Theme:

Title: **Lean Enterprise Web-based Information System for Construction (LEWIS): A Framework**

Author(s): Eknarin Sriprasert[1] and Nashwan Dawood[2]

Institution(s): Centre for Construction Innovation Research, University of Teesside

E-mail(s): s-e.sriprasert@tees.ac.uk[1], n.n.dawood@tees.ac.uk[2]

Abstract: *Generating a realistic plan at the beginning of a project and maintaining its reliability throughout the construction is not an easy task. A case study of a 120 million pounds Private Finance Initiative (PFI) project in UK indicates unreliability of the construction plan (Percent Plan Completion (PPC) < 40%) which was caused by the lack of co-ordination among work-face personnel, project planners, and supportive organisations (i.e. designers, suppliers, and subcontractors). In this case, wastes regarding waiting for design information and discrepancy supply of resources are considerable. These wastes, apparently, lower productivity and affect time and cost of the project.*

Aiming to treat the above problems, this paper identifies an improvement strategy through a synergy of: 1) an innovative construction project management paradigm namely lean construction; and 2) the advanced information technologies namely web-based information management, and 4D visualisation. This has resulted in a developing prototype called "LEWIS – Lean Enterprise Web-based Information System for Construction". A unique structure of the system is an integration of product model, process model, and information management functions. Not being merely the information warehouse, the system allows planners to perform look-ahead analysis, rehearse the plan, and visualise execution constraints in the 4D environment. It is envisaged that this system will facilitate co-ordination among project participants, increase reliability of construction plan, and improve on-site productivity. The focus of this paper is on the overall system architecture, information repository, and web-based interfaces while the 4D constraint-based analysis and visualisation is detailed in a companion paper.

Keywords: *Execution Planning, Information System, Lean Construction, Web, Work Face*

Introduction

The heart of the construction process is at the 'work face'. The 'work face' in this paper is defined as the part of a construction site where activities are being executed. In order to have a smooth running process, the planner has to be proactive and responsive to variability affecting work status. S/he has to consider all possible constraints, rehearse the execution plans, and guarantee constraint-free assignments to the work face. Necessary information and resources should be made available to foremen and crews in the just-in-time manner. Furthermore, physical constraints such as incomplete pre-requisite works, spatial conflicts, and hazardous working conditions should also be cleared. However, the current construction managerial practices are much concerning with contract and cost control rather than with work-face production. It is evident that the current practices are still suffering from low productivity and high production waste (Egan, 1998; and Santos, 1999). Many recent industrial surveys and studies indicate severe problems typically found at the work face. Four categories of problem can be identified as: 1) Separation of execution from planning (Laufer and Tucker, 1987); 2) Poor site management and supervision (Christian and Hachey, 1995; Chan and Kumaraswamy, 1996; Kaming et al., 1997; and Proverbs and Holt, 1999); 3) Informal co-ordination and communication (BRE, 2001); and 4) After-the-fact variance detection (Ballard, 2000). Furthermore, a review of IT applications in construction by Sriprasert and Dawood (2001) highlights a lack of tools for execution planning and management of work-face information.

In order to confirm and identify causes for the above problems, this paper firstly reports and discusses the results obtained from a case study of a 120 million pounds Private-Finance-Initiative (PFI) project in UK. It is concerned that better understanding of how and why the problems are occurring in the real practices will greatly contribute to a formulation of an appropriate improvement strategy. Rather than directing to a process-led or a technology-led paradigm, this paper then attempts to identify an improvement strategy through a synergy of: 1) an innovative construction project management paradigm namely lean construction; and 2) the advanced information technologies namely web-based information management and 4D visualisation. This has resulted in a developing prototype called "LEWIS – Lean Enterprise Web-based Information System for Construction". The focus of this paper is on the overall system architecture, information repository, and web-based interfaces of the LEWIS. The 4D constraint-based simulation and visualisation tool for execution planning and constraints analysis is detailed in the companion paper (Sriprasert and Dawood, 2002).

Current Practices in UK: A Case Study

The objective of the case study was to confirm and gain understanding of how and why the above typical problems are occurring in the current practices. A *'critical case'* in which a clear set of propositions is specified and circumstances within which the propositions are believed to be true (Yin, 1994) was selected for this study. In other words, a project that possesses high degree of complexity and fragmentation in which occurrences of all typical problems can be expected was chosen.

Case Introduction

The project under study is a 120 million pounds private finance initiative (PFI) construction project in UK. The project involves an approximate 62,000 square metres of new and refurbished hospital accommodation on 2 or 3 storeys including 10 plant rooms and all associated external works. Total project duration including design and construction is 32 months. The project was started in August 1999 and will be finished in April 2003. It should be noted that the project is in the 14th month at the time of the case study. Figure 1 shows the overall model of the project.

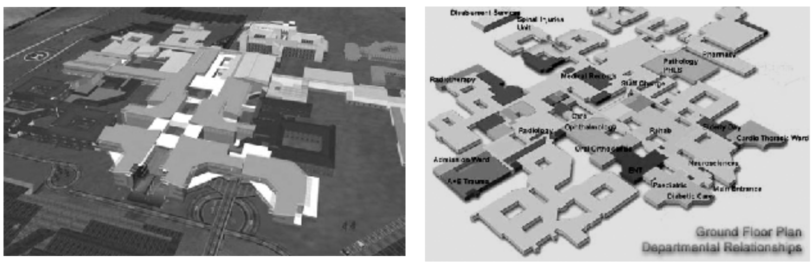

Figure-1: Overview model of the case study project

The construction is divided into 48 zones employing about 120 staff and 650 operatives. Over 120 subcontractors and 150 suppliers are involving in this project. The number of drawings issued to date is over 11,000 excluding revisions. The site is surrounded by the existing operational hospital, a school, and two housing estates. Issues concerning the regulations of environment, and health and safety are very strict. Toolbox talks for each zone engineer and operatives must be conducted weekly. All work packages must be authorised by the client prior to their commencement. Furthermore, permission to carry out works associated with high risks such as excavation, hot works, and isolation of M/E systems must be granted on the case by case basis.

Regarding the project organisations, five major participants are involving in the project. The project client is the UK NHS trust. The concessionaire is a large UK public health group made up from 20% equity by a building contractor and the rest by bankers and funders. Under the concessionaire, there are a large planning supervisor firm who is responsible for the overall construction and facility management and a joint venture (JV) contractor who is responsible for the design and construction. The design of this project, however, is divided into three packages including architectural, structural, and M/E design. These packages are then subcontracted to three separate design consultant firms.

Given the above project attributes, the project is considered as a highly complicated and, therefore, represents the *'critical case'*. Focus of this study was on two major aspects including planning and control system and information management system of the JV contractor. Multiple sources of evidence were collected by site observation, scrutiny of project documents, walking through processes, and interviews with key participants. Results of the study are reported below.

Planning and Control System

Planning and control department consists of two senior planners and a junior planner. According to the JV planning procedure, programme of work can be categorised into four types: 1) Concessionaire construction programme for monitoring of project overview and releasing of milestone payments; 2) Target programme for planning at zone level; 3) Three-months short-term programme for greater detail planning; and 4) Subcontract programme developed by subcontractors. The progress of work is regularly monitored against both the target programme and the subcontract programme. For the target programme, actual percentage against as planned is monitored fortnightly by the section manager/M&E engineer in liaison with the planning department. In a similar manner, every subcontractor has to monitor his subcontract programme and provides monthly progress report to the JV. An overall progress report combining the subcontractor's progress, the internal progress, and the progress photographs is then prepared and issued to the JV board and the client on a monthly basis. Presentations of the progress are in the forms of drop line progress, s-curve, lists of on-going and completed activities, and labour histograms.

Although systematic planning and regular monitoring are in place, two major deficiencies including ignorance of detailed execution planning and ineffective control can be identified. In this case, the development of the three-month short-term programme is simply neglected. It is obvious that field supervisors normally plan the execution. No systematic way to perform this kind of detailed planning is found. The supervisors usually draw the plans up by hand. These paper-based plans can be referred as "cribsheets" (Choo et al., 1999) or "throw away" schedules (Russell and Froese, 1997). Consequently, feedback from the work-face production is not recorded and little relationship can be traced back to the target programme. It is also found that constraints of supportive organisations such as abilities to deliver design information and resources are not taken into account when the plans are generated or updated. The plans may be occasionally revised only when huge deviations are detected. Clearly, this kind of revision does not imply any sense of proactive control but simply follow-the-fact revision. However, this is not absolute fault of the planners since they have no direct authority to make corrective actions. In fact, most decisions are formally made in the monthly board meeting therefore limits chances of timely corrective actions. Over the last 3 months, less than 40% of activities has been completed as planned. This strongly confirms the typical scenarios of separation of execution from planning and after-the-fact variance detection.

Information Management System

The JV site office is fully equipped with standard IT systems. Most staff are provided with a desktop PC and shared printers operating under the LAN system. The network is connected to an in house information management system called PIMS – Project Information Management System. This system acts as an information/mail server system, which stores various types of scanned documents i.e.

applications/permits, faxes, letters, memos, minutes, RFIs, and method statements. Hard copies of these documents are also systematically filed and distributed to the relevant persons. The system records the distribution list and maintains the corresponding actions of each staff. Warning emails about the outstanding issues are automatically sent to the responsible persons. The documents stored in the system can be classified and filtered based on Work Breakdown Structure, title, sender, date sent/received, etc. In addition, there is a library of standard procedures downloadable from the company's Intranet site. It should be noted that details of the drawings i.e. revision, date received, description and distribution list are stored separately in two MS Access databases (one for the design consultant's drawings and another for subcontractors' drawings). At the work face, an electronic swipe card system is utilised for labour time and attendance control. General radio frequency devices such as Walkie-Talkie are available for internal communications between the work face and the site office.

With standard forms and procedures, consistent documentation, and well equipped IT infrastructure, the overall information management in this project is comparable to a good international standard. However, several issues regarding: 1) quality of information; 2) information structure; and 3) co-ordination and communication can be discussed.

In this project, paper-based 2D CAD drawing is a main medium to deliver design information. Generation of working drawings that contain necessary information for work-face execution, unfortunately, is not included in the design contract. A project engineer complained about quality and delivery time of the design information in an interview conducted during the case study. Detailed structural connections and M/E schematic diagrams are normally sketched on site. Over 650 RFIs (excluding informal telephone calls and face-to-face discussions) have been issued. The RFIs have an average of 25 days response time and 10 % of them are still outstanding. In many zones, contractor is forced to carry out the works without complete design information. Several product clashes have been reported from the field, which resulted in reworks or waiting for information. Considering the information structure, each type of document is organised by a simple sequential index i.e. RFI001, RFI002, …, RFInnn. As a result, no link between the document and a specific product or a specific process defined in the plan can be established. Without such a relationship, it is not easy, if at all possible, to analyse constraints regarding information availability prior to commencement of each work package or activity. To an extent, it is also difficult for work-face personnel to retrieve information that they needed. Informal co-ordination and communications among upstream supportive organisations, planners, and work-face personnel can also be revealed. Unlike the administrative information, other important information regarding resources (i.e. material requirements and delivery details) is privately kept in the purchasing department. Furthermore, the feedback information from the field (i.e. problems and causes of variances) is not well documented. In this case, the planners are rarely informed of possible constraints and, therefore, can't rehearse and generate the reliable plans. Without the reliable plans, the upstream supportive organisations are unaware of the real project status and are unable to prioritise their deliverables to the work face. Wastes regarding discrepancy supply of resources, and waiting for instructions, apparently affect time and cost of the project.

Conclusions and Findings

The findings of the case study strongly confirm the four typical problems highlighted in the literature. From the case study, we start to better understand that the problems are occurring neither because of ignorance of management nor the lack of IT infrastructure. In fact, the root causes of these problems seem to be insufficiency of underlying project management theory and improper framework for IT utilisation (Koskela, 2000; and Koskela and Howell, 2001). To be more specific, the current planning and control mainly considers time and precedence constraints. The 'flows' of information and resources as well as detailed execution planning are largely ignored. In the aspect of IT utilisation, it is generally used for administrative works and has not been designed to serve planning and execution at the work face. These findings and conclusions of the case study have paved the way for a new improvement strategy identified in the next section.

Lean Enterprise Web-based Information System (LEWIS)

Strategy Identification

The research presented in this paper can be best described as a *'problem-solving research'* in which a problem from practice is identified and all intellectual resources are brought to bear upon the solution (Phillips and Pugh, 1987). Aiming to treat the typical work-face problems identified earlier in this paper, identification of an improvement strategy through a synergy of an innovative construction project management paradigm and the state-of-the-art information technologies could proof useful.

Among the process-led paradigms such as construction process re-engineering and concurrent engineering, lean construction concept has been chosen as the underlying theory for improvement of work-face production. Many practical techniques including: 1) last planner (Ballard, 2000); 2) look-ahead planning (Ballard, 1997); 3) pull strategies (Ballard, 1998); and 4) transparency (Santos et al., 1998) can be adopted. Several trial implementations of the lean construction concept (Ballard et al., 1996; and Conte, 1998) show an improvement of plan reliability and productivity through encouraging planning at the crew level, measuring planning system through weekly percent plan completion (PPC), and identifying and acting on root causes of failures. For the technology-led perspective, IT is being regarded as one of the most prevalent facilitators of process change (Chan and Land, 1999). A vision of *"Construct IT for Business (2005-2010)"* is predicated on the underlying theme of a central project model that facilitates the co-ordination, exchange, and sharing of project information (Tah and Carr, 2001). Other key elements of the vision are the use of the Internet for project collaboration and virtual reality for construction product and process simulation and visualisation throughout the project life cycle.

As a result of the amalgamation of these process-led and technology-led strategies, a developing prototype called LEWIS – Lean Enterprise Web-based Information System for Construction is proposed as a tool for promoting production-oriented thinking in the construction enterprises. The system architecture and its functionality are explained in the following section.

Architecture and Functionality of the System

A major limitation of the existing commercial project management systems can be revealed as the disintegration between information management and execution planning and control. A further widely acknowledged limitation can be cited as the inflexibility to customise the structure and contents of the systems. To overcome these limitations, the design of the LEWIS, in contrast, is based on the compound applications concept in which data extensibility and making use of the existing capabilities of off-the-shelf application packages can be beneficial (Heindel and Kasten, 1997). The core of the architecture is a central relational database management system (RDBMS) where product model (CAD), process model (schedule), and information (i.e. drawings, specifications, method statements, resources information, etc.) are integrated. SQL Server 2000 is chosen for the database implementation because of its wide availability, scalability, and multi-user supportability. More importantly, an ongoing research project on the development of IFC model server at the VTT, Finland is based on this database platform (Adachi, 2001). For data input, 2D or 3D product data from CAD software (i.e. AutoCAD 2000 or Architectural Desktop 3.3) can be automatically extracted to the database using a developed Visual Basic for Applications (VBA) macro. In a simpler way, the process data from project planning and scheduling software (i.e. MS Project or Primavera) can be extracted to the database using Open Database Connectivity (ODBC) and a built-in import/export template feature. Meaningful data analysis and reports such as readiness of all drawings required next week and workable backlog (constraint-free activities in this period) can be generated using Structure Query Language (SQL). Furthermore, to achieve web-based functionality, HTML, Active Server Pages (ASP), and VB Script are utilised to create web interfaces, retrieve and display data from the database, develop search capability and, last but not least, manage data security. An overall architecture of the LEWIS system is presented in Figure 2.

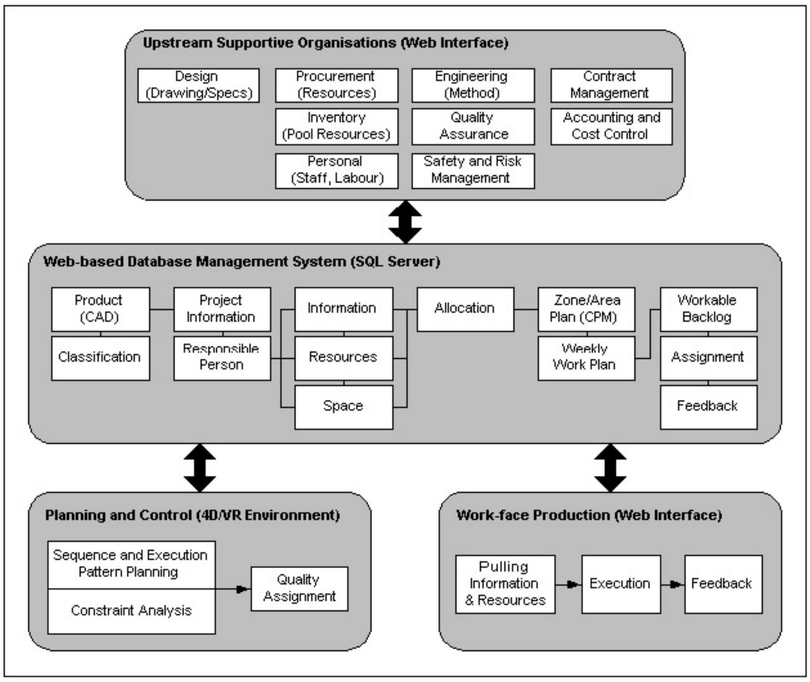

Figure-2: LEWIS System Architecture

The aim of the LEWIS system is to reform the way of construction management from contract and cost centre to flow and production centre. The LEWIS functionality provides a medium for co-ordination and communication among upstream supportive organisations, planners, and work-face personnel. In this case, the supportive organisations will be informed of the current project status and requirements at the work face in real time. Planners will be informed of ability of the supportive teams to supply required information and resources in Just-In-Time manner and, in turn, will be able to realistically update an execution plan and assure quality assignments and instructions to the work face. Finally, work-face personnel will be able to retrieve information and send request or discuss problems to the responsible teams promptly. Figure 3 illustrates web interfaces for main menu and a query result for constraint activities planned to execute next month.

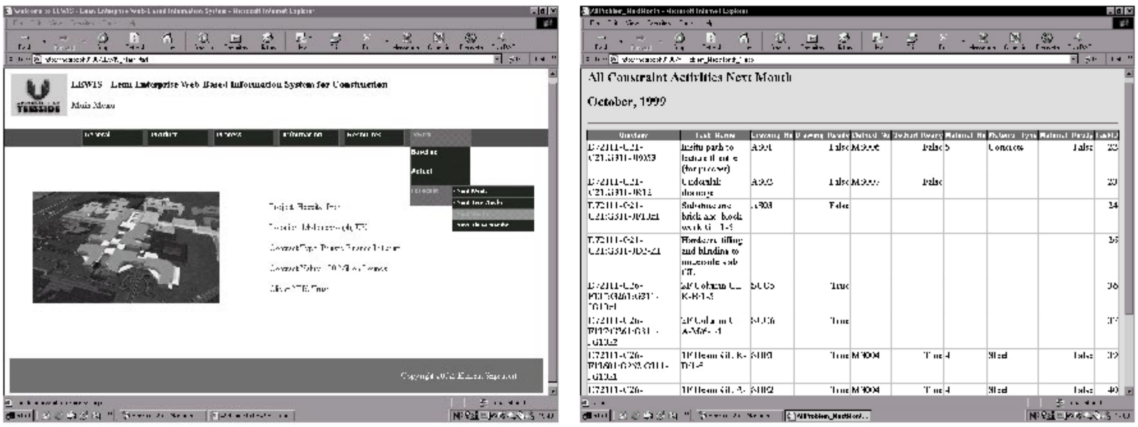

Figure-3: Web Interfaces Presenting System Main Menu and a Query Result for Constraint Activities

The main menu of the LEWIS contains a set of pull down menus that enables users to access different categories of project information ranging from general project information, geometrical product data, CPM schedule and weekly work plan, project documents, resources information, to VRML models presenting work progress and constraints each period. Constraints regarding availability of information and resources for each activity can also be queried. These results will then serve as an input to the 4D constraint-based planning and control module where sequence of activities and associated constraints can be simulated, visualised, and evaluated. It should be noted that the LEWIS prototype is still in a developing stage. A possibility to develop user interfaces in mobile devices or touch screen monitors is being investigated.

Conclusions

The paper has identified typical work-face problems, which are widely acknowledged in the literature. Two major areas including planning and control, and information management system have been investigated in a case study of a 120 million pounds PFI project in UK. The study confirms typical problems of separation of execution from planning, poor site management and supervision, informal co-ordination and communication, and after-the-fact variance detection. It is understood that these problems are not occurring because of the ignorance of management nor the lack of IT infrastructure. In fact, underlining project management theory and the framework for IT utilisation should be reformed. As a problem solving research, the paper seeks an improvement strategy through a synergy of an innovative construction project management paradigm namely the lean construction concept and the advanced information technologies namely web-based information management and 4D visualisation. This has been resulted in a developing prototype called LEWIS – Lean Enterprise Web-based Information System for Construction. The overall system architecture, information repository and web-based interfaces have been illustrated in the paper. A unique structure of the system is the integration of product model, process model, and information management functions. Not being merely an information warehouse, the system allows planners to proactively detect and remove possible execution prior to releasing assignments to the work face. It is envisaged that future implementation of this system will facilitate co-ordination and communication among project participants and increase the reliability of an execution plan. As a consequence of reducing inflow variability, site management and supervision will be more effective and on-site productivity will be improved. It should be noted that the 4D constraint-based analysis and visualisation is detailed in a companion paper.

References

Adachi, Y. (2001). “Introduction of IFC model server.” *VTT-MEMO-ADA-05*, <http://cic.vtt.fi/projects /ifcsvr/index.html> (last visited: 04/2002).

Ballard, G., Casten, M., and Howell, G. (1996). “PARC: a case study.” *Proceedings of the Fourth Annual Conference of the International Group for Lean Construction (IGLC-4)*, Guaruja, Brazil.

Ballard, G. (1997). “Lookahead planning: the missing link in production control.” *Proceedings of the Fifth Annual Conference of the International Group for Lean Construction (IGLC-5)*, Gold Coast, Australia.

Ballard, G. (1998). “Implementing pull strategies in the AEC industry.” *LCI White Paper-1*, Lean Construction Institute.

Ballard, G. (2000). *The last planner system of production control.* PhD Thesis, University of Birmingham, UK.

Building Research Establishment (BRE) (2001). “Communication on the building site: results from a practical study.” *DETR Construction Directorate Project Report*, Project report number 80670.

Chan, D. W. M. and Kumaraswamy, M. M. (1996). “An evaluation of construction time performance in the building industry.” *Building and Environment*, 31(6), pp. 569-578.

Chan, P. S. and Land, C. (1999). “Implementing reengineering using information technology.” *Business Process Management Journal*, 5(4), pp. 311-324.

Choo, H. J., Tommelein, I. D., Ballard, G. and Zabelle, T. R. (1999). “WorkPlan: constraint-based database for work package scheduling.” *Journal of Construction Engineering and Management*, 125(3), pp. 151-160.

Christian, J. and Hachey, D. (1995). “Effects of delay times on production rates in construction.” *Journal of Construction Engineering and Management*, 121(1), pp. 20-26.

Conte, A. S. I. (1998). “Last planner, look ahead, PPC: a driver to the site operations.” *Proceedings of the Eighth Annual Conference of the International Group for Lean Construction (IGLC-6),* Guaruja, Brazil.

Egan, J. (1998). *Rethinking Construction.* Report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction. DETR, London. <http://www.construction.detr.gov. uk/cis/rethink/index.htm> (last visit: 08/2001).

Heindel, L. E. and Kasten, V. A. (1997). “P++: a prototype PC-based enterprise management system.” *International Journal of Project Management*, 15(1), pp. 1-4.

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., and Harris, F. C. (1997). “Factors influencing craftmen’s productivity in Indonesia.” *International Journal of Project Management*, 15(1), pp. 21-30.

Koskela, L. (2000). *An exploration towards a production theory and its application to construction.* Dr. Tech. Dissertation, VTT Publication, Espoo, Finland.

Koskela, L. and Howell, G. A. (2001). “Reforming project management: the role of planning, execution and controlling.” *Proceedings of the Ninth Annual Conference of the International Group for Lean Construction (IGLC-9)*, Singapore.

Laufer, A. and Tucker, R. L. (1987). “Is construction project planning really doing its job? A critical examination of focus, role and process.” *Construction Management and Economics*, 5, pp. 243-266.

Phillips, E. M. and Pugh, D. S. (1987). *How to get a PhD.* Milton Keynes; Open University Press, UK.

Proverbs, D. G., and Holt, G. D. (1999). “The strive for productivity and quality: views of UK project managers.” *15th Annual ARCOM conference*, September 15-17, Liverpool John Moores University, 2, pp. 375-383.

Russell, A., and Froese, T. (1997). “Challenges and a vision for computer integrated management systems for medium-sized contractors.” *Canadian Journal of Civil Engineering*, 24(2), pp. 180-190.

Santos, A. D., Powell, J., Sharp, J., and Formoso, C. T. (1998). “Principle of transparency applied in construction.” *Proceedings of the Sixth Annual Conference of the International Group for Lean Construction (IGLC-6),* Guaruja, Brazil.

Santos, A. D. (1999). Application of flow principles in the production management of construction sites. PhD thesis, University of Salford, UK.

Sriprasert, E. and Dawood, N. (2001). “Potential of integrated digital technologies (IDT) for construction work-face instruction.” *Proceedings of AVRII and CONVR 2001 Conference,* Gothenburg, Sweden, pp. 136-145.

Sriprasert, E. and Dawood, N. (2002). “Requirements identification for 4D constraint-based construction planning and control system.” *Proceedings of CIB w78 Conference*, Aarhus, DK.

Tah, J. H. M. and Carr, V. (2001). “How do small and medium-sized consultancy practices perceive information technology in the new economy?” *Proceedings of CIB-W78 International Conference,* IT in Construction in Africa, pp. 40-1- 40-11.

Yin, R. K. (1994). *Case study research: design and methods*. 2Eds., Sage Publications, Inc., London.