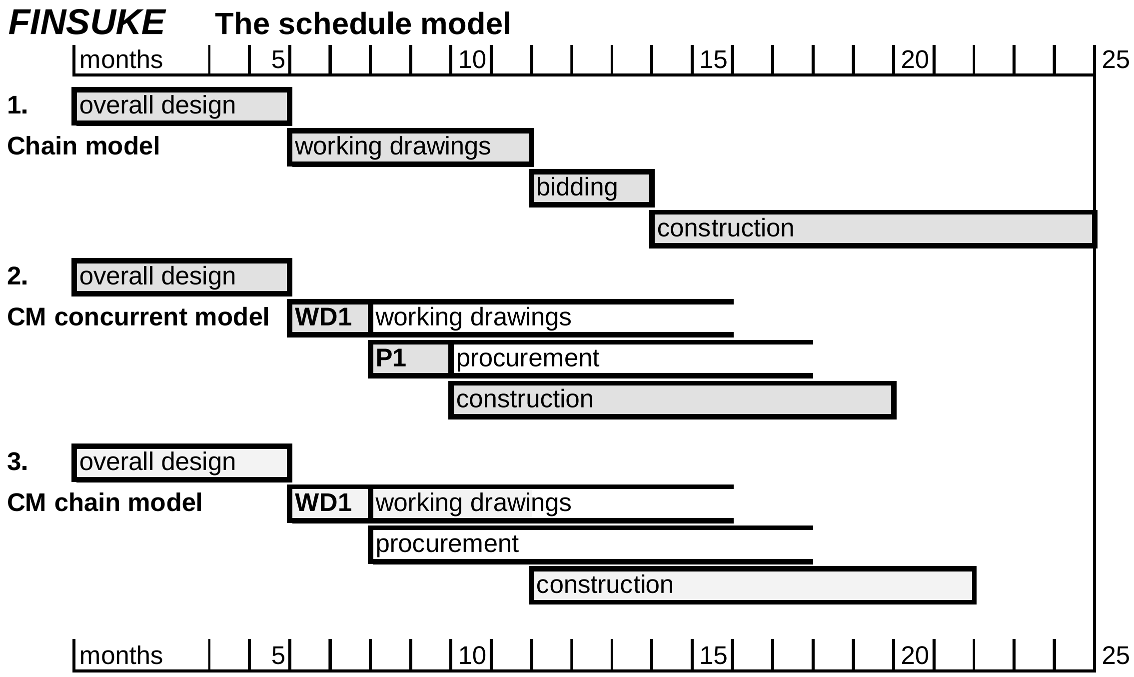

Figure 4: Three alternative project process models illustrated in the case of a typical new building (of 50 000 sqf) in Finland.

4. Design Packages as the Core of FinSUKE model

Under traditional main contract forms, the working drawing phase is often scheduled as one long task (line). Under CM contract forms, the design development is traditionally divided and scheduled based on the project breakdown as **a set of procurement packages**. However, procurement packages are mainly based on trades and so a single procurement package is seldom the most relevant criterion for managing a building design process effectively. Sub-design objects are mostly building elements. Thus, most procurement packages do not contain the complete sets of the enabling sub-designs. This fragmentation of design work causes problems for the delivery of design documents. For example, when only one set of design documents for a procurement package is suddenly needed, the designer must ad hoc solve the related design package as a whole. In the same vein, when the building works are compiled into packages purely by trades, this implies the fixing of many preceding sub-designs too early (concerning e.g. metal works, masonry works).

When the design management is acknowledged as one of the primary, interrelated processes, separate design tasks and documents are compiled into sub-designs based on the concentrations of the primary dependencies among the design tasks themselves. In the suggested FinSUKE model, these sub-designs are managed and called as **design packages**. The model includes a list of standardized design packages with their basic contents.

Table 1.@b@1@e@1 FinSUKE standard design packages, building services (M&E) is not included. Based on Finnish Building 2000 BE classification (translated using UNIFORMAT II) @b@6pr

	Design package		Design package
0	The supplementing design documents	8	Space partitions and doors
1	Excavation works	9	Spacial components
2	Demolition works	10	Other space structures
3	Foundations and slab on grade	11	Interior finishes
4	Elevetors	12	Fittings (to be renoved)
5	Frame	13	Fittings (new)
6	Enclosure	14	Space equipment
7	Roofing	15	Site

In each CM project, **design packages** are determined early as part of a project plan. A CM team compiles and schedules a set of the most effective design packages in cooperation with the designers. The design work is divided on a basis of the standard design packages. Optimally, each project-specific design package includes those parts and works which are procured at the same time and produced accordingly through the preceding design tasks (Figure 5).

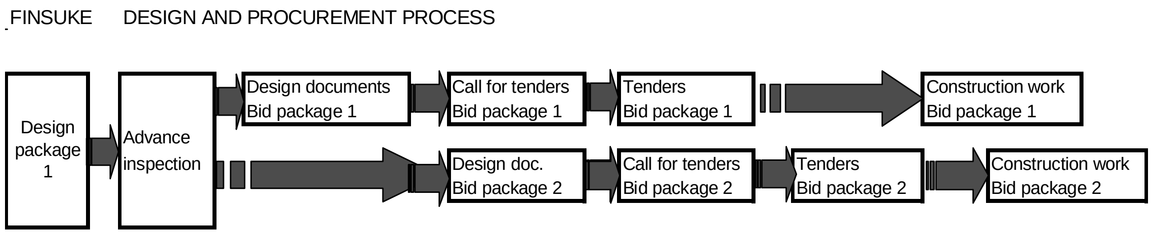

Figure 5. Management of a building design from the design package to its use as a basis for the procurement phase and the construction phase (FinSUKE).

The use of design packages enables **the design team** to achieve many advantages such as:

- To avoid the accumulation of the design work (traditionally scheduled as one task) to the last remaining days through the introduction of design phasing.
- To facilitate effective communication among the designers as well as between the owner and the design team and the procurement team.
- To balance the need and use of design capacity and to enable the flexible increase of the design resources when needed.
- To avoid the preparation of non-constructable sub-designs for single procurement packages.
- To avoid the non-productive preparation of design documents with too small scopes.

- To allow more time, overall, for the attainment of the key objectives of the building design such as functionality, safety, environmental conformance, and aesthetics.

In addition, the use of design packages enables **the procurement team** to achieve several advantages such as:

- To integrate two or more initial design packages to support bigger procurement packages, when this is justified.
- To prepare all the documents of one design package effectively and later to phase the submission of the finished documents according to the related smaller procurement packages.
- To initiate the procurement of a certain package without the need to prepare and submit all the related design documents at the same time.

At the project level, the use of design packages enables **the project management** to achieve the key advantages such as:

- To allow the beginning of the construction work also in the case when all the related design documents are not ready.
- To leave more (enough) time for decision making, especially concerning the final infill of the building.
- To enable the control of the design process and the real-time feedback to the sub-designs.
- To inspect each design package in advance will prevent typical design errors from occurring.

In the FinSUKE model, **a design schedule** is prepared by design packages also in the cases when construction works would not begin before the completion of the design

In the design documents (packages), **a breakdown into the procurement packages** need not to be readily presented . In turn, a CM team determines the contents of each procurement package after the completion of the related design packages. A CM team prepares the tender documents where the contents is specified (often in more detail than in the related design documents) for the procurement. However, some of the traditional trade divisions (e.g. the masonry works for the facade/interior and the steel works) needs to be broken down into parts.

In turn, **a procurement schedule** is prepared by using and integrating the design packages (Figure 6). This is so because the common language is needed in order to ensure the seamless interfaces between the site staff and the designers. Thus, both the design documents and the tender documents are assembled by the design packages.

DRAWINGS	DESIGN PACKAGE	BID PACKAGES
	6 THE FASADE	
Cut-away drawings Details Balcony Windows and outer doors diagrammatic documents	Fasades, outer doors, windows Fasade equipments Balcony, canopy	Fasade timber work Fasade claddings Fasade equipments Flashing Windows Outer doors Painting Balconies

Figure 6. Design package as a linkage between design documents and procurement breakdown.

In the FinSUKE model, all the design documents are drafted and finalized up to the working drawings that enable the actual procurement. The exceptions are stated in a project plan.

In CM projects, **the completion degrees of design documents for a procurement package** may vary In each case, the selected procurement strategy determines the required completion degree. Readily, there are (at least) the three alternative procurement strategies as follows:

- Bidding based on working drawings
- Bidding based on tentative design documents
- Bidding based on design requirements.

In the design schedule of a CM project, the allocation of time takes place at a level which allows to present (a) the preparation periods for the design packages, (b) the dates for the pre-inspections of the design packages, (c) the dates for the uses of the design packages, and (d) the dates for the uses of the working drawings for the procurement packages.

5. Conclusions

In traditional building projects in Finland, all the decisions are made in the beginning of the design process. The easy-way-out attempts are being made to fix the final layout of the spaces and to specify the products by dictating these decisions prematurely. After the prolonged project process, the spaces have become readily outdated and, as usual, any changes would turn out to be expensive Normally, designers specify all building products in detail. When a contractor has been buying these detailed products, the prices have risen to too a high level; while other suppliers offer cheaper products which have same or even better properties.

The suggested FinSUKE model is designed in order to change the aforementioned ineffective procedures. The permanent support (shell and core) of the building will be designed first so that it will meet the demands of the modifiable infill. The detailed solutions of the spaces (infill) are finalized according to the space-specific decisions; taking also into account the choices of the tenants. For a procurement phase, design documents can be prepared well to comply with each of the “chosen” products. During the negotiations, a procurement team (i.e. procurers, project manager, and designers) reviews upon how the alternative solutions influence the final outcome. If the other solution is chosen, the original product will be replaced.

Standard design packages fit the construction of new buildings. Instead, the effective adoption of CM forms is more demanding in the case of renovation projects and in building services (M&E) works. For example, the management of M&E design programs is problematic due to sub-wholes based on each of the spaces (or interior areas).

In the FinSUKE model, the design management is theoretically defined as **a combination of a push technique and a pull technique**, i.e. as a push technique up to the completion of the design package and, thereafter, as a pull technique performed by the site management. The site team secures the status of the design documents for 4-6 weeks ahead. A tool like The Last Planner [13] seems to be effective for the pull-based control at site. In addition, **the principles of open building and the principal procurement strategies** are being incorporated into the later versions of the FinSUKE model.

The testing of the design packages and the other FinSUKE tools will continue up to the year 2006. So far, the parts of the model have been mainly tested retrospectively. The testing of FinSUKE model prospectively will also be carried out. In particular, the ways of managing building services (M&E) design process need to be enhanced further.

In Finland, **the scope of design work and design management tasks** are described with standard task lists published by the Building Information Foundation RTS [14]. The standard task lists are prepared for the main contract forms. Such task lists do not at all support the active participation of the designers in the procurement process and the construction process. The TKK/CEM research team is preparing the lists of additional tasks as part of the FinSUKE model.

Finally, the authors do not believe that, in building projects, one can succeed by trying to attain the set objectives by drawing up the more exact descriptions of the tasks of the various project actors and arranging the low-bid competitions for the accomplishment of the detailed tasks. In turn, **the authors recommend performance based methods** for selecting CM consultants, designers, CM contractors, and subcontractors [see 15, 16] .

The suggested FinSUKE model promotes and creates procedures and methods to improve the cooperation among the parties in the construction project. The essential tool to increase the cooperation is a project plan in which the design packages are integrated. Furthermore, the advance inspections of the design packages and the contract negotiations promote cooperation. The constructability is secured at the negotiations during the selection of subcontractors. It is possible to buy product know-how from the suppliers and it is possible to transfer responsibilities for the products to their actual experts – to subcontractors and suppliers. The best performing contractor (or supplier) is then chosen. In CM projects, it is possible to have enough time for this cooperative design development during procurement process.

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Advancing Building in Finland through Special Systems Contracting (SSC)

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Abstract

In Finland, the Special Systems Contracting (SSC) refers to the design, manufacturing, delivery and installing of the building elements by various Specialty Contractors (SCs). A call for SSC tenders includes readily the schematic design documents with the functional and technical requirements. A contractor is responsible for his system element in question and its interfaces with the other building elements as well as the performance of design solutions. Through the SSC, a true know-how and quality competition or a life-cycle delivery competition can be arranged. Essentially, the know-how of both designers and the SCs is fully utilized within the suggested SSC model. Traditional suppliers and subcontractors can adopt herein a new enlarged role with incentives for system development, innovations, and new delivery packages. The penetration of the SSC will create more effective networking within the building industry. In the on-going study, the first retrospective case projects have been analysed. The prospective testing in the actual projects will follow.

Keywords: Special systems contracting (SSC), specialty contractor (SC), design documents, procurement, Finland.

1. Introduction

1.1 Background and Objective

In Finland, the use of the alternative contract forms has been quite stable during the last years. Normally, an owner relies on a general contractor and some technical prime contractors with fixed prices. Finnish designers are accomplishing computer aided design with modern tools. However**,** the use of design documents as part of call for tenders has remained the same. All design documents are completed before calling for tenders and the competition between contractors is based on the efficiency of construction.

In the design and build (DB) method, general contractors can utilize fully their expertise in project management. In turn, the know-how of systems and products among subcontractors can be utilized through the suggested special systems contracting (SSC) model.

The SSC refers to the design, manufacturing, delivery, and installing of the building elements by various specialty contractors (SCs). A call for SSC tenders includes readily the schematic design documents with the functional and technical requirements. A constructor is responsible for his system element in question and its interfaces with the other building elements as well as the performance of design solutions. Through the SSC, a true know-how and quality competition or a life-cycle delivery competition can be arranged. Essentially, the know-how of both designers and the SCs can be fully utilized. On the other hand, the interfaces of separate deliveries are still problematic in the current uses of the SSC in the building sectors in Finland. Likewise, the responsibilities of designers is not yet well-thought out. A lot of know-how and work is required from all the project parties. The negotiations for an agreement as well as the conditions of these agreements are complex. In addition, the future penetration of the SSC seems to involve a risk that number of suppliers and competition among them might decrease.

This paper is based on the ongoing study project for **a new model (FinSUKE)** for managing building design processes as part of construction management (CM) projects in Finland [1, 2]. The FinSUKE model is being developed within the unit of Construction Economics and Management (TKK/CEM) at the Helsinki University of Technology. The study as a whole aims at developing a new design management system, which will in part ensure the attainment of the project-specific (or building-specific) objectives in terms of performance, quality, costs, and schedule [1].

The main objective of this paper is to introduce the initial special systems contracting (SSC) model, which is in part based on the analysis of some retrospective case projects, as follows.

1.2 Specialty Contractors in the USA

Herein, the definition of specialty contractors in the US context [3] is reviewed in order to offer a benchmark for understanding the Finnish SSC approach also outside Finland as follows.

In the US context, specialty contractors (SCs) are generally construction's 'job shops'. SCs allocate their resources to match various 'delivery' dates demanded by multiple projects. Further, specialty contractor management depends on the quality of production management on projects, i.e., their coordination by general contractors. SCs perform the construction work that requires skilled labour from one or at most a few specific trades (e.g. electrical, plumbing, HVAC, roofing, iron work, and concrete) and for which they have acquired special-purpose tools and equipment as well as process know-how. Because of this specialization, their work is limited in scope relative to the work required to complete an entire facility [3].

Further, **subcontractor activity** not only pertains to construction work on site, but, out of necessity, also to work related to design completion. Indeed, it is seldom the case that contract documents, including design drawings and specifications, are unambiguous and sufficiently detailed to be of direct use to specialty contractors. Shop-drawing detailing followed by architect-engineer (AE) approval is often expected of specialty contractors, but this process more often than not reveals incompatibilities in the design documents that are presented to them and vagueness in their scope of work… It must therefore be acknowledged that the involvement of the contractor and subcontractors in the project begins, not with the start of construction, but with completing the design [3].

1.3 Special Systems Contracting in Finland

In Finland, the special systems contracting (SSC) model in building is defined as a contract in which a supplier takes the responsibility for the system design and detailed engineering, manufacturing, and installation of the building element in question including the in-use-performance of the system as defined by the owner (client). The SSC transfers a part of design responsibility to the system contractor and it also combines the product design and production planning [4, 5]. When competition is based on both design solutions, material choices and production efficiency, the SSC model does not discriminate construction techniques and materials. Competition expands from the production know-how to the system know-how and from the details to the wholeness. In competing with solutions, it is possible for system contractors to achieve more innovations and develop their production. In the SSC, it is possible to compete only based on production technologies but competition can include a system and technical solutions, too.

In comparison, special system contractors are responsible for wider scope of work in Finland than traditional specialty contractors in the USA. The latter are mainly interested in the design phase of the products, but Finnish special system contractors are actually responsible for designing their systems, too.

2. Methods and Forms for Special Systems Contracting

2.1 Key Principles in the FinSUKE Development Project

The principles of the FinSUKE model are presented in Kiiras and Kruus [1]. Herein, the key principles are introduced only briefly as follows.

In the FinSUKE model, **building design management** is perceived as a combination of a push technique and a pull technique. From the beginning, design management is a push technique until the inspections of the advancement of the design package take place. After each inspection, the remaining management of work drawings and specifications is a pull technique which is utilized by management at a site. [1]

From the design management view, the principles of open building [6] offer one plausible way to produce highly flexible building solutions. A design team is guided to approach the design of permanent support with a long life span in a way that differs from the one adopted for the design of an infill part with a short life span.

2.2 Special Systems Contracting as Part of a Building Project

The special systems contracting as part of a construction process is shown in Figure 1.

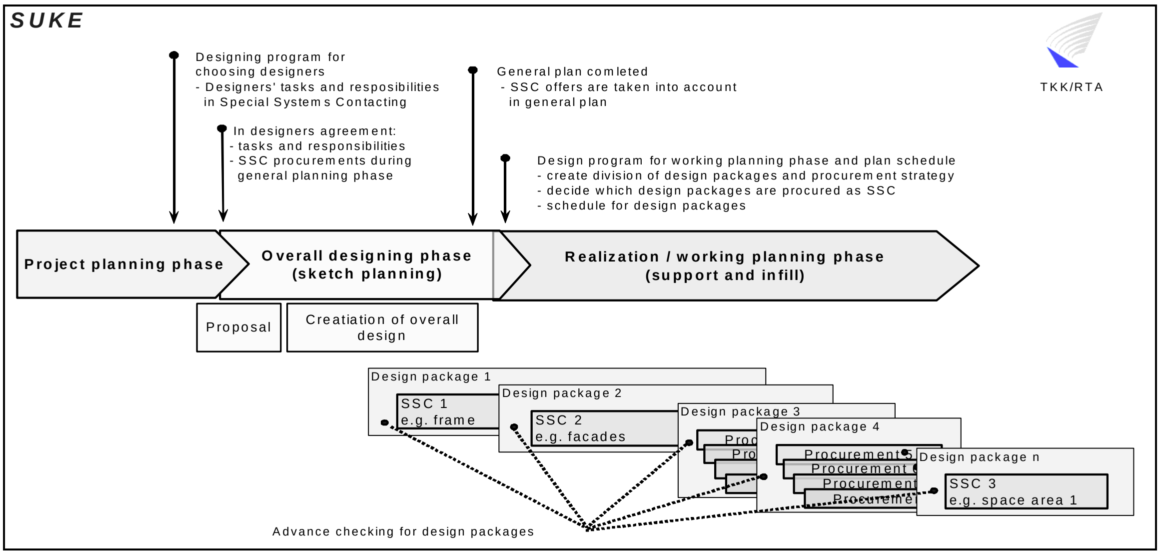

Figure 1. Special systems contracting (SSC) as part of construction process (FinSUKE).

In the beginning of **the overall design phase**, the project management (team) will draw up the design programme for the choice of designers. In the design programme, the designers' tasks for the SSC procurement are defined. The same tasks are presented also in design agreements (i.e. the content, the scope and the schedule of the procurement and the requirements to the accuracy of tender documents).

The design documents for the SSC procurement, which have been completed during the overall design phase, are also taken into account when making an overall design. At the end of the overall design phase, the inspection is performed. Project management draws up the design programme for the working drawings based on the overall design. A project plan shall include a division of design packages and a design schedule and it also identifies readily the particular design packages to be procured through the SSC procedure.

The design documents within the calls for tenders are later taken into account in other design packages. Furthermore, the special system contracts are scheduled in a way that allows, if necessary, the adoption of normal procurements. **A design package** for a special system contract is presented only with requirements and specifications, unless the project management instructs designers otherwise. In the FinSUKE model, only the independent building elements, which are designed as one design package, can be procured as a special system contract. Thus, the model emphasises the shared design and the enlarged responsibility of a contractor. At the same time, the aim is to emphasise the position of the architect and the duty of specialized engineers for checking and combining the separate designs (documents).

2.3 Process of a Single Special System Contract

The main design tasks of a single special system contract are presented in Figure 2.

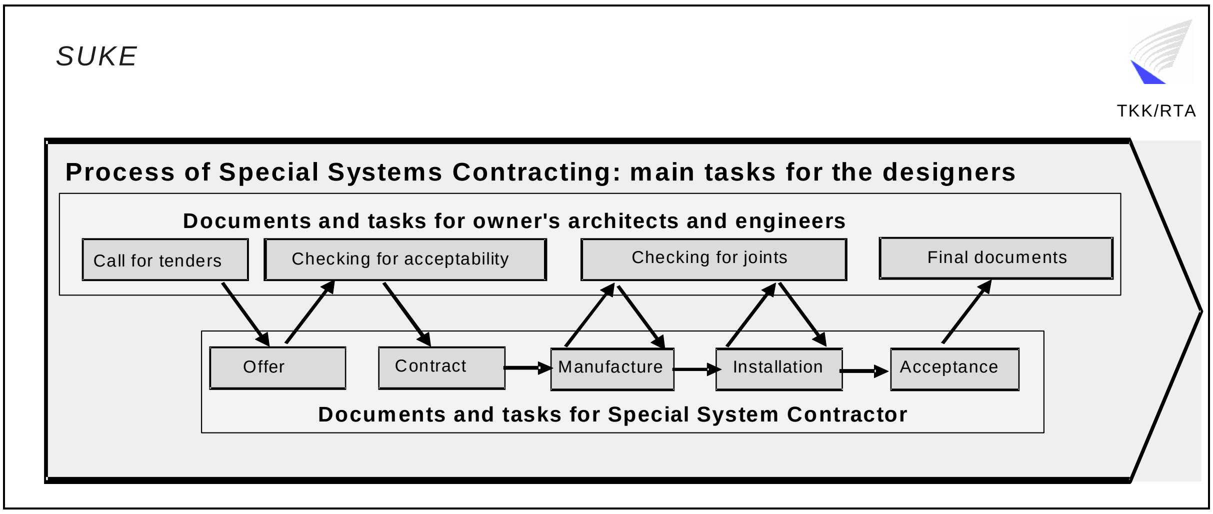

Figure 2. Process description of the special systems contracting (SSC) (FinSUKE).

In the SSC, the main tasks of an owner's architect and engineers are defined as follows:

1. **Create the design documents for the invitation for SSC tenders**
A designer drafts the documents of the call for SSC tenders (the requirements, sketches, instructions etc.) and participates in the preparation of commercial documents. In the preliminary examination of each design package, the definitions and the requirements based on the extensions of the coupled building elements are stated.

2. **Inspect the acceptability of the offered designs**
A designer checks the acceptability of the tender design of each Special System (SS) contractor and performs the comparison of the accepted tender designs.

3. **Participate in the procurement negotiations and the agreement preparation**
An owner's designers participate in the procurement negotiations directing the contractor's design work. A SS contractor's designs are developed into the final level before the signing of the agreement. Thereafter, the solutions of the SS contracts are integrated within an owner's master design and the designs are revised and accepted.

4. **Inspect the production plans of the special system contractor**
An owner's designer checks the compatibility of each SS contractor's production plans. However, a SS contractor has a responsibility for the contents of production plans, but an owner's designer is responsible for the interfaces.

5. **Participate in the inspection of the installation plans in advance**
An owner's designers participate in the inspection of the installation plans before the beginning of the construction work at site. The checking concerns the conformance with the construction and the interfaces.

6. **Check the as-built documents**
As part of the acceptance inspection, an owner's designer checks the final as-built drawings and documents of the system and places the detailed system drawings to the final design documentation of the project.

In the SSC, the responsibilities of building design must be agreed upon early. These significant design responsibilities are taken into account also in the payment schedule for each SS contractor. There are no contractual agreements between SS contractors; their joint participation on a single project is arranged through general contractor-subcontractor agreements. The role of a general contractor is then to manage also all the activities of SS contractors at site.

2.4 Definition of Systems and System Division in the SSC

An abstraction 'system' is determined as an entity, which is independent from other entities, i.e. building elements [4, 5]. The definitions for the term system in the SSC model vary in the literature. At its widest, a system contains the whole building as an individual system. At its smallest, a system includes only, for example, the mounting and planning of a small part of construction work, like concrete reinforcing.

In the FinSUKE model, the SSC is limited to refer only to larger systems where a SS contractor is responsible for the system design, the production planning, and the installation as a functional element of the building in question. The SSC is also limited to refer to entire design packages. A SS contractor's input into the project-specific design of the system element is essential. This differs from the usual CM way of procurement in which a supplier's solutions are included in the final design.

According to the principles of the open building, a building is divided into the systems of the permanent base building (support, shell and core) and the flexible space infills. The flexible space infills are further divided into the interior areas (or departments), the design and the realisation of which are accomplished in accordance with the users' complementary requirements. The fixed spaces are carried out either in connection with the permanent base building or in connection with the flexible spaces (Figure 3).

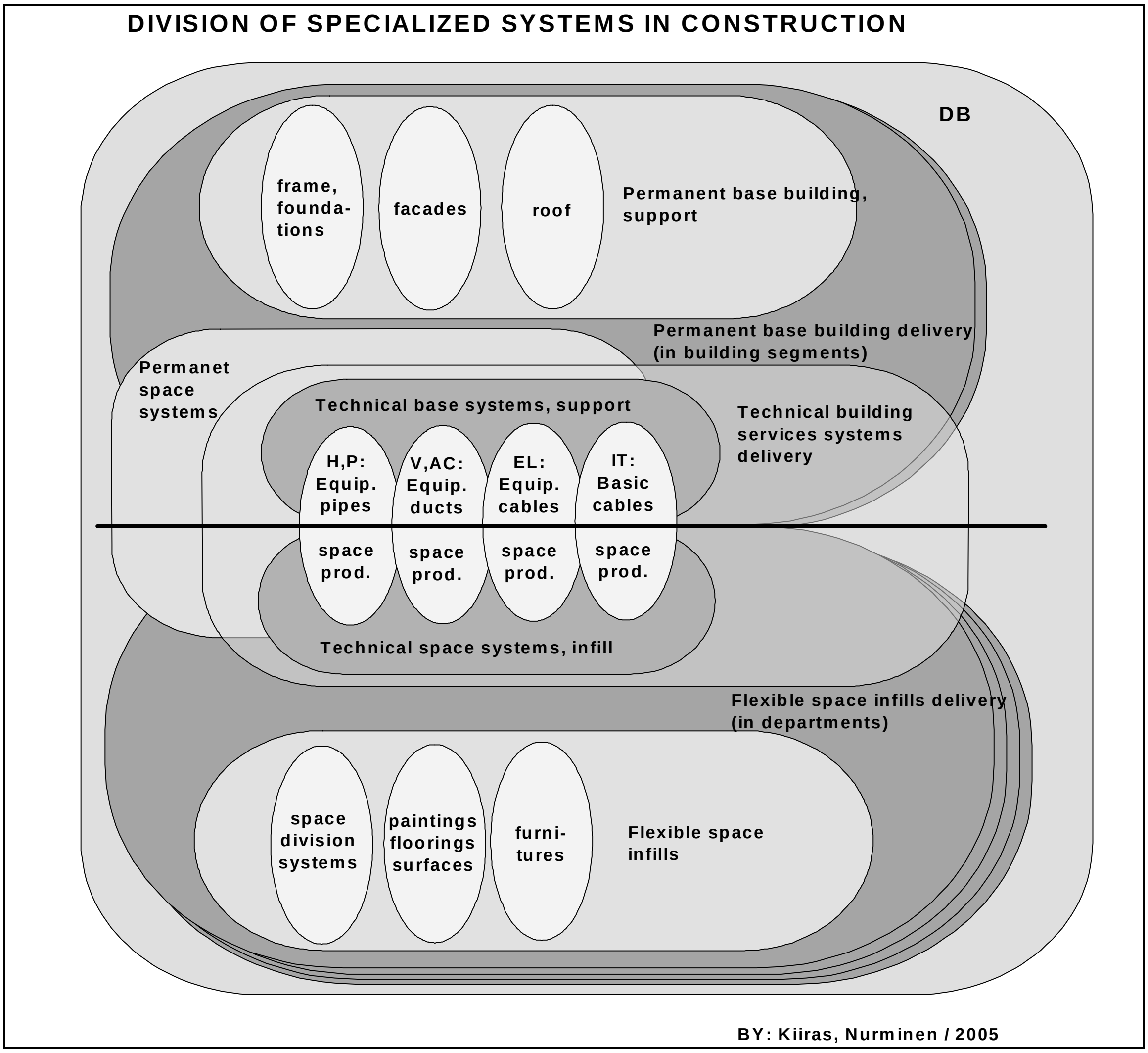

Figure 3. Division of specialized systems in construction (FinSUKE).

Concerning the independence of design and production, the systems are divided **into the five categories:** base building systems, permanent space systems, technical building services systems, flexible space systems and exterior area systems as follows:

- Base building systems (in building segments): ground work and excavations, demolition, foundations and building frame, roof, facades and outer levels,
- Permanent space systems (in building segments): permanent space areas (stairs, entrance halls, auditoriums etc.), space components,
- Technical building services systems: HEVAC systems according to the trades (plumbing, heating, ventilation, cooling, air-conditioning, electricity, information systems etc. separately) **or** technical base systems including central equipment and fixed base system (pipes, ducts and cables) to the border of the interior area (technical core),

- Flexible space systems: separate space areas or departments, HEVAC techniques of the space infills either as their own **or** to be included in the SSC of the space area and
- Exterior area systems: all exterior building area structures, including the HEVAC technical work in the exterior areas.

The SCC of the space infills is carried out by departments, which can be procured as separate units. So the SSC of the space infill contains both the construction and technical design and allows the integration of the production technique with the space parts.

2.5 Design Documents in the SSC Model

In the general FinSUKE model, the three design “as-is” levels are determined for the design documents as part of the call for tenders as follows: 1) final designs according to one solution, 2) “directive” designs or 3) aesthetic, functional and technical requirements. An owner's designers will prepare complete plans according to one solution in design packages, if no other instructions are given [1].

On the basis of the completeness of the design, the invitation for SSC tenders is divided from a level where only the production plans of the system are missing into a level where only needs and requirements are described. According to this “freedom degree” of the design, at the widest each SS contractor is competing on its system and the technical solutions. In addition, the aesthetical, functional and technical requirements as well as the selection criteria are presented in the call for SSC tenders.

In the SSC, a SS contractor’s tender design must be at the level of directive design to prove the conformance with the specifications, the quality of the system and the requirements of the regulations. Furthermore, the integration possibilities of the related systems are secured. In each of the SS contractors’ agreements, the designs are developed into the level of the final designs.

3. CASE Projects and Research Aims

3.1 Building Projects at the University of Helsinki

The University of Helsinki is the largest university in Finland and its scientific base is wide, 11 schools from medical to law and bioscience. The total amount of the students is about 40 000 and the building area is circa 750 000 m^2. The university and its technical department acts as a client and an owner in building and renovation projects. During the last years, the investments in the construction have been 30-50 million euro yearly.

The CM methods are widely used in the university projects because of the flexibility of the method. In addition, an open building ideology, new construction forms, LCC-competitions, partnership contracts and other new methods are being co-pioneered and tested in the projects and, thereafter, during the facility management carried out by University of Helsinki. In the future, one of the aims is to utilize more SSC methods in building projects.

3.2 Analysis of SSC in Case Pilot Projects

The SSC model has been tested in several case projects and the model (described in section 2) was applied to the actual pilot projects. Herein, the results of the analysis of some case projects at the University of Helsinki are summarized as follows.

Learning centre building at Viikki area (Infocenter, completed 1998)

Test scope: A technical specialty contractor was responsible for the design and the construction of the HVAC system. The energy consumption for the first five years was also a part of the procurement competition. Procurement documents: The invitation for tenders was done by functional and technical requirements. The tenders included directional designs and energy consumption calculations. Results: The new method for call for tenders, own designs from all technical contractors, life cycle costs as competition criteria, and low energy consumption.

Medical laboratory building at Meilahti area (Biomedicum, completed 2000)

Test scope: A contractor was responsible for the design, the manufacture, the delivery and the installation of 20 ventilation plants in engine rooms. The properties and the energy consumption of machines were calculated before the contract and tested after the delivery as the complete units. Procurement documents: The invitation for tenders was done by functional and technical requirements. The tenders included the description on the plant and its properties. Results: Life cycle costs and technical properties as competition criteria, machines tested before installing, high reliability on plants and low energy consumption.

Bioscience laboratory building at Viikki area (Biocentre 3, completed 2001)

Test scope: A general contractor was responsible for the design and the construction of the foundations, the frame, the roof and the facades. A technical specialty contractor was responsible for the design and the construction of the HVAC system and also the energy consumption for the first five years was part of procurement competition. Procurement documents: The invitation for the both tenders was done by the outline drawings completed with the functional and technical requirements. The tenders included the directional plans and in technical system contract also the energy consumption calculations. Results: Five different frame solutions for the same architect's outline drawings, five different HVAC solutions for the same frame drawings, developed building frame system and low energy consumption.

Office and library building at Helsinki City centre (Minerva building, completed 2005)

Test scope: A subcontractor responsible for the design, manufacture, delivery and installation of the steel-framed glass curtain wall. Procurement documents: The invitation for tenders was done by the complete drawings according to one solution. The tenders were asked as the contractor's own system with the directional plans and the details. No offers were received. The glass wall was divided and procured in smaller trade parts. Results: SS contractors were not interested in such a difficult and small delivery and this influenced also the master construction schedule.

3.3 Research Aims for Prospective Projects

The research underlying this paper is continuing with new prospective projects as an action research method by piloting all the procedures discovered and developed in the former pilot projects. According to the statements in chapter 2, the hypotheses of the case study of the SSC are initially as follows:

- The supplier of the system is responsible for one specific building system,
- A system division corresponds to the design package division of the FinSUKE model.
- The procurement of building area, permanent structures and spaces are separated.
- A building design is divided in the two phases: the overall design and the realisation design (design development and detailed design).
- The documents for call for tenders are based on system requirements.
- Tenders include directive plans and the attention is paid on the following plans.
- The status of an owner's designers is emphasised.
- The guarantee and the service life objectives of each SS contract are determined separately.
- A construction project can be carried out effectively by dividing it into SS contracts.

Some obstacles for the SSC to become common include the indefinite definitions of the design responsibilities as well as the designers' worry of their tasks not being clear. Also a small number of potential suppliers is slowing down the penetration. An attempt is to reduce difficulties by emphasising the significance of the overall design phase, increase the main designers' consolidation obligation, and extend procurement entities.

The future study aims at solving also these problems, which have appeared in the SSC through the advanced design management. Also the hypotheses, the rules, and the methods that have been presented will be tested in future new construction and renovation projects. The performance based procurement and Best Value Procurement [7] will be tested in some case projects, too.

In addition, the international use of similar methods will be reviewed and then compared with this Finnish way of action. With the help of site visits and research co-operation, it is possible to become acquainted with the use of the special contractors in the international field. Thus, both design management and project management will be enhanced with the help of the SSC model.

4. Conclusions

In the suggested Special Systems Contracting (SSC) model, each SS contractor is responsible for the design, the manufacturing, the delivery, and the installation of the separate building elements. Possibilities for quality competitions and competitions for life cycle deliveries and longer guarantees are created. The SSC model makes it possible to manage the project by independent and causally interrelated entities instead of details.

In the FinSUKE model [1], the SSC is limited to refer only to systems, of which the specialty contractor is responsible for the product design, the specific production planning, and the installation of the system to be a functional and independent element of the building. In SSC the project-specific planning work of a system is an essential part of the delivery. According to the principles of the open building [6] the FinSUKE model divides the building into permanent support elements and flexible space elements.

Thus, one of the main aims is to clarify how both the designers' and the suppliers' know-how can be taken into the best use with the effective SSC. In particular, with the simultaneous analysis of design processes in CM projects and the testing in prospective SSC-cases, the instructions for using the SSC model will be developed. The tasks and responsibilities of project actors during the various stages will be clarified.

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Minimizing Elements of Control of a Construction Contractor

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Abstract

Client control over a construction project is an essential element in the delivery of construction. Construction management is a booming profession in the construction industry. The construction industry also has some stubborn problems to which the industry is trying to find solutions. Some of the problems are poor performance (defective construction, not on time, not on budget, and not meeting the intent of the client), a lack of accountability for problems, a lack of continuous improvement, deteriorating quality of design documents, and a lack of qualified personnel entering the industry. This paper hypothesizes that the problems are being caused by a management/business issue. It uses the example of Ricardo Semler and the transformation of SEMCO, a Brazilian based manufacturing company, from an acceptable company to a very efficient, high performance, successful company by minimizing direction, management, and control. Other successful business practices are used to support the thesis of Semler. The paper proposes that the same approach can be used in the construction industry to minimize the current performance issues. The paper proposes that by minimizing management and subjective decision making by all participants and in all relationships, the construction performance issues can be severely minimized.

Keywords: Minimized control, minimized direction, minimized subjective decision making

1. Introduction

The construction industry is characterized by low performance, sharing of accountability, and the maximization of management [2, 7]. Construction projects are not being completed on time, they are not meeting budget, and they are not meeting the expectations of the owners. Owners cannot identify the source of the problem. Identification of the designer as the problem led to the design-build process where the designer works for the contractor. The inability of the design-build process to meet the client's expectations of performance led to the formulation of the construction manager at risk (CM@Risk) delivery process. There is very little empirical to identify what is causing construction nonperformance [1].

Analysis of the Construction Industry Structure chart (Figure 1) gives some possible clues to why the construction industry has had performance issues. The construction industry has historically been awarded based on low price. The price based environment has the following characteristics:

1. The award is made based on price.
2. Risk is minimized by the client's representative through specifications, management and control.
3. Subjective minimum standards are used for requirements.
4. There is no performance information on contractors and construction systems. Therefore there is no method to identify if a system is an "or equal" to what is specified. This becomes a subjective decision.
5. There are relationships, trust, and maximum information passed between the client's representatives and the contractors. This is a result of subjective decision making of the client's representatives.

There are three major actions that maximize risk. The first is that the client is directing the contractor to bid the lowest possible price or maximize the amount of risk on the project. Note that risk and performance are reciprocal. If the contractor tries to use their expertise to minimize risk, their price will rise, and they will be noncompetitive on the project. The contractors are being directed to not minimize risk using their expertise, but maximize the amount of risk by bidding the lowest possible price.

The second action is that the requirement is based on subjective minimum standards which have no proven correlation with performance. If the requirement is not sufficient, the designer is powerless to rectify it because it is a standard. The third action is that the contractor is being told to do minimal work which is based on subjective standards, and to do things as economically as possible. They are being told that any unforeseen condition is not there responsibility. The contractor is being directed to act in their own best interest, and not in the interest of the client.

The price based environment is creating low performance by giving the low performing contractors the competitive advantage. This creates an adversarial environment by directing the contractor that they have no responsibility to act in behalf of the client. The price based environment then uses subjective minimum standards which have no correlation with performance. The environment is therefore: filled with nonperformers, adversarial, and ambiguous. This environment is inefficient and therefore, nonperforming. It is in this environment that the client is attempting to manage and control the contractor.

2. Hypothesis

Management, control, and inspection are not an efficient way to do business. In the manufacturing sector, lean manufacturing and continuous improvement efforts identified that piecemeal work, incentives, and management, inspection, and control of manufacturing workers and their production lines was inefficient and noncompetitive. This paper proposes that to improve construction performance, clients must minimize management, direction, control, and inspection of the construction contractor. Clients must create an environment that motivates the contractor to do quality control.

3. The Transformation of SEMCO

SEMCO is an example that releasing control can increase efficiency, expertise, and performance. Ricardo Semler, the CEO of Brazil-based manufacturing company SEMCO, implemented a formal structure within his company which shifted control of work to employees who performed the work. This example shows how SEMCO thrived using these practices. It is a potential solution for the construction industry to solve performance issues.

The origins of SEMCO were established in 1954 by Antonio Curt Semler, who patented a centrifuge for separating oils, and started the small machine shop called Semler & Company. Within a short while, the company became a $2 million (gross revenue) a year business. Around 1960, the company formed a partnership with two British marine pump manufacturers which transformed SEMCO into the major supplier of the Brazilian ship building industry. As time progressed, Ricardo Semler, son of Antonio, took charge of the company.

After firing two-thirds of his father's senior managers, and after twenty years of changing SEMCO's business practices, the company now has gone from the founders' peak of $4 million to a $212 million in annual revenue in 2003. In "The Seven-Day Weekend", a book by Ricardo Semler, Ricardo explains that the title "The Seven-Day Weekend" as SEMCOs' way of getting out of control business and back to the companies core competencies [8].

SEMCO's policy was to remain a premium player in each of their markets. SEMCO's products were not the lowest priced products or services. Premium products attract intelligent clients who understand risk and understood the price of minimizing risk. SEMCO moved away from clients who did not understand risk, who therefore were low bidding buyers.

SEMCO strove to put employees in a continuous improvement environment. The key concept that each employee was taught first was to understand is to avoid routine. Once they understand this concept, SEMCO then relinquishes control over the employee. In order to move a business or organization ahead, SEMCO directed the minimizing of management and control. SEMCO allowed workers to align their individual goals with the company goals. SEMCO allowed employees to find the optimal job for themselves in the company. They'll let their new employees to wander around the company until they've found out what it is they want to do. Each employee has a special talent. Many companies throughout the world find out who their least productive employees are and immediately give them the boot. SEMCO treats every individual as a unique person who could help the company in a different way. If an employee isn't performing as they should in a particular area of the company, they're not fired. Instead, they're free to discover for themselves where their talents can be used for the company's benefit. Having employees measure, analyze, and control themselves, and dictate how their strengths and talents can assist the company to be successful. By doing this, managers and workers alike respect each other's differences and it helps to create a less stress-free and productive work environment.

Other practices at SEMCO which showed a release of control include:

1. No formal organizational chart.
2. No rules for office organization or dress code.
3. Removed security checks.
4. Delegated to the lowest level.
5. Workers make their own decisions, operational manuals thrown out.
6. Profit sharing across all employees.
7. Employees help managers make decisions.
8. Memos had to have conclusion as the subject and could only be one page long.

SEMCO's practices identify the following concepts:

1. Only stay in business in the best areas.
2. Minimize the management and control functions.
3. Buy and sell based on value.
4. Force everyone to do quality control.
5. Release control to the workers (contractors in the construction industry).
6. Force everyone to measure themselves.
7. Rely on logic instead of bureaucratic systems.
8. Minimize communication.
9. Make people accountable.

This paper proposes that the same concepts used by Ricardo Semler can be used to minimize the problems in construction. Many of the same principles were also used by Jack Welch in the transformation of GE to a highly successful company [9]. Rudy Guiliani used many of these concepts to transform NYC into a safer city. Deming [4], Ohno [6], and Womack [10], proposed the same concepts in continuous improvement, the statistical control process, just in time, quality control, and lean manufacturing. The authors propose using the SEMCO concepts in the following ways:

1. Clients should only hire the best contractors.
2. Management and control of the contractor by the client, and control of the subcontractors by the general contractor should be minimized.
3. Communication between the client and client representative and the contractor should be minimized.
4. Contractors should quality control their own work.

5. Contractors should be at risk and minimize the risk.
6. Contractors to measure their performance.
7. Anything counterproductive should be minimized.
8. The client's representatives should be accountable for their actions as well as the contractor's personnel.
9. Contractor key personnel should be interviewed and rated as well as the general contractor.

4. Movement to Best Value Environment

In order to implement some of these concepts, the construction delivery environment must be changed. The structure of the current low-bid environment has the following practices which immediately run counter to the proposed concepts:

1. The contractor is directed to maximize instead of minimizing risk.
2. The client's representatives minimize risk through management and inspection.
3. There is not trust, no transfer of risk, and management and control.
4. Clients hire the lowest performing contractor instead of the highest performing.
5. Communication between client and contractor is maximized instead of minimized. The specifications have to be more detailed, more complete, and the contractor is also managed.
6. Contractors cannot quality control their own work. If they do, they will not be competitive, and if they disagree with the client's representative, they will be overridden. Minimum standards do not lead to effective quality control.
7. Contractors are not at risk as long as they listen to the client's representative.
8. There is no performance information of contractors or key personnel.
9. Specifications and subjective decision making override logic.
10. Client's representatives are not accountable. There is no performance information on the client's representatives. The only way to get the client's representative to be responsible is to prove negligence.

Figure 1: Construction Industry Structure (CIS)

The major difference between the Price Based environment and the Best Value environment is that the contractor minimizes the risk instead of the client's representative. Accordingly, the following items must occur:

1. The risk is transferred to the contractor.
2. The contractor uses high performance expectations instead of minimum standards to do their work.
3. The contractors will quality control their own work because they now have the responsibility to minimize the risk.
4. Management and inspection by the client's representative is no longer required. Instead, quality assurance must be practiced.
5. Performance information must be used on all critical components allowing price and performance or best value can be used for the selection process.
6. General conditions which are punitive in nature and are designed for contractors, who are not acting in the best interest of the client, can be eliminated.

5. Obstacles in Changing Environments

Obstacles facing clients in implementing a process that releases control include:

1. What to do with the professionals who have made it their livelihood to manage and control and design processes and standards that are required in this controlling environment.
2. Finding a process which minimizes the risk of the client by selecting the best possible contractor option to minimize the construction risk.
3. How to minimize the relationships that spread risk and override performance information.
4. How to educate their personnel who have been taught the concepts of management, control, and inspection.
5. To change the overall concept that management is the solution to problems.

In the latest Construction Owners Association of America (COAA) identified that 58% would hire construction managers from the beginning of design throughout the construction process. Design-build (DB) and construction management at risk (CM@Risk) were created to minimize construction problems. The differential with the design-bid-build process is merely the transfer of risk. However, DB and CM@Risk can still go awry if the client is represented by a professional who wants to manage and control. Clients have to be educated that the construction delivery process is no different than any other delivery process and can be optimized using business best practices of outsourcing, quality control, just-in-time, and the minimization of management and control.

6. Best Value Procurement

The US Federal Government has identified that the method of procurement of services using the price based, specification, and management and inspection is inefficient, keeps the risk with the government, and does not result in a better price or performance [4]. Several federal agencies (Federal Aviation Administration (FAA), US Army Medical Command (Medcom), US Coast Guard (USCG)) have been testing a best value procurement system, the Performance Information Procurement System (PIPS), developed at Arizona State University. The same procurement system has been tested by the states of Utah, Hawaii, Georgia, and Wyoming. Non-government clients who have tested the process include Harvard University, United Airlines, Motorola, Honeywell, Intel, IBM, and Boeing. The process has the following history [4]:

1. Tested over 10 years (1994-2005) on 400 projects ($260M of construction procurement).
2. 98% performance (on-time, no contractor generated change orders, high customer satisfaction)
3. Consistent results over the ten years.
4. Minimizes construction management, control, and inspection by up to 80% of the price based processes.
5. Biggest resistance was from non-value added functions and nonperforming contractors who felt that their livelihood was being threatened.
6. Being introduced for implementation tests in the Netherlands, and introduced into the UK and Finland education/research groups.

The test results are similar to the SEMCO results. The authors propose that construction is similar to other processes and problems of inefficiency and nonperformance should be solved using the same best practices.

7. Performance Information Procurement System (PIPS)

The PIPS best value process differs from other processes in the following ways [4]:

1. The process minimizes technical decision making in the selection of the best value contractor. There is no technical evaluation.
2. The process using past performance information on all critical entities in a contractor's bid.
3. The contractors are forced to identify, prioritize, and how they will minimize the risk on the project in the competitive bid process.
4. The process is "blind." Value of relationships is minimized.
5. The process uses an artificial intelligence system that compares all the alternatives and identifies the best value.
6. The best value is forced to minimize the risk before they are awarded the project.
7. The contractor, who the best value process identifies as the best performer, looks at the intent of the client, and proposes how they will minimize the risk.
8. The contractor does all documentation during the construction.
9. The contractor takes control of the project and makes the client's representatives, users of the future construction, and procurement personnel responsible to cooperate in a timely manner.
10. The performance of the entire group is rated at the end of construction.

PIPS uses the concepts in the SEMCO transformation. The authors propose that the client, contractor, subcontractors, and client's representatives be viewed as a large company. The results of PIPS are as successful as the SEMCO transformation using the same principles.

A recent survey was taken showing that there are no significant differences between the contractor-performed acceptance data and concomitant highway agency-performed verification data [5]. A consensus of random states took part in the survey. The study proved to show that the performing contractors testing seemed to be more accurate than that of DOT officials. Not only that, but both the DOT and hired contractors felt that the overall construction quality and meeting the schedule was evident by having contractor performed quality control. The only concern, stressed by the DOT, was that the DOT felt they had to have trust in the contractor [5]. The authors propose holding the contractors responsible for the construction, very similar to bonded warranties.

The prevailing practice in construction is still to manage and control the contractors. Of the over 200 construction management education/research programs in the United States, only one unit has an education/research program that assists clients to maximize construction performance by minimizing construction management/inspection.

A concentrated effort is being made to take the education/research to the largest construction programs in each sector of the country. The first prototype was at Central Connecticut State University. The second university will be Colorado State University, and the third will be Florida International University.

8. Conclusion

Ricardo Semler and SEMCO used concepts which minimized management and control to increase their business tenfold. SEMCO had many of the same traditional control mechanisms that are found in today's construction industry. The authors identified the concepts and discovered that the same concepts were already being tested in the construction industry. The same concepts have been proposed by Deming, Taiichi Ohno and James Womack, and Jack Welch in the manufacturing industry. If these concepts are correct, it identifies the major sources of construction nonperformance being the client's inability to identify performing contractors, inability to release control to the contractors, and the inefficiency and nonvalue added functions of construction management. The authors are proposing that the construction industry must move from the price based to the best value environment. Efforts to maximize the performance of construction in the price based environment have been unsuccessful and inefficient. The authors recommend that construction research groups consider changing their focus from optimizing contractor operations in the price based environment to turning the control of construction to contractors, minimizing the use of construction management, and educating construction clients on the potential of the changing from a price based to a best value environment. The authors propose that construction education consider teaching that construction management belongs with the contractor who is awarded a construction project, and should not be a third party or representing the client.

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Appraisal of Subcontractor Performance – Criteria and their Importance

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Abstract

Several influential industry reports have pointed out that a decline in construction quality and productivity could be attributed to the performance of subcontractors who are entrusted to complete majority of the actual works, yet subcontractor performance appraisal is a much neglected subject in construction. A review of the current practice reveals that only some public clients have been keeping track on subcontractor performance based on certain vague criteria. To facilitate subcontractor registration, management and/or selection, an equitable and reliable framework for appraising subcontractor performance would be indispensable. This paper reports the findings of an empirical study conducted in Hong Kong focusing on the criteria for used in subcontractor performance appraisal and their importance. The paper begins by identifying a list of criteria relevant to and suitable for appraising subcontractor performance. Criteria having a high significance to subcontractor performance appraisal are highlighted. Finally, a strategy for scrutinizing the information is proposed to minimize the potential bias induced by the use of qualitative information.

Keywords: Construction subcontractors, performance appraisal, evaluation criteria

1. Introduction

Subcontractors play a significant role in ensuring the success of construction projects, as up to 90% of the total project value are entrusted to various subcontracting firms [1]. Despite that, to survive in a highly competitive market, many lower tier contractors are tempted to recover their desired profit by cutting corners. This could result is a decline in productivity and quality [2]. A general dissatisfaction with the current practices of subcontracting [3] has prompted the introduction of various measures that aim at enhancing the performance of subcontracted works. Examples of these include subcontractor registration schemes [4,5,6] and mandatory disclosure of subcontracting firms at the time of bidding.

Other initiatives include restricting the percentage of work to be subcontracted especially for works of significant importance or where testing, supervisory or performance control is difficult. To promote a non-confrontational relationship, researchers [7] proposed extending the partnering arrangements to cover main contractor and subcontractors so as to help improve the co-ordination and management of subcontracted works effectively. Certain clients now insist on partnering as one of the requirements for contractor selection in their projects [8,9].

While those initiatives may reduce the possibility of recruiting incapable subcontractors, the main contractor and project team seldom measure the performance of subcontractors appointed in a systematic manner [10]. In view of the growth in the size and complexity of subcontracts, there is a need to monitor subcontractor performance more closely [11]. The development of a practical and objective framework for subcontractor appraisal is, therefore, relevant to the current trend and needs of the industry.

The desire to improve the practice of subcontractor performance appraisal has aroused a series of research in Hong Kong. Amongst that, an empirical survey was conducted to examine the importance of criteria for subcontractor appraisal. In this paper, the criteria used by various organizations in appraising subcontractors are first outlined. It is then followed by a brief introduction to the research method. The importance of decision criteria is presented, and the most important subcontractor appraisal criteria are discussed. Finally, a method for evaluating the decision criteria is proposed.

2. Existing Subcontractor Appraisal Models

An extensive literature review and web search unveils the existence of a several established subcontractor performance appraisal models around the globe. These include the models developed by the State of Wisconsin, South Carolina State Government, Los Alamos National Laboratory (LANL), and Fermi National Accelerator Laboratory (FNAL). As the emphases of these models are not the same, there are slight variations in the criteria employed.

2.1 State of Wisconsin's Model

The Wisconsin model [12] is used for appraising the performance of contractors and subcontractors involved in projects commissioned by the State of Wisconsin, USA. The appraisal mainly focuses on (i) schedule; (ii) quality; (iii) cost; (iv) safety; (v) relationship; (vi) communication; and (vii) documentation. These criteria are generic to all contractors and subcontractors, and all criteria carry equal weighting. Compared with other available models, guidelines and procedures provided in this model are by far the most comprehensive. Detailed definitions on the ratings and performance indicators are available, while the guidelines are designed in question form in order to stimulate the thinking of assessors when reviewing the performance of subcontractors.

2.2 South Carolina State Government's Model

The key criteria adopted by the South Carolina State Government for appraising their contractors and subcontractors [13] are very similar to the Wisconsin model. Despite that, this model is rather primitive when compared with that of the State of Wisconsin, as the definitions of the criteria and factors to be considered when completing the report are not clearly specified in the model. Different assessors may, hence, have different interpretations on the criteria and this could affect the objectiveness of the model. A major feature of the South Carolina model is that assessors are required to enter not only the rating but also the weighting for each indicator to reflect its importance. However, weightings are assigned by assessors after discussing with subcontractors, and this could give rise to controversial and biased decisions. The difference in yardsticks renders the comparison among subcontractors difficult if not impossible.

2.3 Los Alamos National Laboratory's Model

The LANL model [14] is designed for measuring the performance of subcontractors who are engaged in the environmental restoration projects of the Laboratory. The criteria adopted in the LANL model include: (i) compliance with planned schedule; (ii) submittal of administrative procedures; (iii) deliverables; (iv) notification of anticipated delays of regulatory deliverables; (v) thoroughness and accuracy of work; (vi) quality program implementation; (vii) compliance with environmental/waste management regulations; (viii) effectiveness/communication; (ix) teamwork; (x) adherence to cost estimate; (xi) adherence to site-specific health and safety plan/health & safety plan/regulations; (xii) occurrence of imminent safety or health incidents or serious safety or health incidents; and (xiii) lower-tier subcontractor safety performance. Comprehensive guidelines and procedures are provided in LANL model. For instance, detailed definition for each criterion and rating is stipulated to avoid possible misinterpretation. While weighting is not considered in this model, assessors have to enter the rating for each criterion to obtain the total score relative to the norm. To increase the transparency of the appraisal process, subcontractors can review and comment on the relevancy and accuracy of the performance report.

2.4 Fermi National Accelerator Laboratory's Model

FNAL is a laboratory specializing in high-energy physics research, and the FNAL model [15] is therefore designed for evaluating the performance of this type of subcontractor. However, the criteria *viz.* (i) business relations; (ii) management of key personnel; (iii) schedule; (iv) cost control; (v) health and safety; and (vi) performance/quality of works, are equally applicable to construction subcontractors. The criteria carry equal weight in the FNAL model. Furthermore, brief definitions on the criteria and ratings are given despite more details on the procedures and definitions of criteria could have been provided to improve the fairness of appraisal.

2.5 Environment, Transport and Works Bureau's Model

Although there is yet to be a subcontractor appraisal model in Hong Kong, a framework for monitoring the performance of main contractors [16] has been developed by the Environment, Transport and Works Bureau (ETWB). The ETWB model examines the: (i) progress; (ii) site safety; (iii) resources; (iv) design; (v) attendance to emergency; (vi) organization; (vii) general obligations; (viii) industry awareness; (ix) workmanship; and (x) environmental pollution control. While these criteria are used for assessing the performance of main contractors, it is worth examining whether they can be applied to subcontractor appraisal.

3. Subcontractor Appraisal Criteria

In order to formulate a common set of performance appraisal criteria for the subsequent study, criteria used in the models described above are summarized in Table 1. Based upon the criteria of the ETWB model, other criteria appeared in the established subcontractor appraisal models including "adherence to cost estimate", "relationship" and "communication" are added.

Table 1: Criteria used in various subcontractor appraisal models

Indicator	*State of Wisconsin*	*South Carolina State Government*	*Los Alamos National Laboratory*	*Fermi National Accelerator Laboratory*	*Environment, Transport and Works Bureau*
Workmanship	✓	✓	✓	✓	✓
Progress	✓	✓	✓	✓	✓
Site safety	✓	✓	✓	✓	✓
Environmental pollution control	×	×	✓	×	✓
Organization	✓	✓	✓	✓	✓
General obligations	×	×	×	×	✓
Industry awareness	×	×	×	×	✓
Resources	×	×	×	×	✓
Design	×	×	×	✓	✓
Attendance to emergency	×	×	×	×	✓
Attitude to claims	×	×	×	×	✓
Adherence to cost estimate	✓	✓	✓	✓	×
Relationship	✓	✓	✓	✓	×
Communication	✓	✓	✓	×	×

Legend: ✓ *= Same or similar indicator is adopted in the assessment model concerned*
× *= Same or similar indicator is not adopted in the assessment model concerned*

As shown in Table 1, "workmanship", "progress", "safety" and "organization" are adopted by all models for assessing subcontractor performance. The Wisconsin, South Carolina, LANL and FNAL models, however, do not put particular emphasis on "general obligations", "industry awareness", "resources", "design", "attendance to emergency", and "attitude to claims". Having considered the peculiar situation of Hong Kong, virtually all identified key criteria were considered to have a high potential for use in appraising subcontractors except for "design" and "adherence to cost estimate" (Table 2).

Table 2: Suitability of subcontractor appraisal criteria

Indicator	*Suitability for further study*	*Reason*
Workmanship	✓	This is the common criteria appeared in all reference model.
Progress	✓	This is the common criteria appeared in all reference model.
Site safety	✓	This is the common criteria appeared in all reference model.
Environmental pollution control	✓	As subcontractors are the parties that actually carry out the works, their strict compliance of the relevant contractual requirements or regulations is critical in protecting the environment.
Organisation	✓	This is the common performance indicator appeared in all reference model and hence should be adopted in the questionnaire survey
General obligations	✓	This criteria does not appear in the subcontractor assessment models of the US. The reason behind may be that subcontractors normally concentrate their effort on the works only while compliance of general obligations rests with main contractors. However, this is not the case in Hong Kong situation. The subcontractor has to comply with the general obligations such as the cleanliness of site, care of utilities, etc. in executing the sub-contracted works.
Industry awareness	✓	This criteria does not appear in the subcontractor assessment model of the US. However, in order to encourage the subcontractor in providing more training opportunity for the trainee craftman as well as the care and welfare of workers, this criteria should be included.
Resources	✓	The resources of the subcontractor directly affect the progress of the works and hence should be equally important as or even more important than the resources of the main contractor. If resources are considered as an indictor for the performance of a main contractor, there is no reason why it should not be considered alike in assessing the performance of a subcontractor.
Design	×	The client normally does not require subcontractor to design permanent works in Hong Kong.
Attendance to emergency	✓	This critieria is critical as subcontractors are required to respond to emergency works as needed to avoid possible delays and disruptions.
Attitude to claims	✓	This criteria is important when partnering approach is not adopted. The attitude of the subcontractor in claiming additional cost could affect the final contract sum as well as the administration cost borne by the client.
Adherence to cost estimate	×	In Hong Kong, as the clients normally rely on consultants to prepare the cost estimation, this indicator is less important to subcontractors.
Relationship	✓	It appears that partnering will become a trend for construction projects in Hong Kong, it is worthwhile including this criteria for further consideration.
Communication	✓	Good communication is essential to the success of construction projects.

Legends: ✓ *= The indicator is recommended for further study in the sub-contractor assessment model*
× *= The indicator is not recommended for further study in the sub-contractor assessment model*

4. Research Methodology

A questionnaire survey was conducted to establish which criteria are more important to subcontractor performance appraisal in Hong Kong. Based upon the 12 key criteria as shown in Table 2, a total of 29 sub-criteria were identified for the questionnaire survey. Respondents were requested to express their perception on the importance of the 29 detailed criteria through a 5-level Likert scale, with 1 representing "very low" importance and 5 indicating "very high" importance.

4.1 Sample Frame

Since the criteria are used for appraising subcontractors, it is unrealistic to assume the views of the main contractors would adequately reflect the concerns of subcontractors. On the other hand, as the clients and consultants may play a less predominant role in subcontractor appraisal (as domestic and specialist subcontractors are employed by main contractors instead), the collective views of the clients and consultants should reflect their position as a policy enforcer.

Random samples were drawn from the three stratified sample groups of client/consultant, contractor and subcontractor. In this study, a sample size of 100 was set for each of the three stratified sample groups. A total of 35, 33 and 24 valid replies were received from the client/consultant, contractor and subcontractor groups respectively, representing an overall response rate of 30.7%.

4.2 Method of Analysis

The 'mean score' method [17] was adopted for analysing the collected data. The mean score (MS) for each indicator was computed by the following formula:

$$MS = \frac{\sum (f \times s)}{N} \qquad (1 \le MS \le 5)$$

where s = score given to each criterion by the respondents and ranges from 1 to 5
f = frequency of responses to each rating (1-5) for each criterion
N = total number of responses concerning that criterion

The rank order, in descending order of importance, of the 29 subcontractor performance appraisal criteria was determined by comparing the individual mean score.

5. Results and Discussions

Table 3 summarizes the mean score and ranking of each subcontractor performance appraisal criterion. It is apparent that the most important criteria include: “standard of workmanship”, “action taken to mitigate delay”, “communication”, “identification of and responsiveness to problems”, and “provision and maintenance of work environment”.

Table 3: Importance of subcontractor performance appraisal criteria

Performance Criteria	*Level of Importance*					*Average Score*	*Rank*
	Very low (1)	*Low (2)*	*Moderate (3)*	*High (4)*	*Very high (5)*		
Standard of workmanship	3	0	17	42	30	4.04	1
Action taken to mitigate delay/catch up with programme	2	3	17	45	25	3.96	2
Communication	0	5	21	39	27	3.96	3
Identification of and responsiveness to problems	0	4	24	41	23	3.90	4
Provision and maintenance of work environment	3	3	28	24	34	3.90	5
Coordination of contractors	1	2	24	48	17	3.85	6
Suitability of method and sequence of work	3	1	22	47	19	3.85	7
Standard of materials or equipment supplied	3	3	22	44	20	3.82	8
Adequacy of site supervisory staff	1	5	25	42	19	3.79	9
Compliance with statutory requirements	2	3	26	42	19	3.79	10
Adequacy of labour resources	2	2	24	50	14	3.78	11
Achievement in progress	2	4	25	46	15	3.74	12
Care to general public	2	4	27	42	17	3.74	13
Care of works	1	3	31	42	15	3.73	14
Provision and maintenance of plant	3	4	29	35	21	3.73	15
Coordination with subcontractors	1	5	29	41	16	3.72	16
Adequacy of material resources	2	2	31	43	14	3.71	17
Reasonableness of monetary claims	3	5	32	30	22	3.68	18
Adequacy of planning	0	8	25	47	12	3.68	19
Adequacy of plant resources	0	7	31	39	15	3.67	20
Action taken to remedy non-compliance	1	6	30	40	15	3.67	21
Adequacy of programme	4	1	28	48	11	3.66	22
Reasonableness of extension of time claims	3	6	33	30	20	3.62	23
Compliance with non-environmental enactments	2	4	35	38	13	3.61	24
Standard of temporary works	3	7	28	40	14	3.60	25
Compliance with environmental enactments	1	8	35	34	13	3.55	26
Adequacy of notice for inspection of works	1	4	38	42	7	3.54	27
Adequacy of pollution avoidance measures	1	7	40	28	15	3.51	28
Care and welfare of workers	4	6	46	27	9	3.34	29
Cleanliness of site	2	13	38	32	7	3.32	30
Training of apprentices, graduates and craftsmen	9	7	34	31	11	3.30	31

Standard of workmanship: From the client's perspective, good standard of workmanship can ensure the designed life of the services; minimize the costs on maintenance; and reduce future disruption to the services caused by the repairs. In the ETWB model, poor workmanship results in a "poor" overall performance automatically and the performance report will be rated as "adverse". As subcontractors are the party who perform the construction works, their standard of workmanship is of paramount importance. The contractors and subcontractors consider good standard of workmanship can enhance their goodwill and hence result in greater opportunities to new jobs.

Action taken to mitigate delay/catch up with programme: For public schemes, delay in project completion would inevitably cause social disruption. However, any delay in private developments would mean postponement in sale and hence a financial loss due to extra interest on loan capital. The contractors and subcontractors also see this as an important criterion as liquidated damage and poor performance report will be resulted from any delay project completion.

Communication: Good communication can minimize misunderstanding, develop good relationship and improve productivity of works. While contractors may be in a more suitable position to determine whether subcontractors have any "communication" problem which could affect the project outcomes, communication with the client and the project team is also needed in a multidisciplinary environment. Therefore, it may be a good practice for both the contractor as well as the client/project team to assess this important criterion.

Identification of and responsiveness to problems: Problems may grow if they are not identified and addressed promptly. Being the one who is responsible for the actual work, subcontractor are expected to keep the project participants informed of the potential problems and propose solutions to prevent any possible delays and reworks. The ability of subcontractors in resolving problems is the most obvious means to determine the effectiveness and efficiency of their organization. Obviously, problems cannot be identified early and solved promptly without good communication, supervision and executive authority of the subcontractors.

Provision and maintenance of working environment: In recent years, continuous and considerable effort has been made by the government and the industry to promote site safety via legislation, education and upgrading safety requirements. It appears that all parties including subcontractors acknowledge the importance of site safety now. All construction stakeholders understand that site safety brings about indirect benefits which will eventually contribute to the direct ones by creating a better working environment and reduced risks.

6. Conclusions

In this paper, a list of criteria pertinent to subcontractor performance appraisal has been established. The results of a survey conducted in Hong Kong indicate that "standard of workmanship", "action taken to mitigate delay", "communication", "identification of and responsiveness to problems", and "provision and maintenance of work environment" are the most important criteria for appraising subcontractors. It is necessary to ensure that these criteria are carefully incorporated in the subcontractor performance appraisal model.

Despite that, the most important criteria like the "standard of workmanship" may not be very easy to measure even when guidelines or procedures exist. As a result, expert judgment is inevitable in establishing the benchmark. To improve the fairness and transparency of subcontractor performance appraisal, the evaluation must be founded on unequivocal yardsticks instigated by the objectives and expectations of the client.

In recent years, certain organizations, such as the US Department of Commerce, Canadian Government, etc., has begun to realize the benefits of the Balanced Scorecard and Gap Analysis techniques and apply these methods to various kinds of performance-based appraisal schemes including business, environment, quality, etc. The research team is exploring the full potential of these techniques in promoting the objectiveness and transparency of subcontractor performance appraisal, and the results of analyses will be reported in due course.

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Delivery Systems as Service Processes in Building Projects

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Abstract

This paper discusses the challenges in examining project delivery systems as service processes. Delivery systems are categorised in four different ways according to the requirements of clients. Certain clients prefer conventional delivery systems and enter into the main construction contract with or without nominated sub-contractors. Project management and design-build systems have gained a significant market-share, too. This paper focuses on project development systems as there is a demand for developing after-sales services which guarantee a long-term profit for investors. The issues for clients in choosing as well as the issues for service providers in offering total service packages, are briefly described. A case study of a market-financed rental housing project is presented as an example of how after-sales services can be included in the service process of a building project.

Keywords: Project delivery system, building procurement system, service process, client, project development, design-build, construction management, building construction, Finland

1. Introduction

In Finland a great deal of effort has been made to develop the building process [1]. The objective has been to promote the internal effectiveness and international competitiveness of Finnish construction industry. In particular, the employment of a design–build approach has been promoted as a means of encouraging innovations by combining the design and production planning sides [2]. At the same time, the use of construction management approaches has increased. Nevertheless, the traditional systems i.e. the main contracting with nominated sub-contractors, have continued to dominate the market because clients want the ability to influence the design [3].

On the other hand, there are clients who are not interested in how the building project is organised. The trend in the real estate market, now that foreign investors are also entering Finland, is that clients consider a built project as one alternative way of investing among existing real estate or other alternative investment options. The major players are forced to enlarge their service supply both to make sure that users' demands are met and to help investors achieve the expected profits.

Major Finnish construction companies like YIT Rakennus Oy, NCC Finland Oy, Skanska Oy and SRV Viitoset Oy have created their own business park concepts to satisfy the demand of those investors interested in commercial properties. A necessary service element has been to commit at least the main user to the planned working environment. Some insurance companies have also utilised project development systems in rental housing production to spread and lower the investment risk.

New services included in built projects are constantly being explored, for example, to guarantee the rest value of the premises as well as guaranteeing the premises are kept attractive for users. However, the problem seems to be that clients are not convinced that the increased added value is worth paying for. The delivery systems are commonly difficult to demonstrate as clear service processes because the terms used in the field are vague. For example, the largest office building project in Helsinki Kamppi is organised and presented with a construction management approach, but the contractual relationship with the city of Helsinki is based on design-build responsibility.

It is hoped this paper will help to analyse different delivery systems from the service process perspective. The aim is to achieve a holistic view of the services included in building projects and thus to give ideas to develop service management. The objective is to promote the understanding of the overall service business in building projects.

2. Traditional Analysis Methods for Delivery Systems

Project delivery system is defined as a comprehensive process to deliver a built project to the owner [4]. However, the procurement system could be defined as the most appropriate method of procuring according to client choice after the decision to build [5]. The choices to form a building procurement or delivery system is varied and categorising them difficult [5].

Traditionally, procurement methods have been analysed according to the responsibilities, the contractual relationships and, less frequently, the ways of inviting tenders. Besides the design and supply, the responsibilities concern the pricing methods, as well as the preparedness of design documents. The vast variation of alternative options stems from the great number of client decisions.

Together with the task allocation, procurement systems can be described through customer-orientation with the help of information transfer and co-operation [6]. The ability to respond to risks and to reach the set project aims can provide selection criteria for procurement options to promote positive and hinder negative project outcomes [6].

When the service providers offer their own concepts, analysis of differences between the delivery systems play a key role. In the international market the one-point-responsibility seems to be significant for design-builders [7]. In project management methods the co-operation with the client both in design and in procurement stage is emphasized [8]. This form of categorising is flexible as all kinds of demanded services are included in existing delivery systems and new service packages have been created from the basis of old ones.

3. Clients in Building Project Business

3.1 Definition

"Client" in this paper is considered to be an organisation that hires professional services from the Finnish building market such as investors as well as public and private owners, who decide how to procure a building project. "Service" is a tailored solution for the client who participates in the service production process [9]. So it is essential to enter into the client's decision-making and, preferably, before the decision to build new facilities is made. Certain services are assumed to be included in defined delivery systems and certain services are self-evident in all of them.

3.2 Operating Environment

The Finnish construction market is characterised by its small size. There are fewer than ten large construction companies with the ability to take on the economic risk of larger building projects. The other companies are small and medium size firms. Architectural and engineering companies are small firms without the resources to take on at-risk responsibility for project management. Few differently oriented project management consultants are available.

In principal, it has been impossible for the firms to build a competitive advantage based on technological benefit or lower cost in built projects [10]. In other words, it has not been possible to differentiate the core product. Individual successes have been based on convenient site location or personal relations. It seems that functioning core products are available in the field, but because long-term relationships have not become common, there are currently no fully functioning total service offerings.

Issues in the operating environment in the building project market are the following:

- The whole building sector is fragmented and the heterogeneity is challenging to manage.
- The core product is less often the reason for dissatisfaction than the surrounding services. Investing in services has not paid off.
- The running costs of working environments are not reasonable and they are not easily calculable apart from in apartment buildings.
- Premises should be suitable for changing purposes.

- The difficulty is to influence the client's decisions-making by offering attractive ways to organise the projects. Traditionally, what is offered is what is demanded, but in more hi-tech industries the firms have been more innovative and forward-looking.

3.3 Triangle of Investor, User and Service Provider

It is obvious that the competitive edge in offering building project lies in the services. In most cases, the service provider is required to manage the expectations of the owner as well as the users and integrate them (Figure 1). The triangle has to be taken into account when developing the service management strategy for project development.

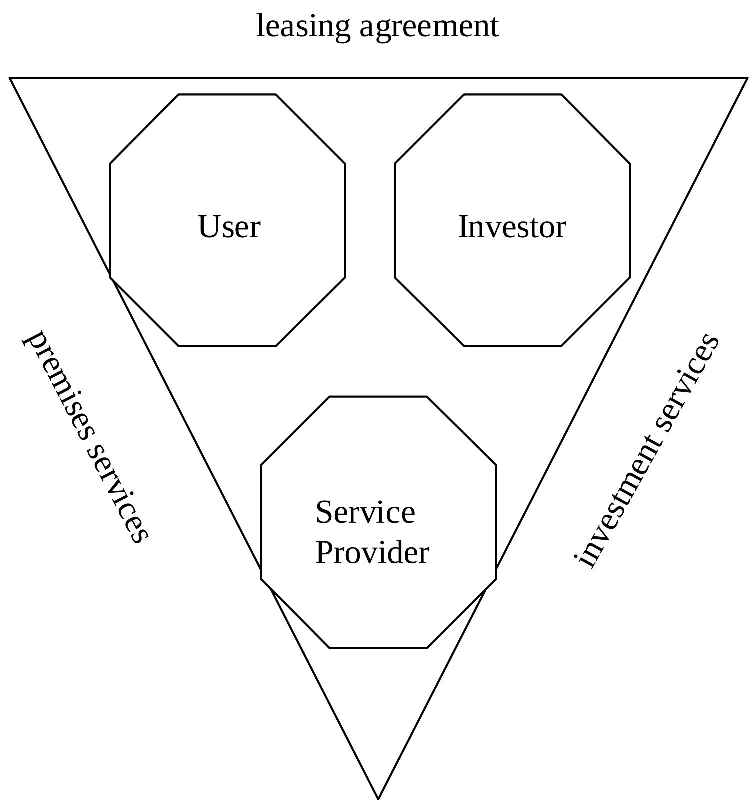

Figure 1: The customerships in project development from the clients' point of view.

3.4 Service Competition

The delivery systems have been categorised in four groups according to the services most of the clients demand from the project implementer. Traditional contracting is for the owners that use separated procurement systems and want to deal with all the organisations involved in the project. Design-build is a system where clients appreciate the one-point-responsibility. In construction management systems clients want to have a greater involvement in the project and the physical construction is carried out by means of packages. Development projects are available for investors to whom building project is just an alternative to invest in. The user is the owner's client and definitely the most important partner for the service provider.

Any quality problems stem from functional quality because all the firms can produce approximately the same technical quality. The trend in the business operations is to include more and more added value to the delivery systems. Formerly the competition concerned the price of materials and labour, but nowadays the operators are in the middle of service competition. In any case, customer satisfaction is hard to achieve and the reason could be that too little attention is paid to the recovery services.

3.5 Service Encounters in Different Delivery Systems

On the following tables, services which clients typically expect with different procurement approaches are listed. The service encounters, that are relevant when evaluating a suitable delivery system, are different on separate organisational levels. On the strategic level the investor decides in which manner the money is invested (Table 1). On the project management level (Table 2) service encounters that help to reach the set project aims are of importance. The key level is the operational one (Table 3) as the user of the premises will pay for the whole process.

Table 1: Service encounters in different delivery systems in strategic level where the demand is for a sound investment. The emphasis is in the after-sales services offered before the project is commenced.

STRATEGIC LEVEL	**Development projects**	**Construction Management**	**Design-Build**	**Traditional Contracting**
Cash flow promises	X			
Leasing responsibility	X			
Financing	X			
Site selection	X			
Life-cycle guarantee	X			
Maintenance	X			
Repairs and replacements	X			
Rebuilding	X			

Table 2: The service encounters offered typically for the managerial level where the demand is for a successful project during design and construction period. The emphasis is on the accomplishment of the contract.

MANAGERIAL LEVEL	**Development projects**	**Construction Management**	**Design-build**	**Traditional Contracting**
Programming	X			
Consultant selection	X	X	X	
Feasibility studies	X	X	X	
Comprehensive responsibility	X		X	
Product modelling	X	X	X	
Power to control design	X	X		
Power to control procurement	X	X		
Cost and value engineering	X	X	X	
Examining alternative design solutions	X	X	X	
Design development and coordination	X	X	X	
Cost control	X	X	X	
Constructability view	X	X	X	
Cooperation with Authorities	X	X	X	
Change order management	X	X	X	X
Construction supervisor	X	X		
Project portal	X	X	X	
Insurances	X	X	X	X
Guarantees	X	X	X	X
Liabilities	X	X	X	X

Table 3: The service encounters offered typically for the operational level where the demand is for working premises when the user operates the building. The emphasis is on maintenance and performance.

OPERATIONAL LEVEL	**Development projects**	**Construction Management**	**Design-build**	**Traditional Contracting**
User Services	X			
Maintenance	X			
Service recovery	X	X	X	X
Project Portal	X	X	X	

Most services are for the management level to achieve and to accomplish the contract. Few services are offered to the users. User services are based on partnering such as occupational health care, catering, telecommunication, fitness services and secretarial services.

3.6 Service Profiles of Delivery Systems

Analyzing the service-orientation of different delivery systems will be useful in describing the roles of the participants in the service process. In figure 2 the service profiles illustrate implementor's service process as well as the clients' participation in the building process. Service profiles can also be one way to roughly compare the delivery systems to each other. The profiles give an image of the significance of the users' participation, too.

Traditional procurement is suitable for clients that are interested merely in the core product i.e. the price of construction. The widest service package is included in project development systems and at the same time the construction stage itself seems to be less important. The one-point responsibility can be an obstacle to clients participation in the design-build service process but at the same time it can save the owner's resources. The project management systems are appropriate for clients who want the power to control the process during the design and construction stages.

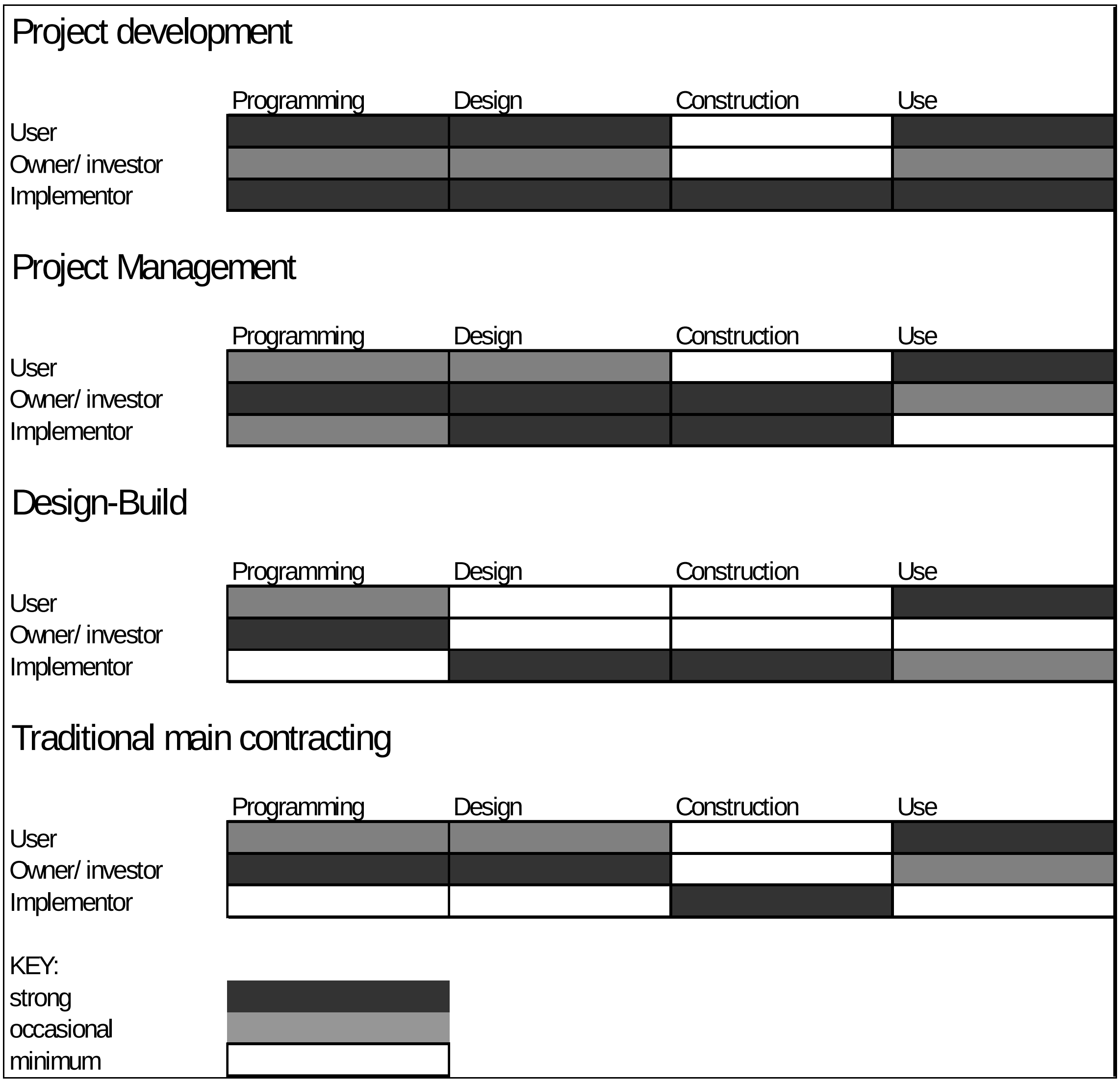

Figure 2: The service profiles of different delivery systems.

4. Guarantee in Rental Housing Projects

4.1 Residential Building Projects

There will be a continuous need for new apartments in the next decade because people are moving from the northern parts of Finland to the greater Helsinki area. The main new housing production is market-financed characterised by the fact that the founding shareholder of a housing company sells the housing shares at the construction stage. Most often the major construction companies are the founding shareholders. Customers as shareholders will form the new board of the housing company after buildings are approved for use.

4.2 Service Package for Residential Real Estate Investors

Market financed housing production is very sensitive to any negative fluctuations in the economic situation especially to changes in interest rates. To prepare for the future risks YIT Rakennus Oy started a product development project to build up a service package for private housing investors. The aim was to offer an agreed profit level by guaranteeing a balance between expenditure and long-term ownership.

According to figure 3, the focus is on the after-sale services instead of site selection, design and construction. To guarantee the agreed profit level, services are provided to take account of both incomes and expenditure. Besides, clients can benefit from the increase in value of the residential property. The idea was to emphasize customer-orientation by keeping the decision-making close to the clients. This means that all the services are options and they can be tailored for each client differently.

The location of the project and the apartment program is the basis for the service provider to commit to the rental revenue and to take responsibility of the renting. Maintenance costs in blocks of flats can be quite accurately estimated and thus the risk of overruns is managed. Certainly, the maintenance serves to keep the property attractive for the tenants.

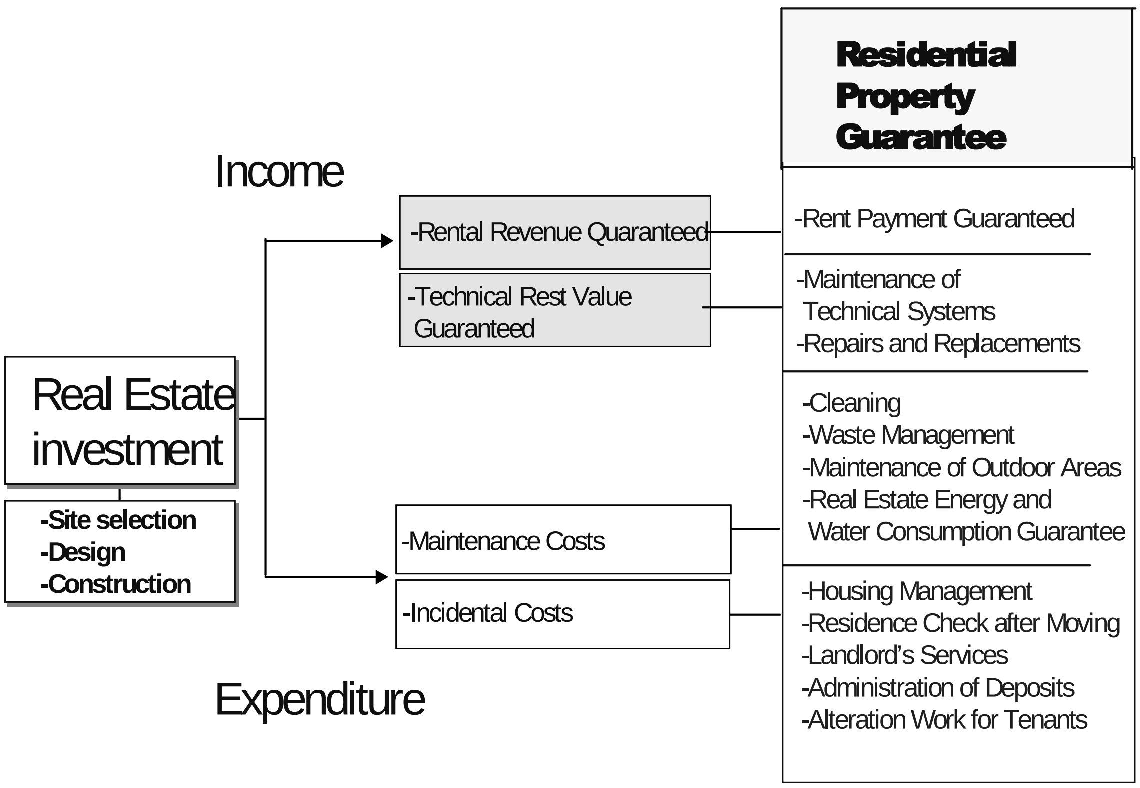

Figure 3: Guaranteed investment in market financed rental housing.

This development work continues. Firstly it has not yet been tested whether the clients appreciate the value of these services and are willing to pay for them. Secondly we must learn how the long-term cost affects our clients. Finally, clients will always remain who are only looking for a core solution and they are not interested in value-adding additional services.

5. Future Service Processes

To develop the future building project delivery systems there is a need for analyzing and comparing the existing, both domestic and international, systems from the service perspective. This kind of study will help clients in decision-making from the earliest stage of a building project. For the operators, perhaps, the results would be of help in service management when the knowledge as well as the weaknesses, the firm has, can be identified. The following benefits may also accrue.

- The ability to describe the service totality to clients will be improved.
- Low price will not be the only decision criterion and clients are willing to pay for the new services.
- It will be easier to market new building projects from the service point of view.
- A core product or the quality of the new facilities is self-evident, but the service quality can vary easily. Quality gaps can be minimised as promises and expectations are more likely to be met.
- There will be expertise to offer all the procurement methods available and to add new options to meet clients' objectives.
- The services as a means of differentiating from the competitors will be encouraged.

6. Conclusions

Service components have become more essential parts of the building procurement than the core product itself. To keep their competitive edge large construction companies will not only offer the facilities, but their complete maintenance, servicing and repairs. Guaranteeing incomes for the future real estate owners will also be necessary.

There will always be a demand for all types of delivery routes. The trend is towards more added value and more sophisticated services. The firms in the field will put effort into differentiating readymade after-sales services that are new to the branch. However, all delivery systems will remain in use because clients' needs, project characteristics and the market situation will vary significantly.

Service concepts will surely become more common in the housing sector, too. Guaranteeing both incomes and expenditures are obligatory services to make the institutional investors invest in residential real estate. In addition to products for investors, purely demand-oriented service encounters, like housing companies for senior citizens including nursing services with reliable partners, will emerge.

To adopt more responsive responsibility for the clients' business, necessitates a vast number of services offered within the delivery systems. Through effective management of these services, success in the market can be achieved.

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Developing the Decision-making of Step-in Rights for BOT Projects

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Abstract

As economy slows down, the BOT/PFI projects become popular in many countries. BOT procurement is undertaken on a service-based output basis rather than an asset delivery basis. Major studies and efforts focused on financial arrangements or project construction management. No serious research on the public sector's step-in rights related issues nor were relevant significant cases been analyzed. To address the uncertainty nature of BOT projects within operation period, the public sector's action should follow Pareto rule, namely to develop a decision–making process which (1) maximize the efficiency of resource allocation and income distribution as well as (2) minimize the transaction cost. Satisfying these objectives is a challenging task that requires identifying tradeoffs among themselves. This paper presents a case study for examining one of the very first PFI agreements in 1993 and the renegotiation of the deal in 1999.The analysis provides some valuable lessons which could be learned from this particular deal for future BOT/PFI contracts design. Furthermore, the outcome of the study will be interdisciplinary works which provide a new approach to BOT/PFI regulators and contracting parties without discrimination.

Keywords: BOT, decision-making, benchmark approach, contract-designing, option theory

1. Introduction

The outset of the Private Finance Initiative (PFI) in 1992 provided concession-based deals which were generally produced on a limited recourse or project financial basis. For the private sector entity to undertake such a long term commitment, it must have sufficient funding to deliver the contracted-for service as well as to ensure that project may be build and then operated and maintained.

Inevitably, BOT/PFI procurements are for the delivery of what amount to indispensable service to the public. The absolute necessity to deliver these services has led to unusual contractual requirements within public-private concession contracts. Legal issues arise across a very broad area and need to be identified carefully. Early studies indicate that governments will seek step-in rights in a board range of circumstances, such provisions are not only made for the public sector to be able to intervene earlier in the event that the private sector is not delivering service to the performance standard but also alarm lenders and other investors - they will not recover the investment they have made in the project unless the private sector borrowers is delivering services and being paid for such services.

1.1 Scope of This Study

We shall introduce the study conducted by researchers on financial and economic law analysis first, and then we shall adopt modern research on real option models and benchmark approaches, to discuss how they can be related with our research objectives. As to contract design related monitor issues arise within the operation period for example, are whether the establishment of the project was consistent with the public sector's long-term business strategy; how the private sector's problems arose; whether the terms of the original contract aided the resolution of crisis; what options considered to tackle the crisis; what the terms were of the revised agreement made to save the project. We tried to collect the evidence in support of our opinions under each of these issues from examination of the Royal Armouries case. According to the scenario case study, this article shows some strategies for improvement of the decision-making system in order to reduce the risk of BOT/PFI projects within operation period...

The paper is structured as follows:

- part 1 contains overview of BOT/PFI and identifies performance risk within operation period;
- part 2 considers step-in rights and provides methods to formulate the critical time issue;
- part 3 reviews an empirical case and examines decision –making process;
- part 4 discusses optimal contract design and monitoring strategies;
- part 5 conclusions

1.2 Risk Management in Operation

Government is responsible for a wide and diverse range of activities including delivering services to the public such as social welfare benefits; procuring and managing major construction projects; regulating industry and collecting revenue. All of these activities involve some form of risks. The Treasury published *Management of Risk - A Strategic Overview* (2000) [1] which defines risk as" *the uncertainty of outcome, within a range of potential exposures, arising from a combination of the impact and probability of potential events.*" Risk management means the public sector has a corporate and systematic process for evaluating and addressing the impact of risks in a cost effective way and having staff with the appropriate skills to identify and assess the potential for risks to arise.

According to the result of survey by NAO in 2000, the main barriers for risk taking in the public sector side are: asymmetric information, risk averse, lack of expertise, lack of formal systems, processes and procedures, unclear responsibilities, the status and activities of public body's limits and time, funding constraints. Instate of tolerating those barriers, the incentives should be incorporated with concessions.

2. Step-in Rights

Step-in rights entitle the public sector to be able to intervene earlier in the event that the private sector is not delivering service to the agreed performance standard .To the extremely circumstance, such a right can be a trigger for the contract termination before contract duration.

2.1 Optimal Time

How often do departments assess overall risks? NAO report (2000) [1] showed thirty-eight per cent of departments do not routinely assess their overall risks. For the private sector entity to undertake such a long term commitment, a further consideration is that priorities change over time and areas of performance subject to assessment need to be reviewed periodically. It is therefore important to identify core areas whose indicators will be collected on consistent basis over time. Later, we shall introduce two financial methods (1) NPV-at-risk method and (2) option pricing theory to identify the critical time issue.

2.1.1 NPV-at-Risk Method

Ye and Tiong (2000) [2] presented the NPV-at-risk method to analyze the impact of the risks on the value of a BOT project. The basic concept of this method is to simulate the primary variables underlying the net present value of a project, and obtain the distribution and confidence level of the NPV. Myers (1976) pointed out the major limitations of the NPV-at-risk method: '*If NPV is calculated using an appropriate risk adjusted discount, any further adjustment for risk is double-counting. If a risk-free rate of interest is used instead, then one obtains a distribution of what the project's value would be tomorrow if all uncertainty about the project's cash flows were resolved between today and tomorrow. But since uncertainty is not resolved in this way, the meaning of the distribution is unclear*.'

2.1.2 Option Pricing Theory

Traditional methods, such as NPV analysis, fall short in reflecting the characteristics of privatized infrastructure projects and the risks involved. Ho and Liu (2002) [3] examined why the evaluation of BOT investments can be improved by applying real option framework and present an option pricing based model for evaluating the project financial viability. So the critical time (bankruptcy condition) can be modeled as

$$V_t - D_t(K_t)e^{-r_d(T-t)} < O$$

Note：

$D_t(K_t)$ is defined as the total outstanding debt at time *T* prices estimated at time *t*.

$D_t(K_t)e^{-r_d(T-t)}$ is the total estimated debt at time *t* prices obtained by discounting $D_t(K_t)$ at the loan interest rate r_d for the period $T-t$.

In order to account appropriately for the asymmetric payoffs under the bankruptcy risk, Equation above suggests that if the project value estimated at t is less than the estimated required total debt at time t prices, the lending bank will force the bankruptcy of the BOT firm to prevent further loss. This quantitative model considers the project characteristics explicitly and evaluates the project from the perspectives of the private sector and of the public sector when the project is under bankruptcy risk. Therefore, the critical time would be pointed out. In that case, the public sector shall have a strong theoretical reason to trigger step-in rights by all means before bankruptcy. Interested readers may refer to Ho and Liu (2002) [3] for details regarding the formulation the BOT-Option Value model.

2.2 Performance Measurement System

In order to trigger step-in rights without discrimination, BOT/PFI contract should contain a reasonable system to measure the private's performance against specified criteria. We introduce two different approaches to explore this issue.

2.2.1 Value for Money

Value for money (VFM) means to achieve the optimum combination of whole life cost and quality to meet customer requirements. Within a VFM framework, evaluation is commonly directed at the following:

- Economy – how much money is spent;
- Efficiency – the relationship between the inputs into activities and the direct outputs from those activities;
- Effectiveness – the relationship between efficiency and outcomes. Outcomes are the ultimate impact of activities and are intended to relate to aims and objectives.

To identify VFM, the illustration between conventional procurement and PFI is showed below (See Figure 1).

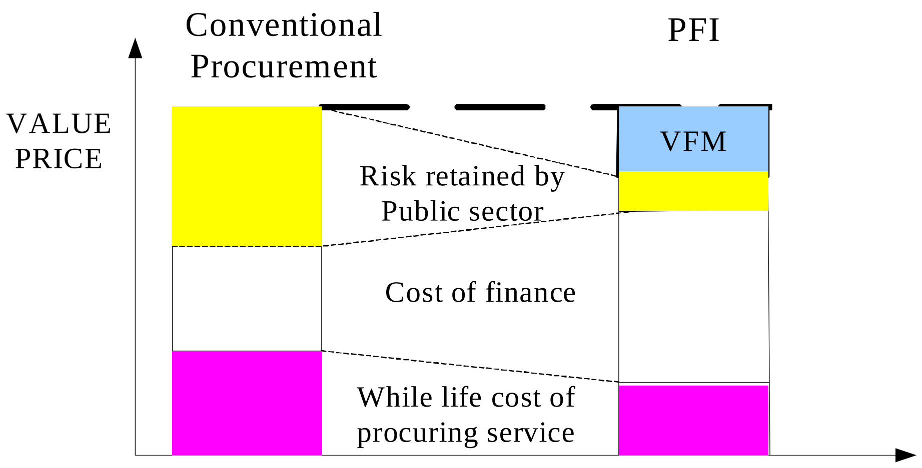

Figure 1. VFM

However achieving cost reductions (or containing costs) does not always represent *good management* – for example if there is a disproportionate, detrimental impact on outputs and outcomes. The transaction cost shall be appraised by including searching cost, bargaining cost and enforcement cost. That is why it is also necessary to evaluate efficiency and effectiveness. Performance Indicators (PIs), for instance, can be used effectively as management tools within an organization to improve the quality, efficiency and effectiveness of museum activities.

2.2.2 Benchmark Approach

Appeals Court Judge Richard Posner, the modern economic law pioneer, pointed out that decisions (judgments) require a benchmark for comparison which implies wealth maximization. Without question PFI's objective shall match the end - wealth maximization. UK experience provided the Public Sector Comparator (PSC) as a benchmark now and it means a benchmark against which VFM is assessed (see Figure 1). The PSC is typically a cost estimate based on the assumption that assets are acquired through conventional funding and that the procurer retains significant managerial responsibility and exposure to risk. The PSC had an inherently high level of uncertainty attached to it, as a result of the difficulty of forecasting not only the demands over 20 years or more, but also the associated running costs and potential income realizable from the project. Risks were modeled in the comparator by using Monte-Carlo simulation and the final output of the final PSC was expressed as a range. The risks modeled in the PSC covered uncertainties in predicting future income in areas such as tickets sand sales and uncertainties in future costs such as ongoing maintenance payments.

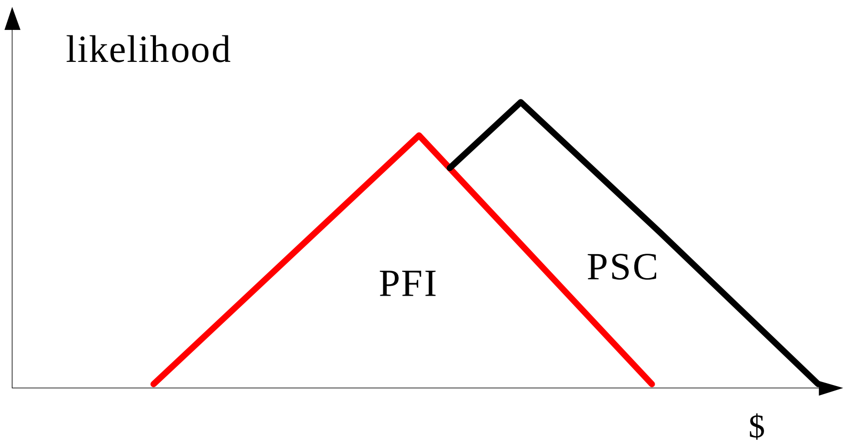

***Figure 2** The Public Sector Comparator (PSC)*

In order to evaluate success, it is necessary to have in mind benchmarks of measuring quality. A key element in this is the perception of value by users. The survey of expenditure may be useful for the private sector to carry out preliminary benchmarking on the relative proportion of expenditure they incur on different types of activity. This may in turn facilitate the gathering and interpretation of benchmarking information.

3. Case Study

The Royal Armouries originally entered into a PFI contract with Royal Armouries (International) plc ("RAI") in December 1993(see Figure 3). Under this contract RAI were to build a new museum which would allow the Royal Armouries to display a greater proportion of its collection. The Royal Armouries agreed to contribute £20 million to the £43 million cost of construction, with RAI meeting over £14 million and Leeds City Council and Leeds Development Corporation £8.5 million.

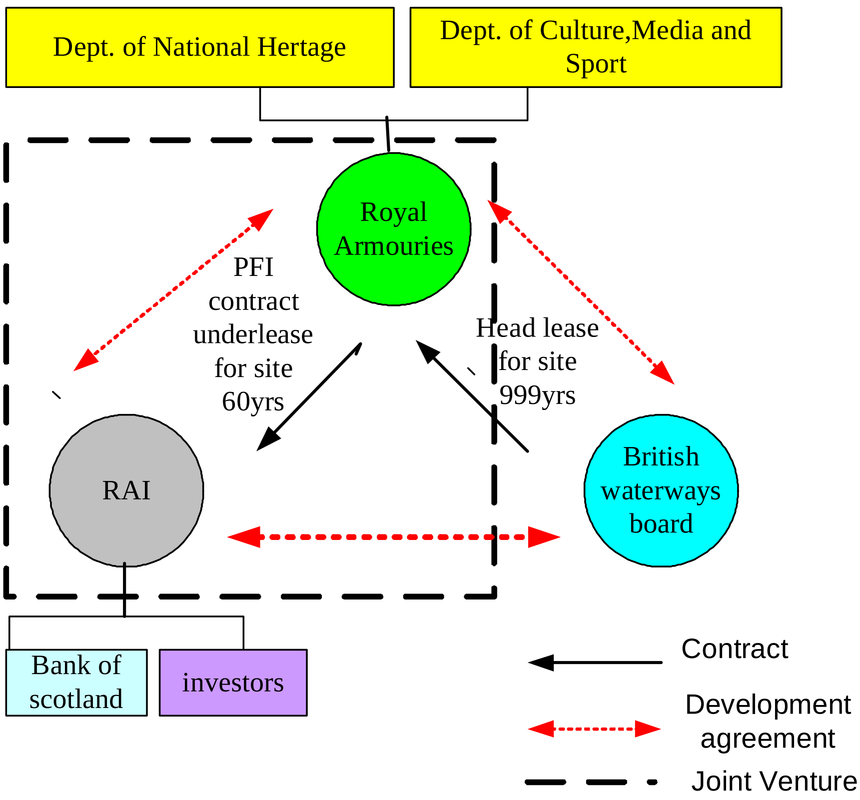

Figure 3 Original PFI Relationship Frameworks in 1993

Once construction was complete, RAI was to operate the new museum for 60 years. (see Figure 4) In return RAI would retain all the income the museum generated from visits by the public. The new museum opened in March 1996; however, visitor numbers were so low that it never made enough money to meet its operating costs and the costs of servicing RAI's debts.

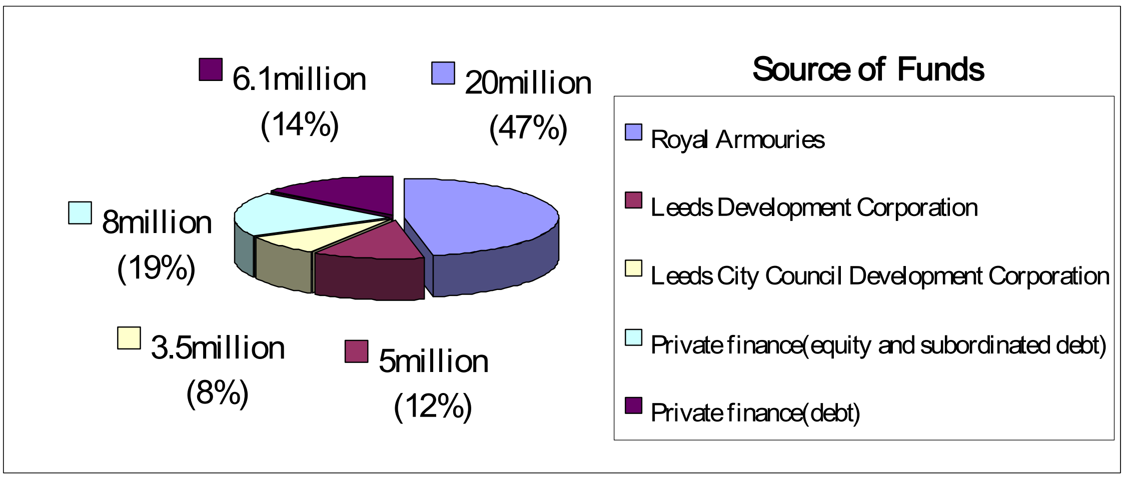

Figure 4 Source of Funds

Consequently, by early 1999 RAI's cumulative losses were estimated at £10 million, despite two refinancing by RAI. As part of the second refinancing in 1998 RAI's bankers, the Bank of Scotland, advised that it would not be able to make additional funding available to RAI after July 1999 if the financial problems persisted. Withdrawal of the Bank's support after that date would have resulted in RAI becoming insolvent. In response, therefore, in July 1999 the Royal Armouries negotiated a revised deal with RAI which ensured that the museum remained open. Under the re-negotiated deal the Royal Armouries took over responsibility for running the museum, while RAI retained responsibility for the provision of catering, car parking and corporate hospitality services at the museum (see Figure 5).

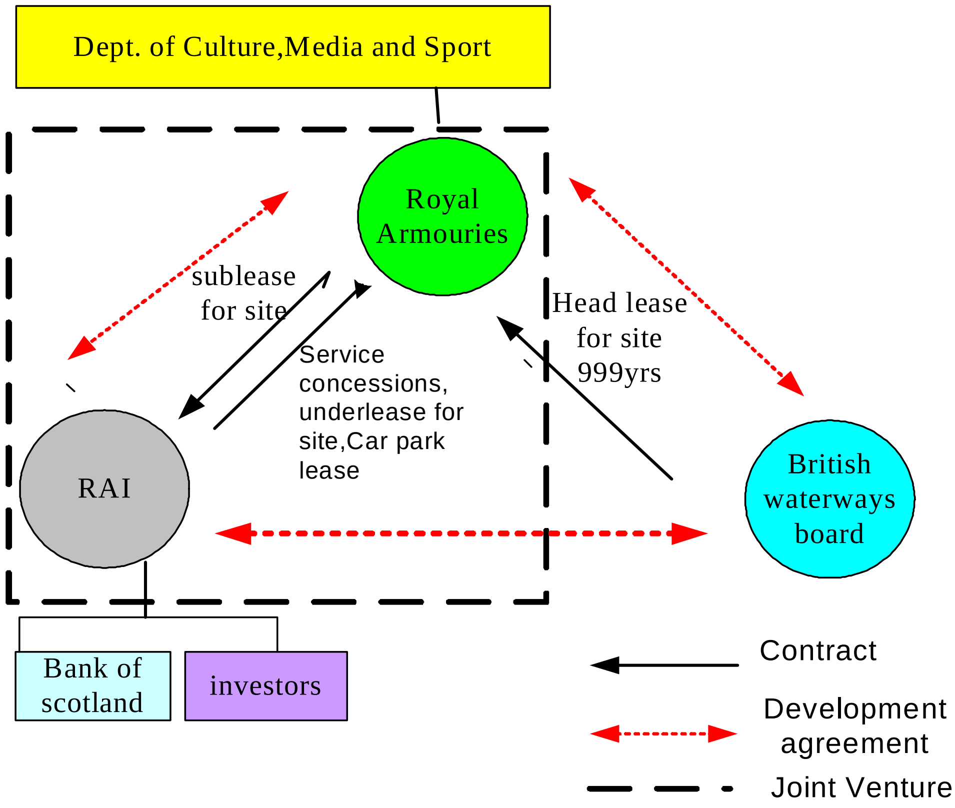

Figure 5 Renegotiation PFI relationship framework in 1999

On the basis of a report by the Comptroller and Auditor General (2000) [4], we explore the public sector's decision-making process by focusing on the forecasts for visitor numbers, the re-negotiation in 1999 and on the extent of risk remaining with the private sector under the terms of the revised deal.

3.1 The Forecasts of Visitor Numbers

The actual number of visitors to the new museum was much less than Royal Armouries and RAI had forecast. However those forecasts were based on a certain pricing assumption and the consultants warned that the actual number of visitors would vary, depending on the admission price charged. The public sector should assess the reasonableness of these projections by comparing them with the performance of comparable existing attractions. In addition, if the project involves a high degree of commercial risk, the project needs to be financed with a high level of risk capital relative to bank debt. If it is necessary to proceed with a project in the absence of adequate levels of risk capital, the government should plan for the contingency that extra funding will be required. The warnings on pricing appear to have been ignored by RAI. RAI had placed over reliance on their own consultancy advice and had charged a high entrance fee of £6.95. One of the first things that the Royal Armouries had done, on taking the museum over in 1999, was to reduce this entrance fee to £4.90.

In addition to the pricing policy, there were a number of other factors which contributed to visitor numbers being less than forecast. Such as delay in the development of the Clarence Dock area surrounding the museum.

3.2 Re-Negotiation an Existing Agreement

Whether the original strategic objectives for the museum had still been met after adopting step-in action？The National Heritage Act 1983 lays down a number of statutory duties with which the Armouries must comply, so the Armouries' objective was to avoid the museum's closure. Obviously, the Royal Armouries did not meet their strategic business objective of becoming more self-sufficient. In contrast, he has taken over the loss making aspects of the museum and will be dependent on extra funding from the government and the income from the lower-than-expected visitor numbers.

In negotiating the deal to save the museum the Royal Armouries did not seek appropriate commercial advice from an insolvency practitioner, although they were faced with a threatened insolvency. Faced with similar situations, the public sector should be clear both about their legal rights and the strength of their commercial position, and be prepared to use those rights and powers aggressively in negotiations. Under the terms of the revised deal RAI had to pay twenty per cent of their turnover to the Royal Armouries once their debt had been paid off. However, there were limits on the capacity of the museum to handle increased visitor numbers. The public sector should ensure that he has the right to share in the benefits of any future windfall gain resulting from any re-negotiated deal.

3.3 Ensuring Risk Remains with the Private Sector

Before signing the contract, the Royal Armouries had taken over comfort from assurances from their financial advisers, Schroders, that the deal was the best available from the market at the time, given the deal's parameters. In considering future deals, the public sector should get impartial advice on the merits of a proposed deal before it is signed. Under the current guidance the public sector would have had to consider at the very start of the project what would happen at the contract's end. On this deal the Royal Armouries' ability to terminate the contract and take possession of the museum due to RAI's insolvency was limited for two years. The public sector needs to consider in advance how they will eventually exit from deals.

There had been a lack of market interest in the deal when it was put out to the market and only one bid had actually been received. The operating specification which was to detail those areas where such co-operation and joint working was required was not agreed subsequently. Even the Royal Armouries were not given access to RAI's financial records and there were disagreements between the two parties over issues which were of fundamental importance to the museum's future. The public sector should be aware of such warning signs that the deal being negotiated will not eventually be sustainable.

Surprisingly the Royal Armouries had no contingency plans in place, as they considered that the risk of the project's failure lay with RAI in the private sector. However, on this deal the business risks ultimately lay with the public sector as the Royal Armouries had been unwilling to countenance the closure of the museum and had therefore stepped in to rescue the project. In considering future PFI projects, therefore, the public sector should consider where the business risks ultimately lie and draw up their own contingency plans accordingly.

4. Contract-designing and Performance Standard

The new museum involved significant commercial risk, as it was a new attraction in a redevelopment area with no proven track record of visits by the public. What gets measured is what gets done. Performance measurement can be used not only to influence behaviour in a desired direction but also to serve as a benchmark. For example, the National Museums and Galleries developed a mechanism for raising standards of efficiency and quality in the sector and to identify examples of good practice. These objectives fit with Government initiatives seeking greater accountability and proof of “Best Value” from public services [5]. Those outputs are as follows

- a Business Model which analyses the activities;
- a long-list of Performance Indicators (PI’s) for each activity;
- An agreed short-list of Performance Indicators to act as the foundation for a performance management regime.

OGC publish valuable reports, guidelines as well as PFI standard form contract [6] which reduce the transaction cost well. What the public sector measure must be meaningful and material to the fundamental mission of the organization and its operation. Strengthening economic legal infrastructure is about improving the quality and accessibility of the law and the capacity of individuals and institutions to implement, apply and enforce those laws. The benefits are:

- improve transparency, predictability and fairness in the rules and regulations and administration of the public sectors; and
- engender business and investor confidence and enhance competition; and

- lead to economic efficiencies, innovation and reduced compliance costs for business

RAI should use the agreed PI's to collect information on outputs and outcomes. Through this they can demonstrate how the museum is contributing to the achievement of government objectives; and The Royal Armouries and the lender should use the agreed PI's to assist with their evaluation of the efficiency and effectiveness of the museum. This will provide an incentive for the private sector to consider where and how to reduce unit costs.

5. Conclusions

The study makes three main types of contribution under consideration:

- introduce an example of current practice;
- consider key issues and critical factors with regard to particular types of BOT/PFI;
- discuss basic standards with which all the private sector should be expected to comply.

In conjunction with investment and facilitation initiatives, strengthening economic legal infrastructure can help deliver significant returns in the form of social outcomes and sustained economic growth. Failure to provide an appropriate standard of decision-making could prove costly as a consequence of market uncertainty and loss of investor confidence. As the issues that need addressing are complex, and in some cases entrenched in legal system, culture and judiciary, measures will need to be undertaken with a long-term perspective, giving rise to incremental but substantive improvements. It is hoped that the work of the study will be continued in the form of an ongoing issues, such as the diversity of the activities, comparability and consistency as well as balancing long and short-term objectives, within performance period by dynamic approaches.

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Section V

Risk Management

CM-at-Risk Delivery System And The Miami Intermodal Center

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Abstract

The Miami Intermodal Center (MIC) is the first "CM (construction manager)-at-risk" project ever funded by the U.S. Federal Highway Administration (FHWA). The size of the project qualifies it for "mega-project" status, but this is not the only thing that makes this an historic project.

MIC, a $2.25 billion project located just east of Miami-Dade International Airport (MIA), is envisioned as a consolidated transfer center for passengers using the airport, intercity and commuter trains, rapid transit, local and intercity buses, and cruise ships in the Port of Miami. The project is being developed by the Florida Department of Transportation (FDOT) and the Miami-Dade Aviation Department, in cooperation with the Miami-Dade Expressway Authority, Miami-Dade Transit, Amtrak, and various rental car agencies serving the airport. The MIC is actually a series of projects, including a consolidated rental car facility, a people-mover connection to the airport, and a number of road access improvements around the airport.

What really makes this project unique, however, is the delivery system chosen by the owners for the early stages of the project. All manner of fast-track construction methods have been used in building construction and industrial construction for years, but these are a relatively recent development in the area of civil, or heavy, construction. FDOT had its first design-build (DB) projects in the early 1990's, with the FHWA beginning to fund DB projects in the state later in the decade. For the MIC, however, the CM-at-risk delivery method was chosen. Very similar to the "Team Approach" taught in construction management textbooks, the CM-at-risk approach is a cost-plus-fee contract with a guaranteed maximum price (GMP). The GMP is based on the sum of the CM's fee, the CM's contingency, the money set aside for General Conditions construction, all the subcontracts, plus an estimate for unbid subcontracts. The CM agrees to pay for costs that exceed the GMP and are not a result of changes in the contract documents.

Keywords: Miami Intermodal Center, CM-at-risk, delivery system, access facility, terminal access roads, MIC/MIA, tri-rail

1. Introduction

The Miami Intermodal Center (MIC) is a world-class mega-project that has drawn intense interest and scrutiny from construction and design engineers both nationally and internationally. It combines the latest in horizontal construction, vertical construction, and project delivery methods. The project scope also includes innovations in project financing and engineering that will be noted, but not discussed at length as they are beyond the scope of this paper.

As early as 1989, the Miami International Airport Area Transportation Study recommendation for the implementation of a multi-modal transportation access facility to help mitigate the growing traffic problem in and around the airport was accepted by Miami-Dade County. However, due to lack of funding and other issues, the project was not started until 2003. MIC will be a world-class multi-modal facility that is estimated to take 15 to 20 years to construct and cost approximately $2.25 billion.

MIC includes the first transportation project using the "CM-at-Risk" (CMAR) delivery system ever to receive federal funding. All of the work currently scheduled using the CMAR system is slated for Phase I of the project, which is now in progress and is estimated to take five years and cost $1.35 billion. The work done using the CMAR delivery system includes the rental car facility (RCF), the MIC terminal access roads, and other items, and is estimated to cost $230 to $250 million and be completed in 2007.

This paper provides an overview of the project, how CMAR works, and how it is performing when compared to traditional project delivery systems.

1.1 Background

The project sponsor was FDOT, and because of its size and significance, the project was classified as a "mega-project" by the United States Department of Transportation (US DOT). FDOT would act as the "owner" of the project even though Federal Highway Administration (FHWA), Miami International Airport (MIA), Miami–Dade County, and the Federal Aviation Administration (FAA) had a vested interest in the project and could also be considered owners. Once the decision was made to build the project, a consultant, Earth Tech, was quickly added to the team by FDOT as the Program Manager.

Several decisions lay before the team. A designer had to be procured, as did construction engineering and inspection (CEI) services and construction services. A delivery system had to be chosen and numerous permits obtained. The proposed facility had to accommodate the rental car companies around the airport, the Tri-rail system (an above-ground train line that connects the three major south Florida counties—Dade, Broward, and Palm Beach—and ends at MIA), the Miami-Dade County Transit Authority (bus lines), Amtrak, cruiseline courtesy buses, hotel courtesy buses, Greyhound buses, the existing street and highway system, and numerous other transportation entities.

One of the most daunting tasks facing the team was trying to please the numerous parties of interest that ranged from the other involved agencies, such the FAA and Miami-Dade County, to private interests, such as the Tri-rail system and the car rental companies that would use the new facility. In addition, any decision regarding the delivery system had to be filtered through FDOT's long-standing policy that any prime contractor must self-perform at least 50% of the project.

2. The Project

The transportation development portion of the project was separated into two phases. Phase I will include all right-of-way acquisition, access improvements (roadways), the consolidated rental car facility (RCF), the MIA Mover (formerly referred to as the MIC / MIA Connector, this is a two-mile bridge on which either trains or trams will transport passengers between the MIC and the MIA), and the MIC Core (Phase I). Actually, only $80 million of the approximately $400 million cost of the MIA Mover will come from MIC funds, as the MIA Mover is primarily sponsored by the county and MIA. [1] Phase II, not scheduled to commence until at least 2007, will include completing the MIC Core, constructing platforms serving elevated Tri-rail, Amtrack, and Metrorail lines, and all construction of MIA landside facilities.

2.1 Phase I

While the entire program will be completed over the next 15-20 years, the first phase is scheduled to be completed over a five-year period of time at a cost of approximately $1.35 billion. This Five Year Program will consist of the activities and corresponding costs shown in Table 1.

Table 1. MIC Cost Breakdown by Activity Type

Amount	**Activity**
$ 615,000,000	Construction
$ 350,000,000	ROW and Environmental Remediation
$ 22,000,000	PD&E Study
$ 84,000,000	Design
$ 42,500,000	Program Management
$ 32,000,000	CE&I Costs
$ 93,000,000	Contingency
$ 65,000,000	Financing
$1,303,500,000	Total

2.1.1 Rental Car Facility

The RCF is the first major component of the MIC being constructed. It will co-locate the rental car companies currently located at the airport and many of the companies located adjacent to the airport. The financial impetus for the early commencement of the RCF was a loan from the Transportation Infrastructure Funding Innovation Finance Act (TIFIA). "The RCF is currently budgeted in the MIC work program at $218.7 million; however, a $190 million scope has been agreed to by all parties and an updated financial plan is currently being reviewed by the joint TIFIA Office. When the RCF TIFIA loan is finalized, the work program estimate will be conformed to the project budget. TIFIA loan draws are occurring more slowly than originally forecast and lower TIFIA loan balances are anticipated for eventual repayment." [2] Details of the TIFIA loan are discussed later in this paper.

The sheer size of the building (1400 feet by 1200 feet, with the top floor sixty feet off the ground) makes construction a challenge; however, the size of the building was not the main consideration. Each floor of the building will house a fuel distribution center where gasoline will be pumped into the rental cars at each level. This is the first time that any building in the United States has had elevated fuel distribution capability; special permits and numerous considerations will be required.

The RCF will include:

- Ready/return vehicle capacity of approximately 6500 vehicles
- Fleet storage capacity (vehicles not in use) of approximately 3500 vehicles
- Quick turnaround vehicle fueling and washing facilities
- Spacious customer service facilities for rental car transactions

The most interesting part of the construction of the RCF, and probably the whole project, will be the construction of the elevated fueling centers. The Senior Program Director for the project said that for the period of time that this portion of the RCF is being constructed, "the Fire Marshall will be running the project." [3] This unique construction will be a subject of widespread interest.

2.1.2 MIC Core (Phase I)

The first phase of the MIC Core will cost approximately $80 million and accommodate the bus depot, Tri-rail passenger parking, and MIA Mover Station. The MIA Mover Station will be built adjacent to the RCF. This facility will allow passengers of Tri-rail, city busses, and rental cars to board the MIA Mover, and be transported to the airport terminal. The MIA Mover will feature large cars that run on either electric rails or rubber tires and will be boarded on the top floor of the building, 60 feet off the ground. This facility is expected to be completed and operational by November, 2008.

2.2 Phase II

The transportation development portion of Phase II will consist of completing the MIC Core, constructing platforms serving elevated Tri-rail, Amtrack, and Metrorail lines, and all construction of MIA landside facilities. There is also a commercial development portion of the MIC that will be completed as part of Phase II per the Joint Development Agreement.

2.2.1 Joint Development Agreement

The Joint Development Agreement was first conceived as a revenue-producing program and comprises the commercial development portion of the MIC. An oversight committee was formed to supervise the commercial development, and they retained ERA, a D.C.-based consultant, to perform a study that found that the area in and around MIA was in need of office towers, parking, ancillary retail, and a hotel/conference center.

In early 2002, an RFP was advertised for a developer to handle the commercial development, and the apparent choice is MIC Development, LLC, a joint venture consisting of equity partners The Codina Group and Mallory & Evans, hotel developer The Continental Company, marketing giant Market Place Development, and two large AE firms. Negotiations have begun with this group, with the expected start date on commercial development set for early 2008.

The commercial part of the venture will include office towers, a world-class conference hotel, restaurants, and other businesses. The plans now call for FDOT to lease space to occupants, raising over $5 million per year to help pay the debt incurred through the loans part of the project financing. Appraisals are already being done to estimate the current market value so lease and rental terms can be developed.

A stipulation in the agreement states that if rents exceed $5million in any year, the amount of revenue over $5million will not go to pay down the debt, but must be used to pay for road and bridge construction.

3. Economic Impact

The construction of MIC will result in numerous temporary and permanent job creations within many sectors of the economy, especially construction, retail, and service. It is estimated that over the 15 to 20 years of the entire construction process, 76,000 construction and construction-related jobs will be generated, and 22,000 permanent jobs will be created to operate the facility once it is constructed. The economy and standard of living around MIA will be enhanced because the facility will encourage travelers to use the various public transportation systems integrated into the MIC. It is estimated that by 2010, 75,000 passengers will use the MIC daily. Of these, approximately 45,000 are expected to be using the MIA Mover to travel to or from the airport. [4]

4. Project Funding

Financing the MIC, with a total cost estimated at over $2.25 billion, was a challenge for the state of Florida and Miami-Dade County. Phase I is projected to cost approximately $1.35 billion over five years and has received funding from a variety of sources. While obtaining the TIFIA award brought significant funding, as well as international notoriety to the MIC project, it was certainly not the only significant source of funding. For Phase I, the MIC has received nearly $165 million in Federal Highway Administration (FHWA) grants, $386 million in state

(FDOT) funds, and a $25 million Florida State Infrastructure Bank (SIB) loan. The Miami-Dade Expressway Authority has provided $87 million in toll-backed funding, and the project has also received $18 million from Florida's SIB specifically for a portion of the project, the SR 836/SR 112 connector. The Miami-Dade Aviation Department will fund most of the $400 million cost of the MIA Mover with airport user fees.

The complete list of funding sources and their contribution can be seen in Table 2. [2]

Table 2. Funding Sources for MIC, Phase I

Source	**Contribution ($Millions)**
Prior and future Allocations of State and Federal Funds in Miami-Dade County's Transportation Improvement Plan (TIP), Long Range TIP, and Other State Funding	$249
MIA Capital Improvement Plan	$400
RCF Customer Facility Charge	$25
Miami-Dade Expressway Authority's Capital Program	$86
Miami-Dade County	$30
Ancillary Revenues for from Concessions and Joint Development	$37
FDOT State Infrastructure Bank Loan	$25
TIFIA Loan	$433
Capitalized Interest and Finance Costs	$64
Total	$1,349

Because of the close economic and geographic ties between MIC and MIA, the events of September 11, 2001 led to a reevaluation of the MIC program which focused on funding and timing. MIA has been much slower to recover from the aftershock of the September 11 disasters than most of the nation's airports due to MIA's dependency on passenger traffic from Latin America and the recent effects of low-cost air carriers operating through neighboring Ft. Lauderdale. The project elements most impacted by events since September 11, 2001 are:

- The MIA Mover
- The RCF
- Resultant program schedule adjustments for a delay of 18-30 months.

5. Delivery System

Three delivery systems were given strong consideration for each aspect of Phase I; the result was that different portions of ongoing work are being handled in different ways. Since federal funding was sought for each activity, FHWA approval was required for each delivery system decision. It was decided that portions of the work would be handled in the traditional FDOT way, which is by the linear method, or Design-Bid-Build (DBB). Other portions of the project would be handled by the Design-Build (DB) method.

FHWA had long allowed FDOT to use the DBB method for federally funded projects. FDOT has received federal funding to use the DB method for almost ten years, developing a high level of comfort within FHWA for use of that method in Florida. For the RCF and the MIA Mover

Station, however, a level of vertical construction expertise was needed that FDOT projects do not typically require.

But since the project also contains quantities of earthwork and site preparation common to FDOT projects, and roads and bridges are called for in the project, a delivery system was needed that would best meet the challenge of both linear and vertical construction.

In July, 2000, Earth Tech performed a technical evaluation of three delivery systems as a means for the design and construction of the RCF and certain other related structures. The three systems considered were DBB, DB, and Construction Manager-at-Risk, or "CM-at-Risk" (CMAR). It was decided that this portion of work, amounting to approximately $230 to $250 million, would be let under separate contract, using the CMAR delivery system. Reasons given by Earth Tech for this choice were that CMAR offered the following :

- Design process control
- Ability to meet or exceed schedule requirements
- Highly qualified contractor
- Highly qualified designer
- Budget/Cost control
- Project team formation
- Constructability input from the CM

This choice in delivery systems meant that FDOT had to waive, for this project, their long-standing rule that all prime contractors had to self-perform at least 50% of project work. In addition, in order to receive federal funding, FDOT had to make a special application to FHWA under Special Experimental Project Number 14 (SEP-14). SEP-14 is a program by which FHWA can fund a limited number of projects that don't follow existing FHWA guidelines, provided the projects include innovative construction practices or delivery systems. Until fairly recently, a DB project had to go through this process, but after several successful DB projects, the FHWA stopped requiring this special application for DB projects. The MIC is the first CMAR project ever funded under SEP-14.

5.1 CM-at-Risk

Clough and Sears state in their well-known textbook that, "An appreciable share of the private construction market is now being done using the 'team approach.' When this procedure is followed, the private owner selects the architect and building contractor as soon as the project has been conceived. The three parties now constitute a team that serves to achieve budgeting, cost control, time scheduling, and project design in a cooperative manner." [5]

Using the "team approach," the owner assembles the project's key players, such as the designer(s) and contractor(s), to study the proposed project. The team determines the project scope and budget, and the designer develops preliminary drawings from which the contractor makes conceptual cost estimates. As the process continues, the designer prepares the final drawings and specifications, and the owner makes the necessary financial arrangements. After financial commitments and required permits are obtained, actual construction begins. The designer and the contractor work closely together, modifying the design and the drawings as may be required. The process offers the owner the advantages of time savings, cost control, and improved quality. [5]

The method chosen to facilitate fast-track construction of the MIC, “CM-at-Risk,” is very similar to this textbook description of the “team approach” and can be viewed as an adaptation of this established building construction delivery system used in private industry to civil or heavy construction in a public forum. The CMAR contract is a cost-plus-a-fee contract with a guaranteed maximum price (GMP). The GMP is based on the sum of the CM’s fee, the CM’s contingency, the “general conditions construction,” all of the subcontracts, and an estimate for unbid subcontracts. The CM agrees to pay for costs exceeding the GMP that are not a result of changes in the contract documents.

CMAR theoretically reduces the amount of risk for every entity involved in the project. From the beginning, the client’s (owner’s) understanding of project requirements is combined with the wisdom, experience, and technical expertise of architect-engineer (AE) and CM firms. This team has control over every aspect of the project, and together they provide an absolute directive for design, construction, and functional requirements. One of the most important benefits is that the arrangement fosters a non-adversarial relationship that furthers collaboration in decision making. The CM can review the drawings beforehand and catch errors, reducing the owner’s risk, while the AE similarly reviews the CM’s approach to the work, providing constructive recommendations.

The CM is allowed to take bids or proposals from subcontractors after entering the contract and prior to submission of the GMP, which reasonably reduces the CM’s risk. The procedure is more methodical and more predictable than the low-bid DBB and affords the owner more control over design than the DB system. This is because the AE is under contract to the owner under CMAR instead of being part of a joint venture under contract to the owner and tied to the contractor, as is the case under DB. The lack of a tie between the designer and the contractor reduces the owner’s risk, and in reality, these factors reduce risk for all parties.

There is a contingency within the GMP to cover unexpected but justifiable costs, and a contingency above the GMP allows for owner changes. As long as the subcontracts are within the GMP, they are reimbursed to the CM, so the CM represents the owner in negotiating any changes with subcontractors.

5.2 CM-at-Risk at MIC

The MIC can be seen as a pilot project for CMAR from the FHWA standpoint because it is their first such project. It is also FDOT’s first CMAR project but is not the first for the state of Florida. The Florida Department of Management Services (DMS) has built several vertical projects using the method over the last 15 years. For this reason, DMS had personnel on the original Technical Review Committee and originally had a financial stake in the project because the CMAR contract was forged using DMS procedures. Immediately after the contracts were signed, DMS assigned all their rights to FDOT.

A negotiated fixed fee is the method of CM compensation on the MIC project. The CMs interested in this project had to submit a GMP for administering this fast-track construction project. The chosen CM is required to prequalify all subcontractors and oversee the bidding of all trades contracts. In this way, all construction work would be competitively bid. The only way that the CM could self-perform any construction would be to outbid the subcontractors on a portion of the work.

The CM is paid a management fee plus expenses for oversight and coordination of the construction process. This could include project close-out, systems start-up, as-built drawings, operations and maintenance procedures, and warranty services. The CEI consultant, Earth Tech, performs the QA verification testing, as well as the Threshold Inspection of the building (permit work). The FDOT District Materials Laboratory performs Independent Assurance and Independent Verification testing. The CM, then, is left to perform all QC and Value Engineering (VE) for the project; any savings realized by any VE change proposal is split, with 70% going to FDOT and 30% going to the CM. Earth Tech was awarded the CEI work under a separate contract from the one for their Program Manager duties.

Another contract provision allows the CM to keep 30% of the difference between the GMP and the actual cost of construction. Described by the program manager as “a double-edged sword,” this gives the CM an incentive to keep costs as low as possible, but also presents the CM with the motivation to set the GMP as high as possible. [3]

On January 29, 2001, a legal notice advertisement requesting Statements of Qualification for a CM for this project was posted. Technical Proposals were submitted by the short-listed CMs on May 1, 2001, oral presentations were heard by the Selection Committee on May 24, 2001 and Turner Construction Company was chosen as CM for the project. Delays occurred in getting the project started due to the World Trade Center and Pentagon disasters of September 11, 2001, and when the runner-up for the CM assignment protested the selection of Turner.

After the selection process, FDOT, DMS, and Turner Construction, Inc., signed a contract on March 1, 2003. The GMP No. 1 bid package was issued to Turner on April 4, 2003, and the notice to proceed came in mid-July, 2003. The Organizational Chart for the MIC project is seen in Figure 1.

Construction items were broken down into separate packages called “GMPs”, each to be negotiated separately and each with its own Letter of Authorization (LOA). At this point, the GMP packages are as follows:

GMP I – RCF foundations and underground utilities. Cost: $17.6 million.
GMP II – MIC Terminal Access Roadways (MTAR), Transit Access Roadways (TAR), tunnels, LeJuene Blvd. water main. Estimated Cost: $21.0 million.

GMP III – Tri-rail Station, MIA Mover Guideway Foundation. Estimated Cost: $22.0 million.

GMP IV – MIA Mover Station (minus 4^{th}-floor lobby), RCF Building and bridge. Estimated Cost: $185 million.

The fourth-floor lobby is not currently planned for completion under this project. This raises the possibility of a GMP V, or that the lobby may be constructed under a separate agreement. [6]

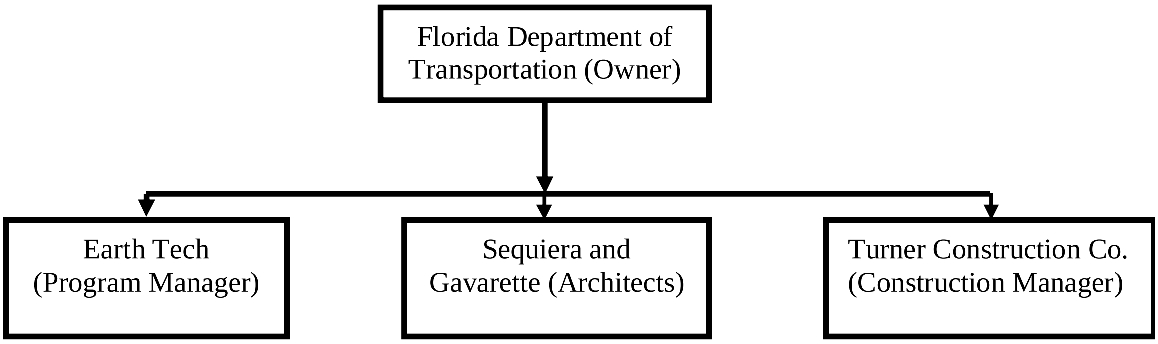

Figure 1. Organizational Chart for CMAR Portion of the Miami Intermodal Center

6. Project Progress

As of the time of this writing, GMP I was completed, GMP II was about 15% completed, Turner had been issued the LOA for GMP III, and the plans for GMP IV were at the 65% review stage. In getting to this point, the CM has overseen the driving of 2779 24-inch-by-24-inch pre-stressed portland cement concrete (PCC) piles, the construction of 672 pile caps, the placing of almost 15,000 cy of grout and approximately 11,500 cy of PCC. Also, over 120,000 cy of fill dirt has been delivered, spread, and compacted and 5000 linear feet of utility lines have been relocated.

Land acquisition and environmental remediation for Phase I and Phase II of the project have been completed. The RCF foundation has been completely constructed, and major roadway projects are under contract. MIA and Miami-Dade County are proceeding toward the procurement of an entity to perform a design-build-maintain for the MIA Mover utilizing advance funds from the county. Customer facility charges have been collected from planned users of the RCF since May, 2004.

7. System Evaluation

Theoretically, the CMAR delivery system brings a wide variety of advantages to a construction project; however, there are important elements that must be in place if CMAR is to bring all of its potential benefits to the project. Two of these essential elements are: 1) The CM must be on board no later than the 35% plans review, and 2) There must be a designer that works especially quickly and efficiently between the 65% plans review and plans completion.

If the CM is not on board by the 35% plans review, then the construction expertise that is so much a part of the CMAR design phase will be lost. In addition, if the designer does not move quickly from the 65% plans review to plans completion, the fast-track advantage will be lost because the CM cannot obtain many of the required permits without completed plans.

Unfortunately, Turner was not brought on board for GMP I until the plans were completed; therefore, there was not the level of constructability review that CMAR is known for. In addition, the project was delayed by the unexpected length of time required for TIFIA loan funds to arrive and was perilously close to being severely delayed by permit acquisition. In both cases, FDOT and the rest of the project team were fortunate. Although 50 change orders were executed in GMP I, resulting in a net cost increase of approximately $600,000, very few of them could have been avoided by a proper constructability review. As for the permits, the project team was again fortunate. The county allowed the RCF to be built under the old (2000) South Florida Building Code instead of insisting it be built under the new (2002), more demanding and time-consuming Florida Building Code, which saved time and outlay equaling at least $5 million. Project personnel estimate that had the authorities not allowed the project to be "grandfathered" into the old building code, the additional delay would have been at least a year. (MIC Personnel 2004)

Another big advantage of CMAR is that, theoretically, there should be a better relationship between the parties to the contract than under the DBB system. While all agreed that this was the case during GMP I, it is apparent that not having the CM on board until plans completion caused things to occur on the project that strained relations to some extent. For example, the CM was forced to act more like a prime contractor than a CM in some of the dealings with the subcontractors because of constructability issues and other questions that could have been solved proactively instead of reactively had the CM been on the team from the beginning. There were also issues between the program manager and the CM early in the process of GMP I that could have been avoided by having the whole team in place from the beginning.

Even with the CM coming on board late in GMP I, the evaluation of the system by the participants was positive overall. Project personnel reported a "great" relationship between the CM and their subcontractors and that there was much less of an adversarial relationship between all parties to the contract than has been experienced under the DBB system.

The difference between working on a project under the DBB system and under the CMAR system was described by one individual on the project as "two different planets. Under the DBB (low-bid) system, all of your profit is made on project changes. Contractor or CM personnel are trained to find potential changes. With CMAR, the CM is responsible for the whole job and the approach to the project is different. The CM under CMAR is much more service-oriented than a CM or prime contractor under DBB. In fact, when this company hires someone out of the DBB environment, it takes an individual about two years to convert from the adversarial attitude bred by the DBB delivery system to the more service-oriented attitude prevalent in the CMAR delivery system.” [3]

Other experiences and insights shared by those involved with the project include:

- The key element in the CMAR system on this project is the contingency fund (10% on this project). Without that, an adversarial atmosphere would appear on the project.
- Instead of the prime contractor or the CM looking for changes as on a DBB project, the subcontractors are doing so, but a strong CM insulates the owner from this problem.
- There was freedom to attract a blue chip contractor (CM), not the low bidder.
- There was much more flexibility and ability to handle the unexpected.
- There was freedom to attract a blue chip designer and pair them with the contractor.
- Much greater ability to handle things that the owner and CM are not familiar with, such as the elevated fueling facilities. [3]

For GMP II, the CM was brought in a little earlier than in GMP I; however, it was not early enough. Turner was brought in only a little before the plans for GMP II were completed but was able to influence the design via the VE process even though they were unable to help at all with the constructability review function. In short, in GMP II, Turner has been more involved in the design than in GMP I but still not fully utilized.

Turner was on board by the 35% plans review for GMPs III and IV. In fact, as of this writing, Turner had just received the 65% plans from which they will calculate and submit a GMP. The intent of CMAR as it is now being administered at MIC is for the CM to assume liability at the 65% plans review, but they have 60 days from receipt of the 65% plans to submit their guaranteed maximum price for any GMP, in this case, IV.

8. Summary and Conclusions

“MIC is a model for infrastructure development and implementation with partners including FDOT, Miami-Dade County (transit, aviation, expressway authority and seaport), US DOT (transit, highways, aviation, and Coast Guard), and various” companies from the private sector. Federal, state, county, and private funding sources are being utilized.

A TIFIA loan has played a critical role in the overall financial structure of the MIC program. It has allowed the parties to commence the project in the most efficient and timely manner and winning TIFIA loan approval won world-wide recognition for MIC.

Although the CM was not involved as early as needed in GMPs I and II, the CMAR system has still performed admirably. The adversarial relationship between owner and CM or prime contractor under the DBB system was greatly reduced even in this incomplete execution of the system. Many of the other advantages credited to the CMAR system were also apparent in the execution of GMP I and, so far, GMP II. Among these are:

- With CM-at-Risk, FDOT has complete freedom to select a design firm completely on the merits of its expertise, reputation, and concept of the project. Similarly, for the

construction work, it provides an opportunity to select a contactor with the expertise needed for a particular project and an excellent track record of completing projects on time and within budget.
- Instead of the prime contractor or the CM looking for changes to increase profits, the subcontractors are doing so, but a strong CM insulates the owner from this problem.
- There is a high degree of flexibility and ability to handle the unexpected
- The owner has much more control over the design process than is possible under the DB system

For GMP II, the design was also almost at 100% when the CM was retained; thus, no constructability reviews were provided by Turner. This time, however, Turner did make some contribution to the pre-construction phase by providing VE for some portions of the work.

GMPs III and IV will be more true to the theoretical CMAR because Turner is thoroughly involved in the design and construction activities with input from the beginning through constructability reviews and VE. GMPs. III and IV will, then, provide a more complete case study of the delivery system than the first two GMPs.

Much of the credit for the flexibility and service orientation of the CM and subcontractors was directed at the contingency fund (10% on this project). Without that, it was feared that an adversarial relationship would manifest itself on the project.

FDOT is very pleased, at this point, with its decision to use the CMAR delivery system, and the research team will continue to monitor the project to learn more about the application of this method to transportation construction.

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Poor Quality Costs in the Swedish Central Government Budget: the Influence on Costs For Construction Projects

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Abstract

The poor-quality costs in construction projects are traditionally estimated to 1-10% of the total project cost. These estimations normally include the projects' own processes. However, in Sweden more than 50% of the costs for producing buildings are taxes. To better understand the total poor-quality costs there should also be an analysis of the processes financed by the taxes. This paper aims to map and quantify poor-quality costs hidden in the taxes, here limited to an analysis of the Swedish central government budget. All the expenditures of the budget proposal for 2005 have been classified according to their proportion of poor-quality costs. The preliminary analysis indicates that as much as 28.9% of the expenditures in the public sector are poor-quality costs. This implies that more than 15% of the production costs of an average construction project are poor-quality costs that are hidden in the taxes. A reduction of these costs would enable a tax reduction or an increase of activities to other more essential expenditures in the public sector. Consequently, it will give the customers more value for their invested money.

Keywords: Poor-quality costs, taxes, construction project, public sector

1. Introduction

There are two main reasons to quantify the poor quality costs within processes, which the governments, the county councils and the municipalities take care of.

First, firms and other organizations, which measure poor quality costs, tend to limit their measurement systems to their own processes. In a few cases they also consider their suppliers' processes. In order to be more profitable, they should however, extend the system to consider all dollars, which transfers through the organization and try to find out why the dollars leave the customers' pockets. One starting-point is here that the organization direct or indirect through their actions can influence all these dollars.

Second, in the debate about the high costs for building, the actors argue that the reason is high costs for material, low productivity etc. The Swedish Construction Federation and The Swedish Property Federation argue that the pressure of taxation is too high. They should, however, not focus on the volume of taxation, but the processes financed by the taxes. The social system takes care of many consequences from poor quality within the industry. It would be worthwhile to look closer at what processes financed by taxes could be viewed as poor quality costs and find out how much it influence the costs for a building project.

The specific aim of this paper is to quantify the poor quality costs, which are hidden behind taxes. The analysis, which is preliminary, is limited to the Swedish central government budget for 2005. An underlying practical aim is to present facts, which stimulate the debate about the costs for building and which also stimulate firms and industries improvements. An underlying theoretical aim is to broaden the views about poor quality costs by taking the customers' view, and to stimulate further research within this area.

2. Poor Quality Costs

The theoretical framework for this study is the concept of poor quality costs. For many years the concept of quality costs was used and these quality costs were divided into prevention, appraisal, internal failure and external failure costs, first described by Feigenbaum [1]. Later the term poor quality costs (PQC) was introduced to highlight that it is poor quality that causes extra costs. The focus on the quality methodologies have changed over the years from an inspection orientation, through process control, to continuous improvement, and to designing quality into the product and process [2,3].

The concept of PQC has furthermore been broadened, because the concept of quality has itself acquired a broader customer perspective [4]. The customer is according to Sörqvist [4] viewed as anyone who is affected by the products and the business, e.g. shareholder, financier, state and local government, supplier, user, buyer, company management and employee. Sörqvist [4] uses this broader perspective by dividing poor quality costs into traditional PQC, hidden PQC, lost income, customers' costs and socio-economic costs. Taguchi has also a society perspective when defining non-quality as "the losses of society caused by the product after its delivery" [5].

When the view is broadened to an industry or society perspective, the concept of PQC will include additional activities, which directly or indirectly increase the costs for the customers. The systems used in industry and society may include activities, which can be considered as not adding any value for the customer. For improving the competitiveness it is necessary to develop the concept of PQC a step further and include costs for all other non-value adding activities as well [6]. Of that reason we define PQC as all costs related to poor quality that affect the customers, short-term as well as long-term. Cost is here defined as the value of resources used.

3. Method

We started from The Swedish central government budget 2005 (see Table 1). We looked at the 485 subsidies in the 27 expenditure areas and tried to find out how much could be classified as poor quality costs. For most subsidies that we have not been able to judge how much is PQC, we have assumed that the PQC is 7.5%. This decision is based on literature studies about PQC in various businesses and experience from on-going analysis of PQC in construction-related activities. When it comes to interest on central government debt (expenditure area 26) and contribution to the European Community (expenditure area 27) we have assumed that the PQC in these areas are in the same size as the average for all other expenditure areas.

We have not considered who has caused the costs. This implies that we have seen all costs, which are related to crime and justice as PQC. It also implies that we have seen most costs related to national defence as PQC as well as most costs included in the expenditure area “immigrants and refugees” as PQC.

The analysis is preliminary. It includes a number of assumptions. However, the aim with the paper is to stimulate the debate and make industry people aware that there are major poor quality costs hidden.

4. PQC in the Swedish Central Government Budget

The Swedish central government budget for 2005 is SEK 738.0 billion [7]. Our preliminary analysis indicates that the poor quality costs within the budget is SEK 213.4 billion or 28.9% of the budget. The major costs are related to three expenditure areas: financial security for the sick and disabled, SEK 68.1 billion, defence and contingency measures, SEK 37.9 billion, and justice SEK 22,9 billion, Table 1.

Table 1: Preliminary analysis of poor quality costs in the Swedish central government budget 2005 (SEK million).

	Expenditure area	Forecast	PQC
1	Governance	7840.222	635.071
2	Economy and financial administration	11432.140	1226.938
3	Taxes, customs and enforcements	8803.944	7043.155
4	Justice	27296.871	22868.473
5	International cooperation	1239.582	277.609
6	Defence and contingency measures	44146.606	37933.585
7	International development cooperation	22417.678	4402.850
8	Immigrants and refugees	6933.423	6693.635
9	Health and medical care, social service	39817.525	8335.284
10	Financial security for the sick and disabled	129691.062	68057.398
11	Financial security for the elderly	46413.203	3799.223
12	Financial security for families and children	56356.834	4422.805
13	Labour market	69313.416	12896.106
14	Working life	1193.970	337.555
15	Financial support for students	20995.726	1574.679
16	Education and academic research	43867.639	3290.073
17	Culture, media, religious communities, leisure activities	8956.525	720.656
18	Planning, housing provision, construction	9139.412	746.336
19	Regional development	3496.768	262.258
20	General environmental protection and nature conservation	3994.805	609.406
21	Energy	1396.435	104.733
22	Transport and communications	31666.492	2461.594
23	Agriculture, forestry, fisheries etc.	14655.991	1099.199
24	Industry and trade	3891.377	374.080
25	General grants to local government	57468.750	4310.156
26	Interest on central government debt, etc.	38770.000	11175.870
27	Contribution to the European Community	26802.000	7751.138
	Total, all expenditure areas	737998.396	213409.865

5. The Effect on Construction Projects

The taxes, which the government gets from construction and other industries, puts in the same bag and then distributes to a number of subsidies. This implies, theoretically, that if for example the number of accidents in construction will be reduced there will also be a slightly less tax burden.

The Swedish Property Federation and The Swedish Construction Federation have investigated how much the tax burden is on typical housing projects. Including all taxes and government-related charges The Swedish Property Federation [8] argues that the tax burden is approximately 58.8% of the cost to produce new houses, excluding cost of land. The Swedish Construction Federation [9] takes the analysis a step further and argues that the tax burden may be even higher. The tax burden varies to some extent between different types of products. If we include the cost of land, the tax burden will vary to a greater extent, since the cost of land is significantly higher in the major cities.

Our analysis is limited to the central government's budget while the total tax burden also includes local taxes for municipalities and county councils. Let us for a while assume that the volume of PQC is approximately of the same size within municipalities' and county councils' budgets as it is in the central government's budget. If this is true, the PQC hidden in the taxes corresponds to 17.0% of the cost to produce new houses!

6. Discussion and Conclusions

This paper considers a problem within quality management practices as well as within quality management research. Quality management is built on a customer-oriented philosophy. But when it comes to investigations on quality costs and poor quality costs the customers seem to be forgotten. Instead, the companies' own processes or cash flow is in focus. By taking a customer view in this kind of investigation, a number of hidden costs for poor quality are revealed.

Our analysis indicates that the PQC hidden in the taxes corresponds to 17% of the costs to produce new houses. This is far more than what is reported in most studies of quality costs or poor quality costs within construction. The main conclusion of our analysis is that further studies are needed to better understand the total picture of PQC within construction. Then single companies and single industries better can evaluate what costs related to poor quality can be reduced or not.

Note that this analysis is preliminary and includes a number of assumptions. However, we believe that a closer examination of the central governments' budget, the municipalities' budgets and the county councils' budgets, will end up in a similar size as we have presented here. Since the main aim with this paper is to stimulate the debate about the high costs for building and make practitioners and researchers aware of these hidden costs of poor quality, we believe that this preliminary analysis is relevant and valid.

We have also made an analysis of the central governments budget for 2004 using the same assumptions. Then we found that the PQC was SEK 211.9 billion or 28.7% of the total budget. It means that the PQC within the governments' budget has increased with 0.2% in one year. The main reason is that the budget for the expenditure area "Financial security for sick and disabled" has increased.

Acknowledgements

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A Risk Breakdown Structure for Public Sector Construction Projects

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Abstract

This research is part of a wider project (ProRIde) focusing on the risk identification stage of the risk management process. The specific remit of the study is to analyse the text of National Audit Office (NAO) reports to identify recurring risk sources on public sector construction projects. A textual analysis software, QSR N6, is used to code the data. The risk source information in organised and presented in a Risk Breakdown Structure (RBS), a hierarchical presentation of risk sources.

The output of this study represents a contribution to knowledge in that it is empirically derived – many risk identification support tools are compiled on an ad-hoc basis through brainstorming or personal experience. This research takes advantage of a rich existing database and employs a systematic methodology to develop an RBS that is specific to the context of public sector construction projects.

Keywords: Public sector procurement, construction, risk identification, risk breakdown structures, QSR N6

1. Introduction

1.1 Overview of the ProRIde project

ProRIde (**Pro**ject **R**isk **Ide**ntification) is an EPSRC-funded project (GR/R51452) concerned specifically with the risk identification phase of the risk management process (see Figure 1). Concurrent studies within the ProRIde project examine risk identification by individual project managers [1] and work is starting on group dynamics.

Comprehensive risk identification is central to the relevance and effectiveness of the subsequent risk management process [2] - unidentified risk sources remain as unknown and unmanaged threats to the project objectives.

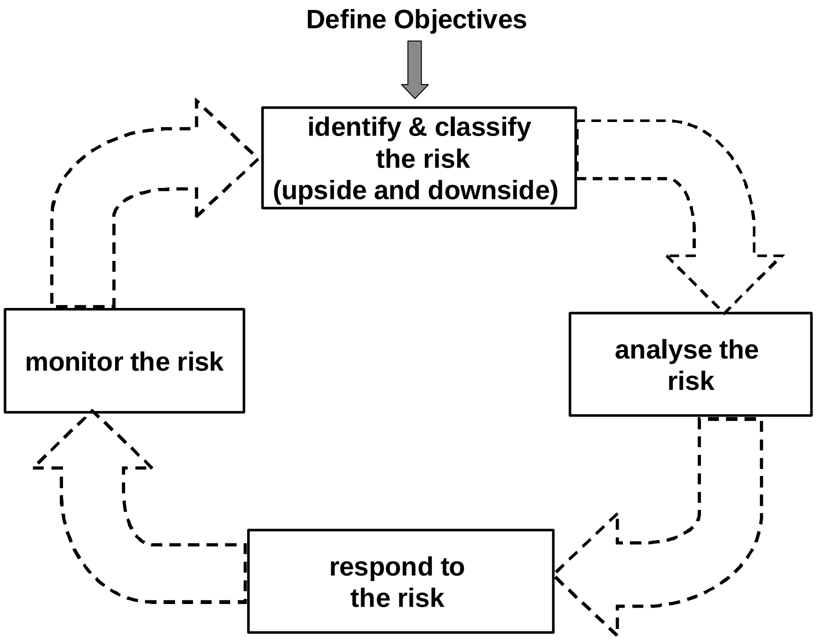

Figure 1: The ProRIde risk management process. After Winch 2002, p.322

Yet the identification stage is relatively neglected in risk management research [3]. There is much emphasis on the risk response stage of the process, with less attention paid to the initial identification and assessment sub-stages. Tah [4] observes that the risk identification stage is omitted from most risk management tools e.g. Monte Carlo simulation and sensitivity analysis, which only operationalise the assessment and analysis phases of the risk management model. Risk identification is assumed to be performed external to, and prior to, the implementation of most risk management techniques.

In the terms of the basic risk management model above, the aim of this study is to produce guidance for the identification phase based on a review of previous projects (the input arrow), leading to improved risk identification performance (the output arrow). High quality risk identification output provides a more accurate basis for subsequent stages of the risk management process.

The ProRIde scoping study [5] identified 'important common causes of concern' in the NAO reports on construction projects. The authors proposed the generation of:

'A feedback loop which offers all parties involved in the management of large, expensive, and complex projects the opportunity to improve efficiency and effectiveness'.

To create this feedback loop, this study takes the individual VFM reports to the next level of analysis. The text of the reports is combined in a knowledge base and reviewed for recurring themes. High-level lessons for risk identification specific to public sector construction projects can be drawn on the basis of multiple projects.

It is important to feed individual project learning in a wider framework so that we develop a systemic approach to risk identification. Ayas and Zenuik [6] note that despite the widespread and successful adaption of project-working, success is usually assessed in terms of a single project or organisation.

Using the past as a guide to future action has obvious limitations. No matter how many project reports are included in review, the final risk breakdown structure can never be considered comprehensive – unpredictable risks will always occur. But while we remain cognisant of this inherent uncertainty, it is important that we take advantage of the information that is available to us. This study takes a pragmatic perspective - reviews allow us to capture a certain amount of useful information and use it as a reference point to improve risk identification on future projects.

2. Risk Identification in the Public Sector

The high rate of failure on public sector projects in terms of time, cost and performance criteria suggests that a review of the Government's current risk management practice is due [7].

Risk identification for large-scale public sector projects is exceptional in terms of its scope and complexity. For example, in a multi-organisational context, as is the case for most government construction projects, it is important to identify systemic risks i.e. 'risk affecting a whole industry or service, as distinct from risks to the position of any individual organisation' [8]. The Office of Government Commerce (OGC) advise organisations to be aware of the risk management approaches adopted by their partners [9]. But NAO findings reveal that only 13% of departmental staff are aware of the risk management systems of other departments or their partner organisations in the private sector [10].

Government priorities also extend the range of risks to be identified. An obligation to secure public value and guarantee service provision means that risks posed by a wide range of external stakeholders and environmental conditions must be considered.

The potential for improving risk identification through project-based learning is limited by the movement of personnel on most public sector projects. Ideally staff would review project performance and record lessons learned centrally. But project personnel are often inaccessible after the event. Baldry [11] acknowledges that the usual method of accumulating past project experience and extrapolating to identify likely risks on future projects is not so straightforward on government projects. Concerted efforts are required to collate historical data due to 'the erosion of large directly employed, professional employee groupings within the public sector organisations' so that experience becomes 'distributed, transferred out or fragmented' (p.38).

2.1 Risk Identification Performance

A survey of risk management performance by the NAO [12] gives some indication of the Government's current proficiency in risk identification. The report highlighted the following areas of concern:

1. Responsibility for risk identification is generally allocated to board level – senior management are responsible for risk identification in three quarters of departments. Only 42% of departments report that other staff are responsible for identifying risks. A dedicated risk manager operates in only 13% of departments (p.57).

2. Departments report using a range of risk identification and risk assessment techniques, including a formal register for recording identified risks and self-assessment questionnaires for staff to record relevant risks. However, only 19% of departments are convinced of the effectiveness of these methods (p.62).

3. Fifty-six per cent of departments report that they identify the main risks relating to their key objectives. Focus group participants reported that 'objective setting and risk identification are treated as two separate processes and these are not routinely linked' (p.55). The NAO recommends that clarifying key objectives in terms of outputs and services facilitates the process of risk identification - departments can 'work back', identifying the risks that pertain to the achievement of these objectives.

4. The NAO warn against 'risk identification overload' – whereby every conceivable risk is recorded regardless of its potential probability or impact. NAO consultation with the private sector indicates that departments should focus on the top 10-15 key risks and opportunities – 'any more than this and management effort can become too diffuse across a large number of less strategically important risks' (p. 87).

5. The internal focus of most risk identification is evidenced by the three most frequently identified risks - financial risk (91%), project risk in terms of time, cost and specification (89%), and compliance risk in terms of failure to comply with regulations (85%). The NAO note the emphasis on departmental inputs and activity - there is less recognition of risk as a threat to outputs and services. The list also illustrates a relative neglect of the importance of external factors e.g. risks relating to external stakeholders.

This corresponds with the assessment of the Strategy Unit [13]. They note that the identification of financial and operational risk sources is relatively advanced on public sector projects. By comparison, the 'systematic assessment of policy risks is much less apparent' (p.46). This pattern of development is reflected in risk management generally – the area of audit / finance risk is most mature, followed by health and safety risk, operational and project risks and finally strategic risk. In relation to strategic level risk, the Strategy Unit states that 'systems still need to be developed that replicate the accountability and responsibility frameworks that exist for financial management' (p.46).

Despite the deficiencies in performance, a review of the available public sector guidance would suggest that Government is at the forefront of risk management – in theory. For example, the Strategy Unit describes the use of progressive risk identification techniques such as futures workshops and horizon scanning by government departments. Another example is the introduction of Risk Maturity Models to measure developments in risk management performance [14]. Also, considerable resources are allocated by Government to research and guidance documents for risk management. But the NAO results suggest that the practice of risk management lags behind the theory. The guidance is in place but it is not consistently implemented.

One reason for this may be a perceived gap between the available models and the conditions of the project in hand. Considerable work may be required to translate the generic guidance so that it is appropriate for individual projects. As such, an objective of this study is to produce a risk breakdown structure that is directly relevant and applicable to the circumstances and events of public sector construction projects.

3. The Current Study

3.1 Data – National Audit Office Value for Money Reports

The NAO is the external auditor for central government departments and all government agencies in the United Kingdom. The Comptroller and Auditor General has the power to report to Parliament at his / her own discretion on how government bodies have used public funds. The NAO presents approximately fifty Value For Money (VFM) reports on government procurement projects to Parliament each year.

The purpose of an NAO investigation and report is two-fold. Firstly, there is the traditional audit function - monitoring departmental spending. Secondly, the NAO has developed a more proactive function - that of adding value to government projects and thereby improving the quality of public service provision. The VFM reports combine both objectives – scrutinising performance against targets while also making recommendations for beneficial change on future projects.

The reports vary in scope, from examination of specific projects to comprehensive surveys of issues and practices across the whole of government procurement. They are primarily concerned with the performance of projects in relation to the time, cost and quality criteria. Reports generally conclude with recommendations for improved practice.

The series of VFM reports constitutes a valuable dataset that has been relatively unexploited to date. This research aims to take advantage of the detailed analysis and unique insights into the operation of complex projects that are available in the reports.

Reports that chart the entire project life cycle of a construction project are included in this study, a total of twenty-five project case histories. To assist the research effort, the NAO supplied electronic versions of all the earlier VFM reports that are not available online. A study of construction projects was perceived to be particularly worthwhile because although the NAO produce an annual report on the performance of major defence projects, there is no equivalent collation of information for construction projects. This is because no single Government department has responsibility for the construction procurement. As such there is no central structure or process for accumulating lessons learned and producing guidance for future construction projects.

Both conventionally procured projects and PFI projects have been included in the dataset. They have been treated similarly in the analysis on the basis that many of the risks to successful project management are generic, regardless of how the project is procured. However, it is anticipated that there will be some variety in the types of risk sources that pertain in each case. When the analysis is complete it will be possible to split the dataset according to procurements strategy to identify idiosyncratic risk sources.

3.2 Methodology – Textual Analysis

This is exploratory research. The aim is to produce a full account of the range and type of risk sources that occur on construction projects, rather than their frequency or impact. A qualitative research method is most appropriate to this objective.

QSR N6 is a textual analysis software, based on a code and retrieve facility. Units of text that are perceived to be connected are coded together into two different types of nodes (see the coding framework in Figure 2 below). **Free** nodes contain text units relating to independent, stand-alone issues. **Tree** nodes contain categories that are related in hierarchies. These nodes make up the coding framework for the project. The option to recode and rearrange hierarchies allows the researcher to change the coding framework as new risk sources emerge and merge. The retrieval function has several aspects. A text search retrieves text from the original document or from selected nodes based on keywords. Various ‘Boolean’, ‘proximity’ and other searches permit more complicated retrievals.

For the current research, the value of the software lies in the discipline that it affords the analytic activity of the researcher. In line with Lewins’ [15] recommendation - ‘it is important to know and to understand your methodological standpoint first, and then to bring a methodology to the software, rather than see the software as being the architect of your method’ (p.303). In this study, the software is used as a tool to support a qualitative analysis, guided by an *a priori* organising framework – the risk breakdown structure.

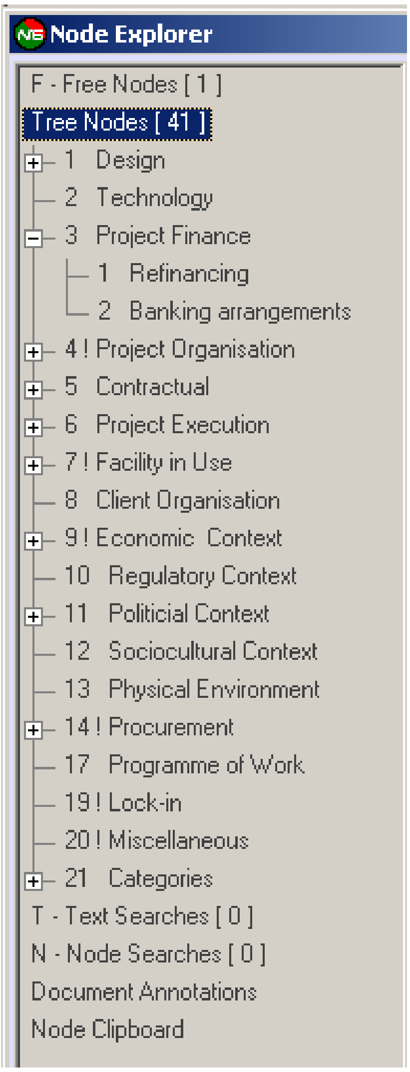

Figure 2: Coding framework in QSR N6

3.3 Organising Framework - Risk Breakdown Structures

An RBS is a framework for organising risk source data. Hillson [16] proposes the following definition:

'*A source-oriented grouping of risks that organises and defines the total risk exposure of the project or business. Each descending level represents an increasingly detailed definition of sources of risk*' (p.2).

Hillson offers a compelling account of the RBS as a means of presenting risk information to aid comprehension and guide the risk management process. It offers a more sophisticated presentation of risk information than the long lists that characterise checklists and risk registers. Checklists are one-dimensional – they do not offer insight into the structure of risk for the overall project. Neither does a list does not represent patterns of risk exposure or highlight areas that require special risk management attention.

An RBS was selected as a suitable organising framework for the current analysis. It provides a structure for the process of extracting and coding risk source information from the reports. An RBS also offers a practical solution for the management and presentation of the numerous risk source categories. An unwieldy list of risk sources can be re-organised and presented more efficiently within a hierarchical framework. There is the further advantage that the RBS and the QSR N6 coding framework share a hierarchical structure. This correspondence facilitates continuity between the data as it appears in the QSR N6 knowledge base and its summary presentation in the RBS format.

Having reviewed the literature, this researcher concluded that no existing RBS was directly relevant to the selected project reports. Therefore, it was decided to take advantage of all the risk breakdown structures generated to date by developing an synthetic RBS based on the range and frequency of existing RBS categories. The method allows the researcher to review, use and synthesise existing results in the research area. Thomas, Kalidindi et al. [17] used a similar technique, to develop an initial list of the primary risk sources on large infrastructure projects in India.

The risk source categories at the various levels of the available risk breakdown structures were collected in an Excel spreadsheet. Similar risk sources were grouped in the same column – this allocation was made when items were considered to describe similar risk areas even if they used different terminology. Some items were re-arranged and column titles were developed during a brainstorm session involving the researcher and supervisor. The resulting synthesis RBS was used as the basis of the coding framework in QSR N6.

3.4 Research Process – Iterative Cycles

A fundamental objective of this study is that the output should be empirically derived, in this case based on a rigorous analysis of the data in NAO reports. Many of the existing tools to support risk identification (checklists, registers and risk breakdown structures) do not have an empirical research basis, but tend to be the product of brainstorming or personal experience.

The research process proceeds in iterative cycles. Five reports are coded and reviewed in each cycle (see Figure 3).

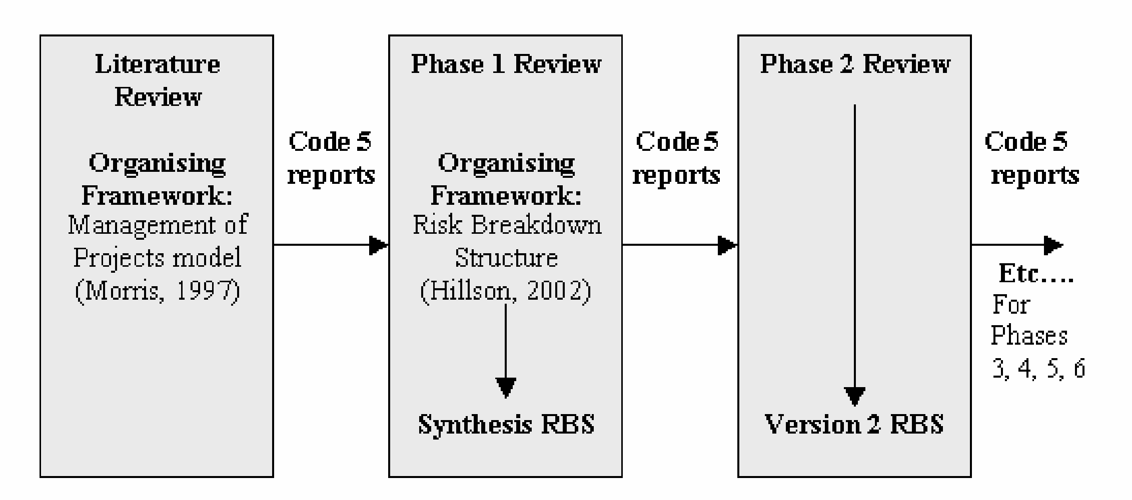

Figure 3. Model of cyclical research process

During the coding stage, the researcher goes through each report, text unit by text unit i.e. sentence by sentence. Text units that are considered to fit with existing nodes in the coding framework are coded into those nodes. Text units that do not fit into any of the existing node categories are temporarily stored in a 'miscellaneous' node.

During the review stage, emerging themes are identified, leading to either the sub-division of the existing node or the creation of new nodes. By this process the coding framework is amended and extended to accommodate those risk sources that are particular to public-sector construction projects. The developing RBS has been presented to NAO staff for feedback at regular intervals.

The cyclical review system also functions as an audit trail – developments in the risk breakdown structure and its underlying knowledge base in QSR N6 are recorded at each review stage.

The final version of the coding framework in QSR N6 equates to the output RBS.

4. Results to Date

4.1 Commentary on Version 5 RBS

To date, twenty NAO reports have been coded and reviewed. One more coding cycle (i.e. five more reports) is planned before the final version of the RBS is complete. This should be available for presentation at the conference in June. In the absence of final results, this section offers a commentary on the progress of the analysis to date.

The latest version of the RBS, Version 5, has developed significantly from the initial synthesis RBS. It contains 231 nodes compared to the fifteen nodes in the original RBS. The hierarchical structure now extends to six levels. In some cases, the nodes contain very few text units. These may be amalgamated with other nodes or removed altogether in the final analysis.

Alternatively, the new nodes may be supported by the next phase of coding, or through the further re-arrangement of text units in the final review phase.

It was anticipated at the outset that the developing RBS would become increasingly sector specific, that is, that the lower levels would refer to the construction context in detail. So far, this is not the case. In a feedback meeting [18], NAO employees agreed that the risk source categories of the Version 4 RBS were sufficiently generic to be applied to projects in most sectors. However, some of the novel risk source categories are specific to the public sector context, such as ‘responsibility to the taxpayer’ and ‘civil estate’.

A cursory examination of the size of the hierarchies attached to the risk sources provides an early indication of risk-critical areas – the ‘design’, ‘procurement’, ‘project organisation’ and ‘project finance’ nodes are characterised by extensive hierarchies. By contrast, the ‘external’ risk sources are relatively clear-cut – the hierarchies for ‘economic context’, ‘political context’, ‘regulatory context’, ‘socio-cultural context’, ‘physical environment’ and ‘programme context’ do not extend beyond Level 3 of the RBS. This suggests that factors within the control of the project organisation pose the greatest risk to the completion of construction projects, although this pattern may also be a function of the focus of the NAO investigation. However, the result does correspond with research on the determinants of project success at NASA [19] in which the authors found that external factors, such as legal-political difficulties, are not necessarily ‘fatal’ obstacles to project success if they are mitigated through effective management of more controllable factors. But the internal factors are more significant - a poorly managed project is most unlikely to be successful. To a large extent the project’s capability to deal with the external forces is determined by the quality and effectiveness of the organisational structure, the contract strategy and the financing arrangements, suggesting that it is not the external event that is decisive, but rather how it is managed.

4.2 Evaluation against Research Objectives

The research is on target to meet its objectives:

The analysis is providing a detailed breakdown of the risk sources that occur on large-scale infrastructure projects. Several of the risk sources represent a contribution to knowledge in that they are specific to a public sector context, and have not appeared in previous risk source taxonomies.

The RBS is empirically derived. A sound methodology of iterative cycles has been utilised so that coding is checked and re-checked in the light of emerging themes in the RBS. The method also creates an auditable trail of the evolving versions of the RBS.

The research has harnessed the rigour and discipline afforded by the data management functions of the textual analysis software.

The analysis is retaining the rich qualitative data. Data is stored at several levels of detail - the RBS is a summary of the text units stored in each node (the knowledge base). The original NAO data in each node is available by accessing the relevant node.

Feedback from staff at the NAO indicates that the final version RBS should have potential for further development as a practical risk identification tool. Indeed, it may be useful within the NAO as there is currently no generic risk register available to guide VFM investigations - the issues to be investigated by the NAO are chosen on a project-by-project basis. A comprehensive account of the risk sources encountered on previous projects would facilitate issue identification and provide a context for analysis.

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Factors Affecting the Complexity of Construction Projects

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Abstract

The construction stage is one of the major phases in the life cycle development process of a project. During this stage, it is essential for the project manager to understand and thus to determine the risk elements of the project prior to entering into a construction contract. As the determination of the contract period is crucial amongst other factors, contractors are sensitive to the time factor of a project during tendering. Time/cost trade-offs would be activated whenever the project duration is short. Unreasonably shortening of the contract period may render contractors to pass the risks back to the client through elevated tender prices or contractual claims. A fair allocation of risks can therefore balance the interests of all parties, which is essential for the successful accomplishment of a development project that helps foster a harmony relationship between the project team including the client, designers and other participants. All these ask for a good understanding by the project manager on the project nature, constraints and the complexity of a construction project.

There have been previous works studying the relationship between project durations, contract sums and floor areas, giving a generic understanding about the link between time, costs and volume of work for building projects. However, they do not address the complexity of a project in terms of site production constraints. In this study, apart from the general contract particulars, space-related factors affecting site production are also examined. This study attempts to analyse and identify the characteristics of building projects from the production perspective, aiming at enabling project managers to assess more accurately the project complexity, and thus the risk assessment and analysis for a construction contract.

Cluster analysis will be used to classify building projects into groups of various levels of complexity in a defined level of significance. The characteristics of each group will be reviewed and discussed. The interrelationship between the factors will also be examined. The findings of the study will give project managers some guidelines in assessing the risk factors of a project while the designers or the clients can appreciate the production constraints. A classification system for various levels of project complexity will be developed, with which, a better risk allocation can be made and a more realistic construction duration can be estimated

that help contractors to arrive at a reasonable tender and establish a more efficient production plan.

Keywords: Project characteristic, risk, complexity, cluster analysis

1. Introduction

The construction stage is one of the major phases in the project development process. In managing a development project, it is essential for a project manager to understand and thus to determine the risk elements of the project prior to preparation of the contract documents for a construction contract [1]. The determination of the contract period is crucial amongst other factors. Contractors are sensitive to the time factor of a project in tendering. Time/ cost trade-off would be activated whenever the project duration is shorter than the normal duration or when the project budget is exceeded [2]. Unreasonably shortening of the contract period may render contractors to pass the risks to the client through the tender sum or contractual claims. Lawyers tend to resolve the problems by revising and updating the conditions of contract [3 & 4]. A fair allocation of risks could balance the interests of the parties. This fosters a harmony relationship between the various project parties; namely, the client, designers and the construction team. This can only be achieved if the project manager has a very good understanding of the project nature and constraints.

Studies have been conducted to reveal the relationship between project duration, contract sum and construction floor areas [5]. This can give a generic understanding about building projects. However, it does not address the complexity of a project in terms of site production constraints. In this study, apart from the general contract information, factors affecting site production are included and examined. These include the design of building, forms of structure, building layout, site space and production facilities, etc. This research attempts to analyse and identify the characteristics of building projects at the production perspective. With such understanding, project managers could rate projects in terms of their complexity and are able to develop a fair risk allocation for the construction contract.

2. Appraising the Difficulties of a Project

“How difficult or complex is the project?” This could normally be the first question asked by a project manager or the senior management of a building contractor prior to the preparation of a tender or a production plan. Most construction projects have been commonly described as complex and unique that could not be defined in simplistic terms. This is certainly not a question that could be answered with just a glance at the contract documents especially during the tendering stage. In making decisions during tendering, construction planning, resource allocations and company strategies, detailed information would be prepared for scrutiny by the senior management. The critical information for a construction project will include the estimated contract sum, contract period, floor areas, building design, any special features and site conditions. However, such generic information may not be able to depict the complexity of a project and it would be worthwhile to analyse and integrate these information to develop an overall picture to reveal the project characteristics.

Facing with the time constraint in tendering and pre-contract planning, it is common for senior managers to make decisions largely based on two or three attributes of a project from a macro perspective. “Contract sum”, “construction period” and “construction floor areas” are the typical primary information to build up the decision tree. These attributes can depict the scale of a project and were thought to be good indicators for describing the complexity of the project. However, they cannot explain the difficulties or the constraints on production planning; for example, a small scale project classified in terms of the contract sum can give misleading results if the site is very confined without sufficient working space and good access. Supervisory staff at the production frontline always expresses their resentments about the oversimplification by the senior management in defining the project scope and inadequacy in resource allocation. The allegations are based on the fact that senior management may allocate the manpower and site facilities, including plant and equipment in a pro-rata scale based on the contract sum and construction floor areas.

There were some researchers studying the facility layout problems aiming at optimizing the site space at operational level [6, 7, 8 & 9]. Contrasting with them, this study aims at providing a better understanding in the classification of building projects, and thus to improve decision-making with respect to site production planning at the contract planning stage. Apart from the aforesaid attributes, seven factors will be identified, which can be extracted from the project data for analysis.

3. Factors Affecting the Complexity of Building Production

Information of 30 high-rise building projects have been collected to examine the validity and the robustness of the aforementioned three primary project attributes and another seven space-related attributes in describing the complexity of a project. These projects are widespread in size in terms of contract sum, site area and gross floor areas. Also, they consist of public housing projects, private residential projects, commercial building projects and composite developments. Table 1 shows a summary of descriptive statistics of the projects.

Table 1 Summary of Project Information

Variable	Cases	Mean	Std. Dev	Maximum	Minimum
Contract Sum	30	672.18	574.74	3000.00	41.00
Contract Period	30	26.17	4.91	37.00	18.00
Gross Floor Area	30	97106.13	73611.52	315990.63	5289.20
Site Area	30	12871.37	12523.97	67790.54	448.26
Podium area	30	5907.87	5515.91	26796.09	448.26
Tower block area	30	2794.21	2114.78	8253.34	179.29
Number of building	30	3.37	2.43	12.00	1.00
Working Space	30	6946.78	8456.72	40994.45	0.00
RWSPBA	30	2.32	1.92	8.40	0.00
RTWSPSIA	30	0.52	0.24	0.93	0.10

Where:

(i) Contract sum denotes the contract price or estimated construction budget (in millions of dollar)

(ii) Contract period denotes construction time for the construction of superstructure (in months)

(iii) Site area denotes the total site area falling within the site boundaries (in square meter).

(iv) Gross floor area denotes the total construction area (in square meter)

(v) Podium area denotes the total floor area of the podium of a building or buildings (in square meter)

(vi) Tower block area denotes the total areas occupied by the buildings above the podium floor (in square meter)

(vii) Number of building denotes the total number of buildings to be constructed

(viii) Working space denotes the site area not occupied by the permanent structures (in square meter)

(ix) RWSPBA denotes the ratio of working space to the tower block area (in square meter)

(x) RTWSPSIA denotes the ratio of working space to the site area (in square meter)

Variables in relation to site space, which are critical production constraints, are introduced in the analysis. In building production planning, the site layout plan represents the production line set-up of a factory. In formulating the site layout plan, it is necessary to balance the space requirements for different site activities. However, if space is more than adequate to meet the demand of the production process, there is no need for the trade-off exercise and it becomes largely a space allocation problem [10]. For example, if heavy building materials or components can be stored within a large storage space with good access for delivery and unloading which can be reached by a tower crane, production planning is a simple exercise to minimize the hoisting time for transferring the materials from the storage position to the work place. However, a site with irregular configuration and insufficient space, it is necessary to trade-off the storage areas for different materials or components, the schedule for the installation processes, the storage areas and the access roads. The inclusion of the space related variables gives a more accurate assessment on the complexity of projects in the context of production management.

As shown in Table 1, the seven space-related variables describe the areas to be constructed and space availability for a project. In addition to the gross construction floor area, the floor area of a tower block and the area of the podium supporting the tower blocks are included. In some extreme cases, the podium area could occupy 90% of the site area. However, the building structures sitting on top may occupy just 40% of the site area. In order to reflect the relationships between these variables, two ratios, namely the RWSPA and RTWSPSIA, are derived to assess the adequacy of site space.

4. Classification of Building Projects

It is often difficult to define the nature and complexity of a project and construction management people always use the following terms to differentiate the characteristics of a project: large, small, medium, simple, difficult, complex, complicated, highly integrated, confined, unique, etc. The use of these semantic terms can give some inference to the basic constraints of a building project; namely time, cost, quality and space, and is simple and easily understood by readers. The disadvantage is that it could be misleading to depict the complexity of a project.

In order to derive an objective classification system for projects, cluster analysis techniques, which have been widely used in areas of marketing, biology and medicine are adopted in this study [11]. To start, building projects are reviewed, classified and verified by using SPSS Hierarchical Cluster Analysis (HCA), K-Means Cluster Analysis (KCA) and Discriminant Analysis (DA). The projects are firstly classified by using the HCA and then verified by KCA and DA. The use of DA can establish classification function coefficients for classifying future projects. Further, the study attempts to compare the classification generated by using the three primary variables and subsequently by all the ten variables.

The objective is to classify the projects into groups with distinguishable characteristics. The analyses aim at dividing the project samples into five groups using the concepts of natural classification without limiting the number of group membership. This would facilitate the project mangers to describe the project definition [12].

4.1 Initial Appraisal for Building Projects

The first attempt is to compare the classification derived by using general project information, namely contract sum, contract period and gross construction floor areas. Table 2 shows the membership of the projects classified by using the general project information. Tables 3 and 4 show the characteristics of the groups in terms of minimum and maximum values of variables for the groups.

4.2 Classification by Contract Sum

In the groups classified by contract sum, the resultant groups are ranked in ascending order. Apart from Group 1, the subsequent four groups have a similar range with the group boundaries between 137 million and 183 million. Although the classification would be affected by the data in the analysis, it is reasonable to observe that the classification is similar to the conventional semantic description for a project in terms of large, medium and small.

4.3 Classification by using Three Basic Project Variables

In the classification using the three basic project variables, the groups overlap in the ranges of contract sum. It becomes inappropriate to describe the projects by using the conventional semantic terms. The characteristics of the groups are governed by the interactions between the variables which can be explained by the group characteristics and the classification function coefficients shown in Tables 4 and 5 respectively. The following characteristics are observed:

1. Groups 1 and 2 – These two groups have similar characteristics with negative coefficients for contract sum and gross floor area. It means that the contract sum is less significant to describe the project. On the other hand, the contract duration is the dominant factor and covers a broad range of 18 to 34 months. From the observations, it may reasonable to state that projects of small to medium size in terms of contract sum have significant difference in project duration, which is relatively longer than projects of other groups. It may infer that the time factor for these projects is not critical.

Table 2 Classification for building projects

Project Reference	Classification Variable		
	Contract sum	3 Basic Project Variables	Basic & Space-related Variables
1	1	1	4
2	1	1	4
3	1	1	4
5	1	1	3
8	1	1	4
9	1	1	3
11	1	2	4
14	1	2	4
17	1	1	4
25	1	1	4
27	1	1	3
4	2	2	4
6	2	3	4
10	2	4	2
15	2	2	4
21	2	3	4
22	2	3	1
23	2	4	2
29	2	3	2
7	3	3	4
18	3	3	1
24	3	4	4
26	3	4	5
28	3	3	1
30	3	3	3
12	4	5	5
13	5	4	2
16	5	3	1
19	5	3	1
20*	x	x	x

*Project 20 contains extreme data and was excluded in the classification.

Table 3 Classification of projects by contract Sum - Group Characteristics

	in million $	
Group	Min	Max
1	41	400
2	497	680
3	740	877
4	1000	1179
5	1756	1756

Table 4 Classification of projects by contract sum, construction duration and gross floor area - Group Characteristics

	Contract Sum in million $		Contract Duration in months		Gross floor area in meter square	
Group	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
1	41	400	18	25	5,289	70,708
2	200	500	28	34	24,297	157,776
3	577	1070	22	26	58,436	235,115
4	500	1179	30	36	91,132	176,996
5	1756	1756	37	37	217,501	217,501

Table 5 Classification of projects by contract sum, construction duration and gross floor area - Classification Function Coefficients

	Group				
	1	**2**	**3**	**4**	**5**
CONTSUM	-0.0061	-0.0048	0.0098	0.0032	0.0356
CONTPERD	4.8732	6.8313	4.8786	6.7053	7.1917
GFA	-0.00000407	-0.00002373	0.00002566	0.00002750	0.00001834
(Constant)	-54.9755	-106.9848	-65.6303	-111.9356	-167.9171

2. Group 3 - The contract duration is still the dominant factor whereas the coefficient for contract sum is positive and thus has more influence on the classification. The range for project duration covers a relatively narrow range between 22 and 26 months. Further, the gross floor area has a positive influence on the classification and covers a broad range of 58,436 to 235,115 square meters. It may be reasonable to state that the projects of this group which are conventionally described as medium to large size generally having a relatively tight project duration and with a high variation in the work contents in terms of gross floor areas.

3. Group 4 - the contract duration has imposed further influence on the classification and the contract sum and gross floor area have similar influence on the classification as in Group 3. It is observed that the range of contract sum of 500 to 1179 million for this group is similar to the range of 577 to 1070 for Group 3. However, the project duration for these projects has a relatively longer duration between 30 to 36 months.

4. Group 5 - There is only one project which is the same as that in the classification by contract sum. This project is unique amongst other projects in terms of contract sum, contract duration and gross floor area. The project can be described as mega size and thus needs to be considered separately.

The project classification generated by the basic project information provides further understanding about the nature of the project and could enable project managers to identify the dominant factors of a project especially on the time factor. On the other hand the classification reveals that there may be imbalance for project duration as it appears that projects in Group 3 have a relatively tight project schedule. This would be a good reference for clients or the design teams for determining reasonable project durations.

4.4 Classification by Using Basic Project Information and Space Related Variables

With the inclusion of seven space related variables, the governing factors for the classification becomes complex and is significantly different from the previous classifications. The characteristics of the groups and the coefficients of the variables to the cluster centre are shown in Tables 6 and Table 7 respectively. The characteristics for the groups are discussed below.

1. Group 1 – Site area and the site space are the dominant variables in this group. In view of site planning, these projects have sufficient space for site layout planning as the ratio of working space to building area, between 2.21 and 5.54, is the highest among the other groups. The negative coefficient for project duration implies that time may not be critical in this group. The scale of the projects in terms of contract sum is between medium to large size. With sufficient working space and reasonable project duration, it may conclude that there will be less constraints, more flexibility on site layout planning and project scheduling.

2. Group 2 – Contract duration, gross floor area and the ratio for total working space and site area are the dominant variables in this group. The range for contract duration is between 24 and 36 months and gross floor area is between 101,838 and 146,068 square meters. Although the work contents for the project is high as reflected also in the contract sum, there are relatively less working space, between 1.76 and 3.38, in this group when compared with Group 1. The significance is shown by the high coefficient assigned to the space ratio. Projects in this group would therefore have a reasonable project schedule but with moderate difficulties in site planning.

3. Group 3 – Space related variables have large coefficients and become significant in this group whereas the contract duration has a large negative coefficient. Comparatively, both the scale and the contract duration are moderate in this group. But, the working space available is high for the projects as reflected in the ratio of working space to total floor area, from 1.68 to 5.11. With the sufficiency in working space, production planning for the projects would not be too difficult.

4. Group 4 – This group, which has the highest number of members, consists of 14 projects. Except for the contract duration, all the variables are assigned with negative coefficients. The contract duration varies between 22 and 34 months. This may be due to the broad range of contract sums, from 41 to 870 millions. The projects can be described as small to medium size. However, the total site areas for the projects in this group are small when compared with other projects and thus, the working space to

building area ratio is low. Therefore, these sites can be classified as confined site and there will have more constraints on site layout planning and production planning.

5. Group 5 – There are two members in this group. They are high-rise buildings with tower blocks sitting on a large podium area. They are large projects with high contract sum, long contract duration, and high work contents (gross floor areas). However, there is limited working space as reflected in the working space ratio (0.5 to 0.54). The sites are therefore highly confined with small working space for production planning. Project scheduling and site layout planning for these projects should be well co-ordinated so as to optimize the use of site space for supporting work schedule. Multi-stage site layout planning is expected in such site conditions.

The project classifications generated by the basic project information and space related variables provide different views on characteristics of the project and give more information about the relationship between the contract size, work contents and work space. Although the order of the grouping may not be able to determine accurately the complexity and difficulty of the projects, the classification is able to alert planners about the potential constraints on production planning in relation to project scale or project duration. The characteristics and the degree of complexity of the projects are summarised in Table 8. The indications on production complexity also enable contractors to improve risk assessment for construction projects.

5. Conclusion and Recommendations

In this study, apart from the general project information, factors affecting site production are also examined in the evaluation of project complexity and nature. This study attempts to analyse and identify the characteristics of building projects from the production perspective, aiming at enabling project managers to assess more accurately the project complexity and the project risks. With a good risk planning and risk allocation, this would mitigate contractual disputes [13].

The classifications generated in this study have successfully grouped the projects in terms of basic project information and space related variables. This study provides a new approach in analysing the interactions between the ten critical project variables. It is observed that the memberships for grouping are significantly different. The classification by using the three basic project informations reveals that there may be imbalance for project duration with respect to the contract sum. With the inclusion of the seven space related, there are significant changes in the memberships for the project groups. The resultant groups are more able to address the complexity of a project. The ranking of the project groups is able to indicate the degree of project complexity. Practitioners may apply a heuristic approach in classifying projects in similar ways. But, it may be difficult to rank the complexity accurately and consistently. This study provides a systematic approach to determine the complexity of projects with reference to the interactions between the ten project variables. The information would alert and be useful for planners to assess the risk and complexity of projects. Specific attentions would therefore be given for projects with confined site space, tight schedule and high work contents.

Apart from the variables selected, there are other project variables which could be used to assess the complexity of a project. It is suggested to explore these variables in order to build up robust models to improve the classification and to determine the risk level of a project. The findings described in this paper provide a stepping stone for future in-depth studies on project risk and contract planning.

Table 6 Classification of projects basic project information and space related variables: Group Characteristics

	Range	CONTSUM	CONTPERD	GFA	SIA	PODA	TBA	BNO	WSPA	RWSPBA	RTWSPSIA
1	Max	1070	26	235115	25155	5735	5735	7	19480	5.54	0.87
	Min	680	24	137628	16660	3441	3441	3	11475	2.21	0.69
	Diff	390	2	97487	8495	2294	2294	4	8005	3.33	0.19
2	Max	1179	36	146068	12886	6515	3441	5	9445	3.38	0.90
	Min	500	24	101838	10416	3251	2214	3	3901	1.76	0.53
	Diff	679	12	44230	2470	3264	1227	2	5544	1.62	0.37
3	Max	877	22	90500	22499	14043	5028	5	8456	5.11	0.93
	Min	315	18	38522	8760	2408	1139	2	5117	1.68	0.39
	Diff	562	4	51978	13739	11635	3889	3	3339	3.43	0.54
4	Max	870	34	91132	9301	7855	6135	4	4620	4.03	0.78
	Min	41	22	5289	448	448	179	1	0	0.00	0.10
	Diff	829	12	85843	8853	7407	5955	3	4620	4.03	0.68
5	Max	1756	37	217501	18912	15662	8253	7	4162	0.54	0.38
	Min	790	33	176996	18660	14750	5503	4	2998	0.50	0.16
	Diff	966	4	40505	252	912	2751	3	1164	0.04	0.22

Table 7 Classification of projects basic project information and space related variables: Final Cluster Centre Coefficient

Variables	**Group**				
	1	**2**	**3**	**4**	**5**
Zscore(CONTSUM)	0.719	0.353	-0.298	-0.531	1.808
Zscore(CONTPERD)	-0.378	0.750	-1.315	0.045	1.758
Zscore(GFA)	1.183	0.671	-0.452	-0.733	1.737
Zscore(SIA)	1.425	0.120	0.460	-0.831	1.093
Zscore(PODA)	-0.011	-0.265	0.673	-0.478	2.554
Zscore(TBA)	0.941	0.096	-0.081	-0.621	1.965
Zscore(BNO)	1.055	0.372	0.235	-0.740	1.328
Zscore(WSPA)	1.831	0.342	0.119	-0.729	-0.392
Zscore(RWSPBA)	0.969	0.309	0.663	-0.479	-1.016
Zscore(RTWSPSIA)	1.005	0.820	0.198	-0.505	-1.013

Table 8 Characteristics of projects classified with space related variables

Group	Contract Sum	Project duration	Site Space	Production Complexity
1	Medium to Large	Medium	Large	Low
2	Small to Large	Long	Small to medium	Average
3	Small to medium	Short to medium	Small to Large	Moderate
4	Small to medium	Medium to long	Small to Medium	Intricate
5	Medium to Very Large	Long	Small	High

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Risk Management in Small Sized Construction Projects

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Abstract

Risks and other uncertainties can cause losses, which lead to increasing costs and time delays, both during the project and at the end. The need to prevent failures during the construction process and other losses related to construction has been emphasised in various reports. Example consequences are failure costs in civil works which can be close to 8% of the total budget for projects – more than 60% of these are costs due to 'self-inflicted' uncertainty. However, this paper is focused on small sized construction projects (in the range 1-15 MSEK), which are dominant in the Swedish construction sector today. They account for 83% of the total number of projects.

The aim of this paper is to describe how risks and uncertainties are managed in small sized construction projects. Some characteristics of these projects are presented, for example their organisation, financial size and type of contract undertaken. The paper identifies and describes the ways in which risk analyses are performed on a number of small projects today and where the common risks are believed to lie. The study is based on interviews with personnel selected from a number of construction companies. In order to be able to make improvements in the construction sector, a clear focus on uncertainties, which means both opportunities as well as risks, is needed. Organisations working mainly on small projects, that wish to improve their performance, need systematic methods for managing risks.

Small sized construction projects are found to be managed both intuitively, i.e. based on experience and systematically, i.e. using methodologies for risk and uncertainty management. The systems are, however, developed with the intention of fitting all sizes of projects and not specifically small sized projects. Some common risk sources in these projects are contract documentation and tight schedules, the client, individual planning and logistics, cost estimates used to compile the tender, subcontractors, technical solutions, safety of third parties and weather.

Keywords: Risk, uncertainty, risk management, uncertainty management, small projects

1. Introduction

1.1 Background

Risks and other uncertainties can cause losses, which lead to increased costs and time delays, during the currency of projects and at their end. The need to prevent failures in the construction process and other losses relating to projects has been highlighted many times over the years and figures strongly in a recent major report in Sweden [1].

The most common project size in the Swedish construction sector is less than 15 MSEK (roughly €1.65m). In the study reported in this paper, projects in the range 1-15 MSEK have been chosen, whilst those in the range of 0-1 MSEK have been excluded. According to Sveriges Byggindustrier [2], as much as 83% by number of projects are in the range of 1-15 MSEK. The reason for choosing this particular segment is that the smallest projects, the ones between 0-1 MSEK, are less interesting from a project risk management perspective. Their nature is inherently more like continuous business than project-based.

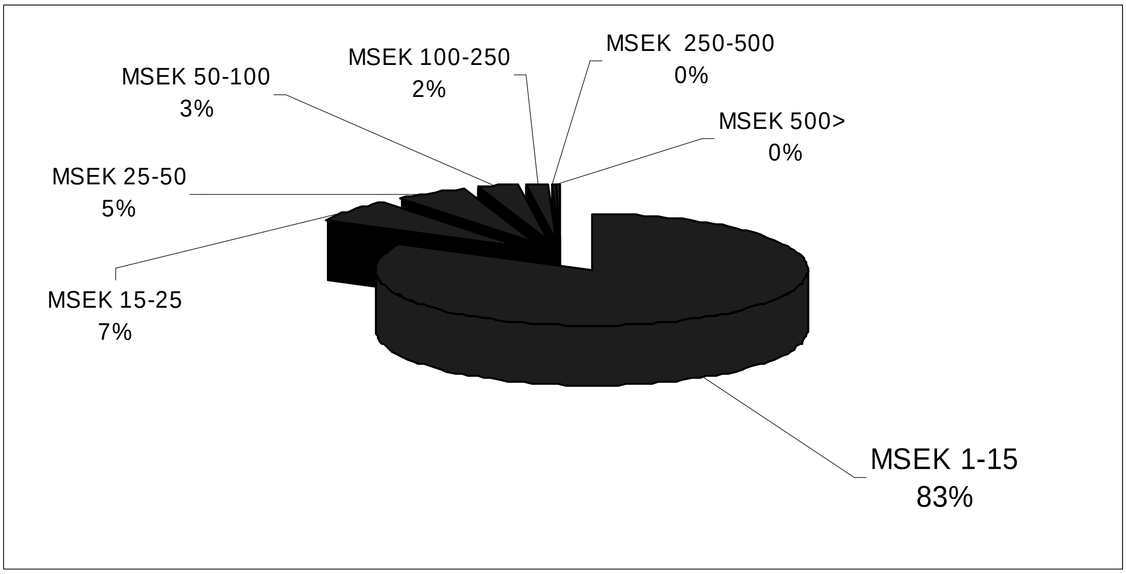

Figure 1. Number of projects divided into segments in relation to their size in the Swedish construction sector 2004.

Risk management and other types of applied management have been used routinely in construction projects, but have often been exclusive to large and exposed projects. Studies tend to cover large-scale projects, often with many different participants [3], [4] and [5]. The risks cover a spectrum of events from financial, political and legal to technical, often relating to complex construction.

In one study [6], failure costs for civil works were identified as being close to 8% of the total budget for projects and more than 60% of those costs were due to 'self-inflicted' uncertainty. The study also focused on large projects and clients' perspectives. 'Self-inflicted' uncertainty is due to ignorance of earlier experience of failures that continue to appear in similar projects in the future.

In small sized projects, the risks are more moderate and the consequences are less dramatic. These projects are more vulnerable to changes of the kind that have an impact on time since there is less chance of catching up if the schedule slips. On the other hand, the nature of the construction work and the project environments are often rather straightforward and the technical challenge is limited. This picture of the situation for small sized construction projects is based on the author's own observations and that of the study's reference group.

1.2 Aim and Objectives

The aim of this paper is to describe how risks and uncertainties are managed in small sized construction projects. Three specific objectives have been set as follows.

- Present the characteristics of small sized construction projects.
- Describe the ways in which the risk analyses are performed today.
- Define common risks that occur in small sized construction projects.

In order to reach these objectives, interviews have been conducted to collect data.

This paper presents the results of a pre-study forming a part of a research project which is investigating uncertainties in small sized construction projects. The research question to be answered in the pilot study is 'how to find out how risks and uncertainties are managed in small sized construction projects today'. Further research questions to be addressed in the research project are related to the relationship between theories, companies' policies and practical work, and also to the identification of obstacles and ambitions/incentives for uncertainty management in small sized construction projects.

1.3 Definitions

1.3.1 Small Sized Construction Projects

Searches of the literature did not provide conclusive evidence of what exactly characterises a small sized construction project, neither did discussions with different actors in the sector. The characteristics of a small sized project were subsequently discussed and agreed within the study's reference group. The result is sufficient description to distinguish these projects from very small projects, which are more in the nature of continuous business operations and, at the other end of the scale, from large projects.

The characteristics agreed upon of small sized projects for the purpose of this study are:

- contract value between 1-15 MSEK
- a site manager responsible for a maximum of two projects simultaneously
- limited construction time, maximum 12 months
- established technique, no development work
- project environment is independent
- personnel involved are more generalist than specialist

1.3.2 Risk and Uncertainty

In order to be able to discuss risks and uncertainties there needs to be some sort of definition of these concepts within the study. Uncertainty is part of everyday life, since we are not able to predict the future accurately. The amount of uncertainty and the ways in which we can handle this uncertainty could, however, be defined and structured.

According to Aven [7] uncertainty could be either aleatory or epistemic. An aleatory uncertainty is of a random nature and is hard to predict. An epistemic uncertainty is “lack of knowledge about fundamental phenomena”, which refers, for example, to the use of models and assumptions. In this study, uncertainty refers to both aleatory and epistemic uncertainty using Aven’s terminology.

Chapman and Ward [8] state that there is a need for a clearer focus on the upside effects, i.e. the opportunities. They also think that is desirable to let go of the historically close connection to events, conditions and sets of circumstances and instead shift attention to the different sources of uncertainty that could lead to threats of failure or, equally, opportunities. Their opinion is that it is vital to understand where and why uncertainty is important in a given project context and not to focus solely on threats and opportunities connected to given events, conditions or circumstances. Chapman and Ward [8] continue their line of argument with the suggestion that “uncertainty management” should replace traditional “risk management” to indicate that a wider perspective is being sought. This study starts with the aims of Chapman and Ward in order to widen the concept of risk management and use the concept of uncertainty management in its place.

The definitions of risk and uncertainty found in the literature are not consistent. There are several different definitions and approaches from different areas of research. According to the Project Management Institute [8] a definition of risk should take into account both positive and negative effects on a project objective. This is a broad view in terms of threats and opportunities and how they are connected to an event, a condition or a specific circumstance. Even if the risk according to [9] includes upside effects, the tradition is to focus on the downside, i.e. the negative effects. Project risk is defined as the “combination of the probability of an event and its consequences for project objectives” [10]. This definition is well known in the construction sector and elsewhere and is, by tradition, closely associated with a threat. Conversely, opportunity is neglected despite the enlightened definition found in [9].

It is necessary that each study defines its own approach and view of risk and uncertainty. In this study, the term uncertainty is used to point out the possibilities for both types: “risks”, with the negative effects; and “opportunities”, with positive effects. The definition of risk used here focuses on the negative outcome of an uncertainty and is seen as more dramatic than uncertainty.

Uncertainties are handled everyday on a construction project, but not all are of the type that needs special attention. In this study, uncertainty is defined as something that occurs and which was neither foreseen in the project description nor in the contract, being often caused by lack of knowledge on the part of one or more of the parties. The uncertainty could be an event that occurs during the project. It could also be something that is known from the beginning that makes the project unique, i.e., that makes it different from the standard procedure. Those uncertainties could lead either to risks or opportunities and need to be taken into account.

1.4 Research Limitations

Risks appear at different levels and likewise have different consequences for their surroundings. Depending on the approach taken, different risks will be found. In this study, risks in construction projects are examined, from the contractor’s perspective. Risks that appear at other levels are not considered, although they could affect the project’s objectives (figure 2).

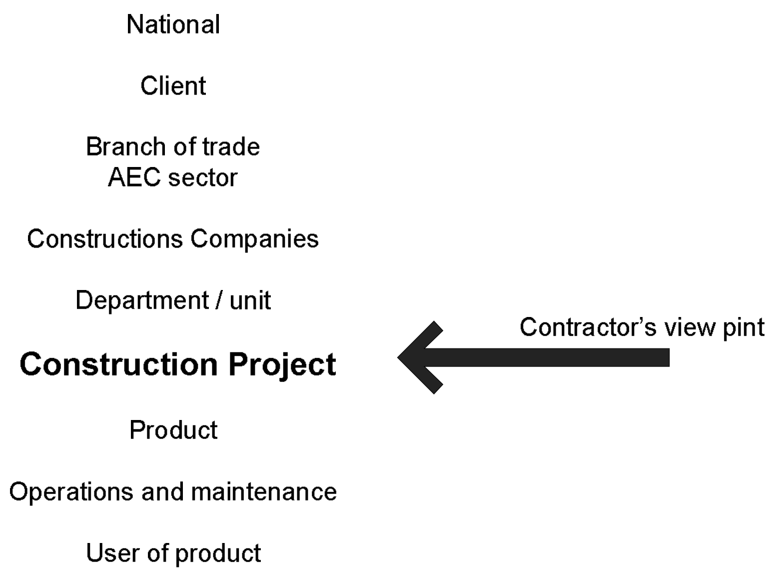

Figure 2. Selected approach for this project.

In the context of a construction project some further limitations regarding uncertainties and risks are considered in the study. Risk sources which are outside the framework of the study are, for example, political decisions, the financial situation of the client as well as the contractor, changes in organisation and illness among personnel involved in the project. These risks could have both positive as well as negative effects on the project's objectives, but are often out of the control of the site manager. For that reason, they will be left outside this study. Risk sources that are to be considered in this study are the project's economic boundaries, relationships with the client, technical solutions, aspects of production and weather. These risks are either within the control of the site manager or affect the project directly without interference from other levels of the company's organisation, for example, weather. Between these defined areas, risk sources from geotechnical engineering and the work environment will be found. These two areas represent many of the risks in the construction sector and have been studied separately earlier in other studies [3]. For this reason, they will not receive any special attention in this study.

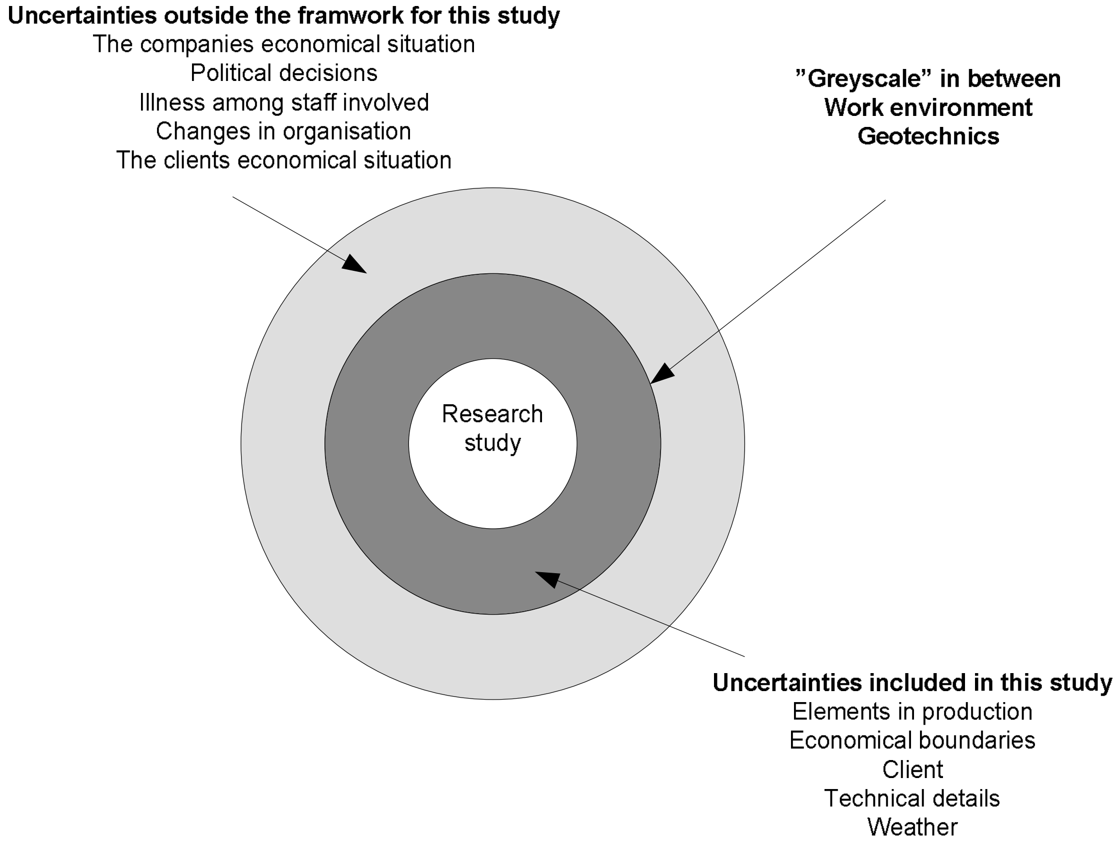

Figure 3. Risks and uncertainties in relation to the project.

2. Risk Management Today

2.1 Collection of Data

2.1.1 Method for Data Collection

The principal method used to collect data is interviews with managers of different projects from different companies. The strategy used for selecting projects is that the project must be either in a state of production or “fresh in memory”. Projects that have just started have not been selected because of the risk of the researcher affecting how risks are managed if the project is in the planning phase. There could be, as well, uncertainties in the answers if the projects were finished and the site manager had moved on to another project. Projects should also be selected according to criteria in the definition of small sized projects, not by who happens to be the site manager. Interviews with managers of projects from different construction companies have been adopted to provide a flavour of the wider construction sector.

In order to be able to see patterns in data from the interviews, the information has been sorted into different categories. Projects have been sorted by type: buildings, new production and renovation, and ground works. There is also some categorisation relating to the geographical situation, i.e. a medium sized community such as Luleå and a large city such as Stockholm, and the age of the site managers.

2.1.2 Interviews

Ten interviews have been undertaken with personnel from five different construction companies in Luleå and Stockholm, Sweden. The interviews were conducted in a semi-structured manner with a number of questions prepared in advance. The interviewees were free to speak about risks and opportunities in their projects and the researcher asked questions and gave some guidance to ensure that the prepared questions were covered. The interviews were conducted in a positive atmosphere and the interviewees have expressed an interest in seeing the final results of the study.

2.2 Findings

The findings from the interviews give a picture of what site managers in a few small sized construction projects think about risk management. They have shared both how they work with uncertainties, risks and opportunities and also indicated what they regard as the most common risks from their perspective. They have also given their view on what is defined as risk and uncertainty.

2.2.1 Perspectives on Risk Management

According to the site managers, risk is something that can have negative consequences for the project and is more dramatic than uncertainty. Conversely, uncertainty is regarded as something that can have positive as well as negative effects.

According to the site managers of the projects investigated, there exists a systematic framework for how risks and uncertainties are managed. There are manuals, routines and patterns to be used, not specifically for small sized construction projects, but specific to the actual type of project. For example, there are manuals for risk identification in ground works, general construction and buildings.

Managers of these small sized projects use the manuals and patterns to a certain extent, with some differences in application amongst them. They apply what they think is useful and leave the rest of the documentation alone. It is notable that there is a difference between the interviewees with respect to their age and experience. The older and more experienced managers tend to document less than others. This means that there are some who actually follow a systematic approach and others who work on intuition based on experience. Common for several of the managers is that they think continuous planning is the best way to manage uncertainties. "Risk analysis is quite good, but it is good planning and logistics that offer the best possibility for minimising uncertainties" (Andreas Rydberg, site manager NCC). In terms of planning, they are able to identify new uncertainties and to take precautions with respect to risks identified in the risk analysis. Risk analysis is performed for the tender and is part of the information the site manager gets before he takes on the project. The site managers refer to this risk analysis as a "living document" that should follow the project throughout the construction process. However, there are differences in how this is actually performed.

Risk analysis and "risk thinking" is not dependent on project size according the site managers interviewed. The approach to risk thinking is more dependent on the type of project than on the contract size of the project. It is the consequences of the risk that decides if the risk is qualified in the risk analysis and, in the first instance, the consequences for health and safety (Patrik Lamberg, Skanska). There are neither differences in available documentation nor in the extent of information in the documentation between large and small sized projects. This means that in very small projects the managers think that more time would be consumed to do documentation for the sake of the system than is actually required for production. The consequence of this is that the managers skip part of the documentation, if not most of it. There is also a time related aspect of these small sized projects expressed by this site manager: "In small projects it is vital that the personnel involved start off immediately since the time available is limited" (Leif Eklund, NCC). There are more possibilities to save a large project if a risk should appear, but the consequences of that risk if not saved might be large. The consequences of that same risk in the small project would be less, but might not be as easy to save due to tight schedule.

2.2.2 Identified Risks

In the small sized projects there are some risks that are more common than others. The relation to the client is one; lack of information in documents provided by the client is another. Yet another risk or actual uncertainty is the tender that establishes the boundary of the project. It is not possible to receive more money than the tender (i.e. contract) sum. The interviewees also think that there is a considerable difference in approach to risks and opportunities depending on what kind of contract is used. General contracts are considered safer in all respects. All aspects should be included and if something is missing it is the client's responsibility to solve the problem, not the contractor's responsibility.

For ground works projects the managers feel that there are a few risks. Small projects are rather straightforward, with known technology and known conditions in the project environment. The risks that appear are the same ones from time-to-time and there is limited uncertainty that crops up along the way.

In renovation projects, more uncertainties appear during production. The activities and technical solutions often need to be adjusted at the site level due to lack of information in the tender about the existing building. There are seldom standard solutions and whether something is a risk or an opportunity is much dependent upon the attitude of the client. Since there is a lot of uncertainty when doing renovation work it is hard to achieve a complete and reliable cost estimate for the tender. The tender (and, hence, the contract sum) does, however, define the financial boundaries for reaching the objectives of the project. This is also to be considered as an uncertainty.

One considerable uncertainty in new building projects is a tight schedule. Physical factors such as drying time for concrete are sometimes neglected, with the consequence that projects can end up with damp concrete. The risk of built-in faults could cause higher costs for both the contractor and client if not handled properly. Building projects also often include subcontractors and this involves uncertainties in relationships as well as in their attitudes to risk and uncertainty management.

Common risks for the small sized projects in this study are, without any ranking:

- contract documentation and tight schedules
- the client
- individual planning and logistics
- cost estimates in the tender
- subcontractors
- technical solutions
- safety for third parties
- weather

3. Conclusions and Further Research

The definition and characteristics for small sized projects are:

- contract value between 1-15 MSEK
- a site manager responsible for a maximum two projects simultaneously
- limited construction time, maximum 12 months
- established technique, no development work
- project environment is independent
- personnel involved are more generalist than specialist

Results from interviews show that there are common factors for small sized projects. These projects are managed both on intuition based on experience and systems for risk and uncertainty management. The systems are, however, developed with the intention of fitting all sizes of projects and are not specific to small sized projects. This leads to differences in the ways of applying risk management and is much dependent upon who is doing the risk analysis more than what the management system might advise. Site managers are also dependent on their own planning rather than having support from other personnel in the organisation.

Results from this pre-study have helped to sharpen the questions to be addressed in the next stage. The aim is also to give a picture of where risk management in small sized construction projects stands today. Knowledge about this situation makes it possible to continue with the remaining research questions:

- What are the differences between theories, companies guiding principles and the practical work in order to conduct uncertainty analyses?

- Why does uncertainty management work satisfactorily in some projects and not in others? What are the obstacles and ambitions of uncertainty management?

The plan for future work is to perform case studies during late 2005. In those case studies, further empirical results will be collected in order to arrive at an understanding for the performance of uncertainty management in small sized construction projects. The result of this future work will be a licentiate thesis to be finished by late 2006.

Acknowledgements

The author would like to thank the people involved in the research project’s reference group for inputs and discussions in the research area. They have been of great help in the task of finding definitions and defining research boundaries. The reference group consists of people from different companies representing clients, contractors and consultants with practical as well as

research experience. They have all reached advanced positions in their field and it is a major benefit for this study to have access to their experience and knowledge.

Thanks are also due to Valter Hultén of Sveriges Byggindustrier for his help with statistics on number of projects.

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Using a Construction Process for the Risk Identification

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Abstract

Every construction project can be divided into discrete phases each of which has its purpose, duration and scope of work. Risk management is a continuous process and should span to all phases through the project. A realisation of construction project is a process. A process is a group of activities undertaken with the goal of successful project realisation, and these activities are potential risk sources that may lead to an unsuccessful project. Risk management should be subordinated to the construction process.

This paper shows a new approach to risk identification in construction projects: process - driven risk identification. The Process Protocol developed at Salford University was chosen to show how construction process can be used for the identification of key risks. The Process Protocol is a plan of works and divides the construction process in ten phases from the Demonstrating the Need to Operation and Maintenance.

Keywords: Construction process, risk management, risk identification, Process Protocol

1. Introduction

Every construction project passes through phases, each of which has a purpose, duration and scope of work. Breaking the project down into phases is an important part of every construction process. The project must start from some kind of definition of need, after which follow design, contracting, construction and project completion [1]. Risk and uncertainty are inherent in all the phases through which the construction project passes, from Demonstrating the Need do Operation and Maintenance. Risks do not appear only in major projects. Although size may be a cause of risk, complexity, construction speed, site and many other factors that affect time, cost and quality to a greater or lesser degree cannot be overlooked. All the participants in the deciding process should observe risks and their effects on all key points of decision-making before and during project realisation.

Process in construction needs important changes and should be continuously improved. The process itself, and the changes and improvements made to it, are accompanied by risks whose adverse effects may increase planned costs and the time necessary for project completion, and decrease execution quality. Efficient and quality management of risks should make these changes in the construction industry possible and enhance quality and efficiency. Changes may be brought to the construction industry through improved risk management. One possibility is to study the causes of risks. In this case it is possible to muster the help of experts in that field, to identify the risks in all the phases of the project life cycle in great detail, to use a large database compiled from prior experiences on similar facilities, and to propose the most adequate risk response. This approach to improved risk management is partial solution with limited applicability.

A new aproach described in this paper starts from the fact that executing a construction project is a process and risk management should be adapted to this process. Risk management is a continuous process needing an integral risk management system in all the phases that the construction project passes through. It is necessary to identify the key risks that appear in all the phases through which the construction project passes, regardless of the type and size of the facility [2].

Risk management always starts with risk identification, which may be considered the most important phase of the risk management process [3]. Its purpose is to compile a list of risks important for a particular project. To form this list, it is first necessary to research the potential sources of risk, adverse events that include risk, and the unfavourable effects of an undesirable scenario. Risk identification greatly depends on the manager’s experience. If his/her experience with particular methods and techniques of risk identification is good he/she will continue to use them, whereas bad experience leads to avoiding approaches prepared earlier.

2. Process in Construction

A process is a series of activities (tasks, steps, events, operations) that takes an input, adds value to it, and produces an output (product, service, or information) for a customer. Customers are all those who receive that process output [4]. Construction developed as an industry when the approach to it changed and the process was introduced in building. In comparison with other industries, many special features burden process in construction and this makes changes leading to process improvement difficult. Structures are often very large and complex and it is necessary to organise construction processes on the building site according to space and time, while making optimum use of existing capacities. A production process of this kind is almost impossible to simply transfer among structures of different sizes and complexities. Production processes in construction last for a very long time, which increases the probability of detrimental events and the risk of running behind schedule. In its level of mechanisation construction still lags significantly behind other industries, and although machinery is increasingly replacing human work this is taking place much more slowly than elsewhere. Unlike industries predominated by production for an unknown client, structures are almost as a rule commissioned by a client or investor who stipulates the location, size, quality and purpose of the future product. Thus the investor should take part in the production process. Investors are usually inexperienced in this, which makes process development in construction additionally difficult.

According to Hughes [5] every project goes through similar phases in its evolution. The phases may vary in size and intensity, depending on the project. Hughes compared 7 plans of work published to date and concluded that many of them are more than a check list. Activities in construction projects to make up plans of work should be described in as much detail and in such a way that different projects may be compared. It is much more useful to concentrate on common aspects among projects than to begin analysis by describing the unique points of each project. He stated that the uniqueness is at a greater level of detail than the commonality, and therefore it should be modelled as such.

The division of the project into phases resulted from the desire to find a set of activities that should be carried out in the realisation of every construction project. This is the first step in establishing the construction process. Flanagan and Norman [6] divided the construction process in 4 phases. The RIBA Plan of Work [7] proposes 11 phases. The BPF Manual [8] proposes 5 phases. The Construction Industry Board [9] also divides the process in construction in 5 phases.

The Generic Design and Construction Process Protocol was developed as the result of a research project at the University of Salford by Professor R.Cooper and her team, in cooperation with several companies that were in various ways connected with the construction industry. The EPSRC (Engineering and Physical Sciences Research Council) under the IMI (Innovative Manufacturing Initiative) financed the project.

The Process Protocol [10] divides the construction process in 10 phases:

1. Demonstrating the Need
2. Conception of Need
3. Outline Feasibility
4. Substantive Feasibility Study & Outline Financial Authority
5. Outline Conceptual Design
6. Full Conceptual Design
7. Coordinated Design, Procurement & Full Financial Authority
8. Production Management
9. Construction
10. Operation and Maintenance

Lee, Cooper and Aouad [11] gave some advantages of the Process Protocol as an industry standard. It is these advantages that form the basis for an efficient framework for managing risk in construction projects:

1. *It takes a whole project view*. Process Protocol manages the project from recognition of the need for a building to its operation and maintenance and it is basically a generic process. Risk must also be managed through all the project phases independently of project type and size. Risk management must be placed in the function of the generic process, which means it is necessary to develop process-driven risk management.
2. *It recognises the interdependency of activities throughout the duration of projects*. Every activity that takes place within a project includes potentially risky events. Identification, analysis and response to these risks are the basis of every risk management framework. However, some activities are interdependent, overlapping or stretch through one or several phases of the project. This interdependence carries new risks which the framework must manage.
3. *It focuses on the front-end activities, paying attention to the identification, definition and evaluation of client requirements*. This makes it possible, at the end of each phase, to implement a new identification, analysis and find an appropriate response to the risks of the following phase.
4. *It provides the potential to establish consistency to reduce ambiguity, and it provides the adoption of a standard approach to performance measurement, evaluation and control to facilitate continuous improvement in construction*. Consistency, performance measurement and continuous improvement in construction are the foundation on which every risk management framework must develop.
5. *The stage-gate/phase-review process approach used facilitates concurrency and progressive fixity and/or approval of information throughout the process*. It illustrates the need for completing all necessary phase activities before proceeding to the next phase (hard gates) or allows concurrency (soft gates) without jeopardising the overall project success. Some types and/or sources of risk stretch through several project phases. Gates are the checkpoints where prior activities are reviewed and the decision made to start the next phase. The hard gate/soft gate philosophy may be directly applied to the risk acceptancy philosophy. Thus in risk terminology hard gate means that the risk is unacceptable and must be eliminated or transferred, and soft gate means that the risk is acceptable provided it is managed.
6. *It enables co-ordination of the participants and activities in construction projects and identifies the responsible parties*. Process Protocol groups project participants in Activity Zones according to their responsibilities. In Process Protocol risk is managed by introducing a new Activity Zone: risk management.
7. *It encourages the establishment of multi-functional teams including stakeholders. This fosters a team environment and encourages appropriate and timely communication and decision making*. One of the greatest risks in the early phases of the project is misunderstanding the client’s real demands. As an answer to this risk, Process Protocol anticipates the client’s active participation in all the project phases.
8. *It facilitates a legacy archive whereby all project information is collectively stored and can be used as a future learning vehicle*. The legacy archive is a very good place for

accommodating the Risk Register and database that may serve to identify, or analyse risk.

3. Identifying Risk in Construction Projects

As it unfolds the construction projects passes through several phases and in each of them it is possible to identify a large number of potential risks, i.e. events whose unfavourable outcome may be adverse for project success. Something could go wrong during practically any activity in project realisation. It would be very difficult to make a general list of all the risks for construction projects of any size or type, which would cover all the specific features of a particular project. A list of this kind would contain a certain number of high-exposure risks, but also a great number of risks whose exposure is such that they could practically be neglected. There would never be enough data for a quantitative analysis of a large number of risks, whereas a qualitative analysis of a large number of risks would be a time-consuming process subject to inconsistent assessments because of the great number of decisions that the risk manager would have to make to obtain their exposure and determine risk acceptability.

Reference sources provide a large number of attempts to compile a specific risk list in construction projects (Table 1). Most of these lists group risks in categories thus forming a hierarchical risk structure. The risk manager may analyse and compare the risk exposures of entire risk categories, he may select one or more key risks from a category and disregard all the others, or he may analyse risk acceptability for all the identified risks in a particular category.

Table 1 shows risk categories in construction projects according to several authors [12,13,14,15,16]. The risk categories in other industries are similar. These risks may appear and be analysed in all construction projects regardless of size or type. Although similar risks often appear under different names, the table shows the great diversity in identifying risk categories among different authors. The five risk lists in the table contain as many as 31 risk categories.

Risk identification with the help of previously existing risk lists is completely adapted to risk-driven project management and does not take into account that executing a construction project is a process and that risk management must be subordinated to that process.

Table 1: Risk lists

	RISK	CARTER at al. (1994)	GODFREY (1996)	SMITH (1999)	DEY (2001)	RAMP (2002)
1	Political		x	x	x	x
2	Environmental		x	x		
3	Planning		x			
4	Market	x	x			
5	Economic		x		x	x
6	Financial	x	x	x	x	x
7	Natural/Act of God		x		x	x
8	Project		x			x
9	Technical		x		x	
10	Human		x			
11	Criminal		x			
12	Safety		x			
13	Strategic	x				
14	Contractual	x				
15	Master Plan	x				
16	Definition	x				
17	Process	x				
18	Product	x		x		
19	Organisational	x			x	
20	Operational	x				
21	Maintenance	x				
22	External	x				
23	Legal			x		
24	Social			x		
25	Communications			x		
26	Geographical			x		
27	Geotechnical			x		
28	Construction			x		
29	Technological			x		
30	Statutory clearance risk					x
31	Business					x

4. Risk Identification Based on Process Protocol

The risk management process, and thus also risk identification, which is part of it, have to be subordinated to the construction process. A process is a group of activities undertaken with the goal of successful project realisation, and these activities are potential risk sources that may lead to an unsuccessful project. The construction process consists of phases through which the project passes. Regardless of the project characteristics, the key risks of the construction project are the risks that may prevent the goals of a particular phase in the process from being achieved.

The goals of each phase depend on several activities or processes that affect phase realisation in various ways. Not achieving the goals of one or more of these processes may lead to non-achievement of the goals of the phase they belong to. Depending on their complexity, some processes contain sub-processes that may be broken down even further.

Independently of level, the processes in a particular phase that have the greatest probability and the greatest impact on the time, cost and quality, and thus also the greatest bearing on successfully achieving the goals of that phase, are the optimum choice as sources of key risks that are not project related. This means that the key risks on which the success of the process depends can be reached by analysing the construction process. In this way risk management is placed in the service of the construction process, and leads to process improvement.

Process Protocol II, developed by R.Cooper at Salford University in cooperation with Loughborough University, resulted in breaking down high level processes (Level I) into sub-processes (Level II and Level III) in each phase through which, according to Process Protocol, the construction project passes from Demonstrating the Need to Operation and Maintenance [17]. Process maps were made for each level. These process maps show the advantage of Process Protocol over other plans of work because they provide better insight into the elements of the process and thus also into risk identification. Figure 1 shows an example of dividing a process into sub-processes according to Process Protocol II. For Phase Zero, *Demonstrating the Need*, it shows the division of the high-level process *Establish the Need for a Project* (Level I) into sub-processes (Level II and Level III).

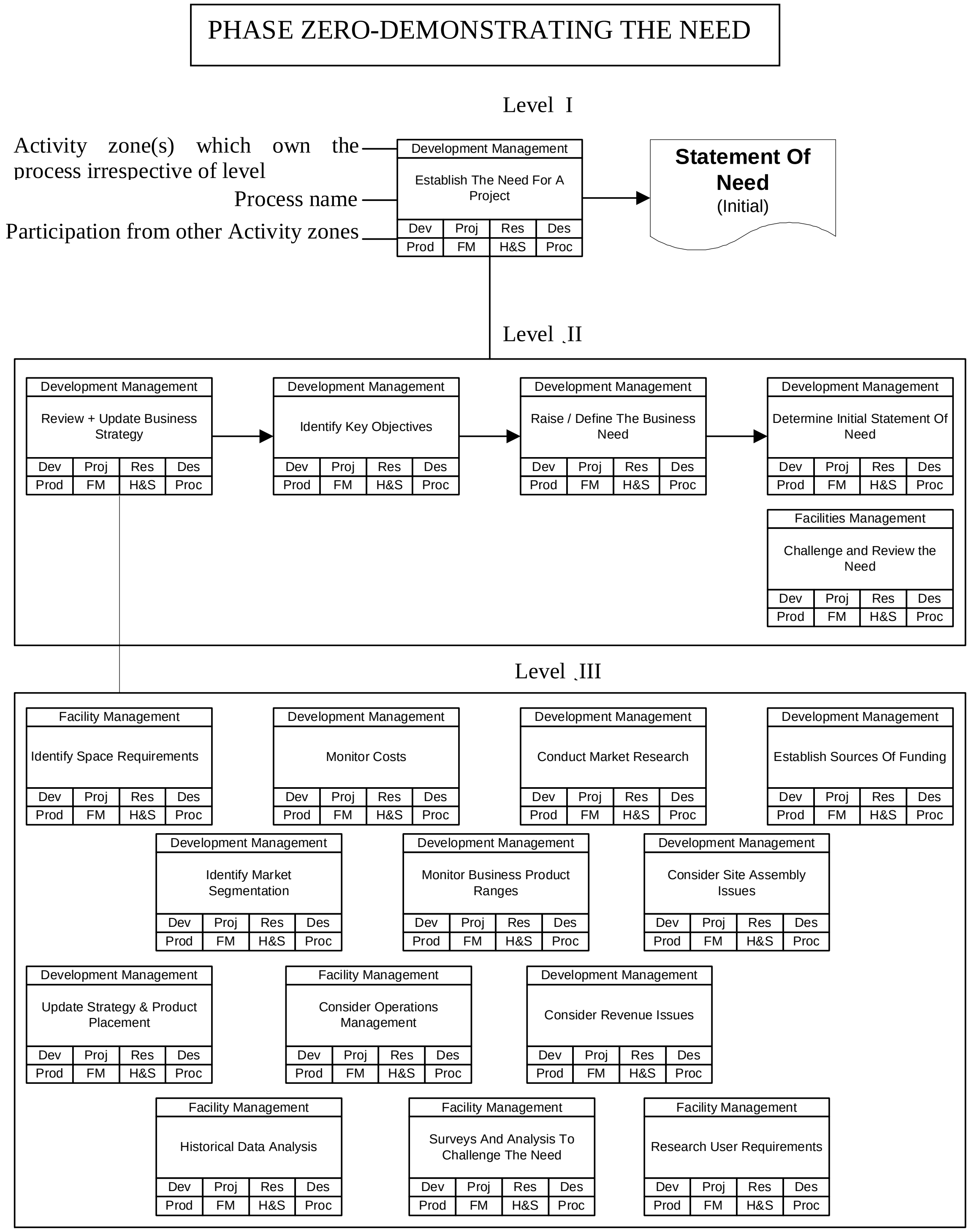

Figure 1: Development of sub-processes

Abbreviations: Dev - Development Management, Proj - Project Management, Res - Resource Management, Des - Design Management, Prod - Production Management, FM - Facility Management, H&S - Health and Safety Management, Proc - Process Management

The author of this paper compiles the proposed list of key risks for Phase Zero, *Demonstrating the Need* to show how construction process and sub-processes can be used for risk identification:

Risk 0-1: Unsatisfactory Market Research

In this earliest project phase it is necessary to research the market of existing structures which may help the client express his requirements or demands as clearly as possible. This is especially important as some of the stakeholders will be participating in the realisation of such a project for the first and only time. When they see what they could obtain, clients will be able to express what they really want much more clearly. Without market research and the presentation of the research results to clients there is a significant risk that the goals of phase zero will not be fulfilled.

Risk 0-2: Ill-defined Initial Statement of Need

All the client's needs, goals and demands should be described in as much detail as possible in a document according to Process Protocol called Statement of Need. In this early project phase it is very difficult to define all the demands and needs. In further project phases the elaboration and evaluation of potential solutions will lead to their reduction or may even extend the demands of the client, i.e. the stakeholder.

Risk 0-3: Incomplete Stakeholder List

Each stakeholder has his needs and demands, depending on his investment in the project. An incomplete stakeholder list makes it impossible to form all sources of funding and means that demands differing from earlier ones may appear. An incomplete stakeholder list is a risk for the entire phase zero not fulfilling its basic goals.

Risk 0-4: No Historical Data Analysis

In the earliest project phase, after the client's needs, goals and demands have been defined, it is necessary to analyse available data about all risk sources on similar projects that have already been executed. There is also a risk of leaving out of the risk list a risk that in the past showed significant risk exposure in a project phase. Analysing available data considerably contributes to a better understanding of the problem.

Risk 0-5: Poor Communication

In the earliest project phase it is necessary to establish a communication strategy within the management team participating in the project phase (development, resources, facilities, project and process management) and between the management team and the client and stakeholders. Success in realising the goals of phase zero greatly depends on this communication.

5. Conclusions

Risk management is by nature a cyclical process. Risks must be identified before the beginning of project realisation or the realisation of any phase through which the project passes. The environment in which the project is realised produces new risks during project realisation. The new risks must be analysed together with those identified and analysed earlier, in a continuous attempt to assess the probability and adverse effect of new risks in relation to existing ones. This creates the need for continuous risk management in all phases of project realisation.

The execution of a construction project is a process. The process in construction contains many special features in comparison with the process of other industries, which are an impediment for changes leading to process improvement. The risk that the project might be unsuccessful is in fact the risk that particular elements in the construction process might be unsuccessful. Risk management should be subordinated to the construction process. Improving certain elements of risk management lead to better understanding and to changes, in other words, to improvement of the construction process, which is one of the main goals of the construction industry.

The Construction Process Protocol is by nature a generic process and is thus suitable for the construction process within which risk management will be situated. As a plan of work, Process Protocol enables managing the project from Demonstrating the Need to Operation and Maintenance regardless of the type, size and purpose of the project that is being realised. According to Process Protocol, every project can be executed through the successful execution of 10 phases. Every phase contains so-called high-level processes as a group of activities that must be realised for the successful conclusion of that phase. High-level processes are broken down into sub-processes in as many levels as the Protocol user deems necessary for the project. The break down of the process in sub-processes provides a good foundation for identifying key risks that are independent of the project being realised. Sub-processes are potential risk sources so risk management in fact means ensuring the success of each sub-process within the entire construction process. Ensuring the successful execution of the construction process leads to process improvement, which gives additional weight to Process Protocol.

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Breakeven Analysis for Selecting Construction Methods: Precast vs. Cast in Place Concrete

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Abstract

In Saudi Arabia, it is common practice that most of the structures of individual housing and small building is erected by Cast in Place (CIP) concrete while most of the structures of mass houses and large building and malls are one of Precast concrete (PC). The reason for the previous characterization is dictated by the economics, shortening of construction period, knowledge of the contractor, and aesthetics. Gradually but slowly, PC is taking more territory for the traditional CIP. The aim of this paper is to devise criteria for selecting either of the above methods from an economic perspective. The criteria will help the owner/contractor/designer to decide the favor ability of either construction method based on the size of the project.

Keywords: Precast Concrete, cast in place concrete, and construction method, Saudi Arabia

1. Background

Many structural systems have been used in the housing and building industry of Saudi Arabia which is predominated by the two systems, Cast-in-Place concrete structures, short named CIP; and that is of Precast concrete structure, short named PC. This practice has been dictated by cost competitiveness, contractors experience, aesthetics, flexibility and lower cost of change orders and other factors. It is common to have individual family detached dwellings of two stories built with CIP concrete because it is more economical and flexible whereas mass housing and large commercial and office buildings are built with PC concrete for their modular design, repetition of standard structural members, and economics of scale.

The choice between the two structural systems by owners/designers/contractors, based on their areas or space volumes and thus costs, are comparable in some cases of construction projects.

2. Problem Formulation

Designers and Engineers are frequently requested by the owners to advise them more accurately on the most economical structural system when their estimates are based on previous projects, quotations and rules of thumb. Hence, in the case of evaluating a CIP concrete structure versus PC concrete structure for a given project, a quantitative method of comparing the two alternatives in terms of their construction costs, is desirable in the early stages of architectural and structural design. The total costs for the contractor in a construction projects equal to the total direct costs and total indirect costs. For simplicity, this relation can be expressed as cost function as follows [1]:

$$\sum RC\_Cost = \sum DC \times Qi + \sum IC \times Ti \qquad \textbf{Eq.1}$$

Whereas the following symbols represent the stated variables:

RC_Cost (in SR):	Total concrete cost in Saudi Riyals for either CIP or PC.
DC (in SR/Cu Meter):	Direct costs of proportional erected concrete (i.e. dependant on the quantity of erected CIP or PC concrete).
***Qi (in Cu Meter)*:**	Quantity of concrete in cubic meter for either CIP or PC.
IC (in SR/day):	Indirect costs for concrete works that is proportional to the duration of concrete erection.
Ti (in Days):	Duration of Concrete Erection (including Manufacturing for PC Concrete)

The relationship between the cumulative cost of concrete works (including pouring/erection) and quantity of concrete measured in cubic meters can be simply expressed by the following equations.

3. Example Project Real Data

To examine the formula for selecting either of the two structural systems of CIP or PC, relevant input data is drawn from two compatible projects utilizing both structures. Table 1. presents unit prices and quantities of concrete for major structural members for CIP and PC systems, which are drawn from two colleges building projects in King Saud University located at Riyadh, Saudi Arabia [2], [3]. The two projects have similar project definitions and are presumably equivalent in price, size and quality. The CIP concrete activity duration, per schedule of the contractor when reviewed by the author, is 320 days while the PC concrete activity duration (design and manufacturing and erection) is 240 days.

Table 1: Quantities of Concrete Works by Structural Members [2], [3]

	College of Architecture and Planning Project			College of Computer Science Project		
Type of Structure	**Cast-In-Place Concrete**			**Precast Concrete**		
Structural Member	**Quantity of Concrete (In Cu Meter)**	**Unit Cost (In SR/Cu Meter)**	**Total Cost for Individual Structural Element (In SR)***	**Quantity of Concrete (In Cu Meter)**	**Unit Cost (In SR/Cu Meter)**	**Total Cost for Individual Structural Element (In SR)**
Foundations	2675	700	1872500	2174**	650	1413100
Columns	772	800	617600	564	1520	857280
Beams	4702	800	3761600	4100	1700	6970000
Slabs	6295	800	5036000	2678***	700	2574600
Stairs	161	900	144900	161	2800	450800
	Cumulative Costs		11432600	Cumulative Costs		9691180

* SR, Saudi Riyal, is Saudi Arabia currency which is equivalent to US $ 0.27
*CIP Concrete is used for foundations and slab on earth for PC structure
** Volume of the PC slab is much smaller than the CIP slab since it is a hollow slab with 0.3 meter of thickness

4. Formula Derivation

4.1 Cast-in-Place Concrete (CIP) Structure Costs

From Table 1., total Quantity of CIP concrete is 11,769 cubic meter is to be erected in 320 days (from project schedule) at average price of 800 SR/M³ for all structural members excluding foundation and stairs (which are common for both alternatives); therefore

Total cost = 11769 * 800 = 9,415,200 SR.
Assuming an inverse linear relationship between concrete cost and duration of its erection and that all concrete works fall on the critical path, then

Cost of 1000 m³ CIP concrete = 8,000,000 SR Eq 2.
And if the Time for erecting 11769 m³ of concrete is 320 days; then
Time to finish 10,000 m³ of concrete is 272 days.

Assuming indirect cost & profit margin is 25% (of 8 millions) of total costs which is 2,000,000 SR; and then
The indirect cost & profit margin / day = 2,000,000 /272 = 7353 SR /Day Eq. 3
Thus, the direct cost for 10,000 M3 of CIP concrete is 6,000,000 SR, i.e.
Direct Cost = 600 SR/ m³ Eq. 4

For simplification, the findings of equations 2-4 are represented by the following variables:

DC1: Direct cost = 600 SR/m³
T1: Time for finish 10,000 m³ = 272 days
IC1: Indirect cost & profit margin = 7353 SR

Substituting the above variables in Eq.1, then it can be written as follows:
Total Costs (in SR) of CIP concrete = DC1*Qi + IC1*Ti
= 600 * Qi + 7353*272
= 2000016 + 600 * Qi Eq. 5

4.2 Precast concrete (PC) Structure Costs

From Table 1., total Quantity of PC concrete is 12699 cubic meter is to be erected in 240 days (from project schedule) at average price of 1060 SR/M³ for all structural members excluding the foundations and stairs; therefore,
Total cost of PC concrete = 12699 * 1060 = 13,460,940 SR.
And by extrapolation between concrete cost and duration of its erection given all concrete works fall on the critical path, then

Cost of 10,000 m³ PC concrete = 10,600,000 SR Eq 21.
And if the Time for erecting 12699 m³ of concrete is 240 days; then
Time to finish 10,000 m³ of concrete is 189 days.

For the sake of simplicity, assume that the indirect cost & profit margin for the PC contractor is similar to contractor of the CIP, then
IC2 = IC1 = 7353 SR/Day Eq. 31
Total Indirect Cost for PC concrete = 7353 SR/Day * 189 Days
= 1,398,717 SR

Thus, the direct cost for 10000 M^3 of PC concrete = 10,600,000 SR – 1,389,717 SR
= 9,210,283 SR, or
= 921 SR/ M^3 Eq. 41

For simplification, the findings of equations 21,31 and 41are represented by the following variables:

DC2: Direct cost = 921 SR/m³
T2: Time for erecting 10,000 m³ of PC concrete = 272 days
IC2: indirect cost & profit margin = 7353 SR

Substituting the above variables in Eq.1, then it can be written as follows:
Total Costs (in SR) of CIP concrete = DC2*Qi + IC2*Ti
= 921 * Qi + 7353*189

$$= 1389717 + 921 * Qi \qquad \text{Eq. 51}$$

4.3 Finding the Breakeven Point

Having developed Eq. 5 and Eq.51 for the relationship between both CIP and PC quantity of concrete versus total costs of erection, then a breakeven point whereby both linear equations are equal in total costs and equal in quantity of concrete can be found by equating Eq. 5 and Eq.51 as follows:

TC1 = TC2, i.e., 2000016 + 600 * Qi = 1389717 + 921 * Qi, and thus

Qi = (2000016 - 1389717) / (921 – 600) = 1901.24 Cubic Meter of concrete.

Table 2. Presents the values of CIP concrete and PC concrete costs in SR/Cu Meter for ascending quantities of concrete in Cu Meter. When the two previous variables plotted in X-Y plane as in figure 1, which it shows the breakeven occurs at Qi = 1901.24 Cubic Meter at a total cost of 3,200,016 SR. From the figure, we can see if the total quantity of the used concrete is less than 1901 cubic meter then it is cheaper and favorable to use the PC concrete while if the required quantity of concrete is more than 1901 cubic meter, then it is cheaper and favorable to use CIP concrete for the structure of the building.

Table 2 : Data of the Concrete Quantities vs. CIP/PC Costs

Data No.	Quantity of Concrete (Cu Meter)	Cost of CIP Concrete (SR/Cu Meter)	Cost of PC Concrete (SR/Cu Meter)
1	500	2300016	1850217
2	1000	2600016	2310717
3	1500	2900016	2771217
4	2000	3200016	3231717
5	2500	3500016	3692217
6	3000	3800016	4152717
7	3500	4100016	4613217
8	4000	4400016	5073717

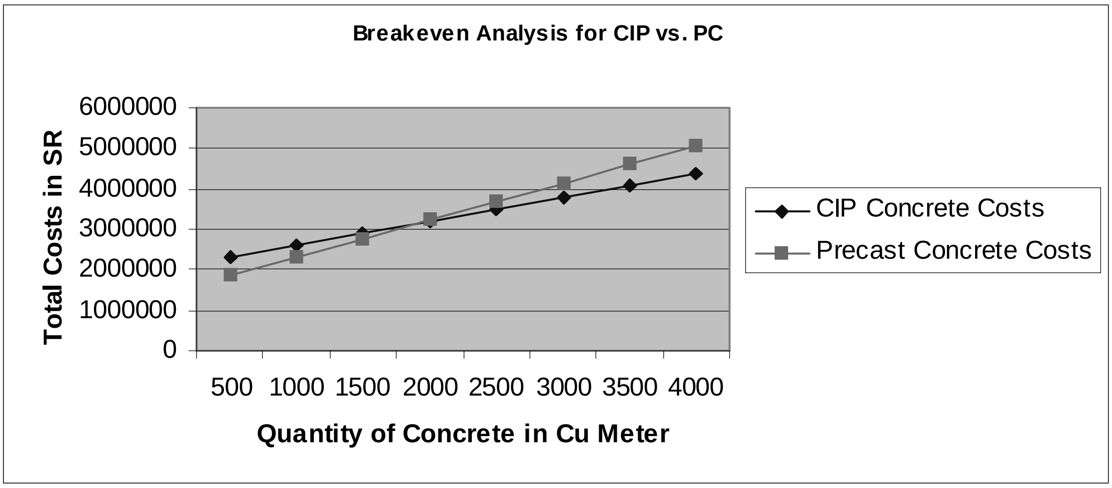

Figure 1: Plot of Concrete Quantities vs. CIP/PC Costs

5. Conclusions

Breakeven formula is derived to preliminarily evaluating and selecting best alternative between two competing construction methods offered by two different contractors for the structural members, those of Cast-in-Place concrete vis-à-vis Precast concrete. The criterion for selection is based on the most economic solution. The quantities of works, i.e., concrete, are treated as independent variable while the component of contractor overhead is held constant and equal for both contractors. The outcome of this research assist decision makers and engineers to compare both concrete construction methods early in the construction planning phase of a project. The approach developed herein can be also applied for similar construction methods for other project activities.

The author intends to further treat the validations of the findings in upcoming paper.

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Systemic Innovation in the Management of Construction Projects and Processes

In an industry that is dominated by one-of-a-kind projects, and a thin profit margin, a key challenge in the new global economy is to ensure delivery of projects that are on time, within the cost limits, of high levels of quality, sustainable, and provide value to the customer. All this, while ensuring that contractors remain profitable without raising project costs. This calls for systemic innovation in the management of construction projects and processes that takes into consideration all relevant aspects and stakeholders of the complete building lifecycle.

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