First International Conference on Construction in the 21st Century (CITC2002)
"Challenges and Opportunities in Management and Technology"
25-26 April, 2002, Miami, Florida, USA

AN INTELLIGENT DECISION SUPPORT SYSTEM FOR PROJECT MANAGERS

Saad H. Al-Jibouri
Assistant Professor, Department of Construction Process Management, University of Twente, The Netherlands

Michael. J. Mawdesley
Senior Lecturer, School of Civil Engineering, University of Nottingham, UK

G. Al-Mohamdi
PhD Student, School of Civil Engineering, University of Nottingham, UK

ABSTRACT

Projects are executed to overcome an existing problem by providing a solution to it. The solution is accomplished by a collaboration of efforts of different participants (under direct or indirect control of a project manager) bringing together their various capabilities to achieve specific objectives. In order to achieve these specific objectives, a number of tasks have to be performed. These tasks interact in a complex manner: each task require information before it can be performed and produces information once it has been performed. The information moves towards the objective in a timely manner through the organisation of the projects until it reaches the person who performs the task. The flow of information between the tasks and the links between the information is a key factor, as it will provide the basis for planning, monitoring and controlling.

This paper describes an effort to identify the information required by these tasks and to model their interdependencies. In particular the paper concentrates on the development of a decision support system, which will furnish pertinent information to the project manger. It is aimed to enhance the effectiveness of the project manager's decision-making abilities in planning, monitoring and control of his project.

KEYWORDS

Decision Support System, Knowledge-based System, Project Control, Information Flow, Project Manager

1. INTRODUCTION

Many researchers have addressed the significance of timely and accurate information in decision-making in construction projects, see Abdul-Kadir and Price (1995). All project participants acquire, transfer, and consume information. Delaying the process of transferring and receiving the information is the most important cause for project delays (Assaf et al., 1995).

Despite the considerable number of tools that currently aid project control, the management process of a project is information-driven. Most difficulties occurring during the management process of a project are those that relate to information. Researchers such as Usmani and Winch (1993) for example has supported this view and considered the management of projects as the management of information that is produced, evaluated and transferred. Thus, an effective project management system has the significant feature of maintaining the linkage and flow of information between the manager's tasks.

In construction project managers make decisions that can be made complex due to economical, political or social constraints. The project manager, however, still has to make these decisions in a timely manner. The applications of Decision support systems show that these tools are beneficial and aid the decision making process of a manager, see Makarand (1994), Kahkonen (1994) and Yates (1993). Decision support systems, in broad terms are computer-based systems that aid the process of decision-making and are designed to support, not to replace, the decisions of decision-makers. Recently decision support systems have also incorporated expert systems as components.

This paper describes a basic model developed, based on information and information flow, to identify and link project manager's tasks. The model is used as part of a Decision Support System for project management to assist the project manager in generating the tasks that need to be carried out and to support in project planning, monitoring and controlling.

The system described in this paper can be classified to share characteristics of a knowledge-based system and a decision support system.

2. THE BASIC MODEL

In this work an initial information link model has been developed which establishes the linkage between project manager's tasks. The links between the tasks were established based on literature review and also by interviewing a small number of experts. Further, this initial link model was taken as a tool to facilitate a structured interview with experts from the construction industry. These interviews were aimed at defining tasks in terms of the information they require and the information they produce, a task being the main building block in the basic information link model. All tasks were mapped out to define their interaction based on their information requirement.

In the second phase of this research, the initial link model was then extended into a basic information link model. The process representing the development of the basic link model can be seen in figure 1. The following sections contain brief descriptions of the main steps constituting this process.

2.1 Knowledge Acquisition Process

A structured interview method is one of a set of techniques that researchers in AI usually consider in building systems that require capturing knowledge. In this work it was chosen as a technique to acquire the knowledge because it was suitable for the problem (see below) and all other sophisticated techniques were considered impractical. The use of interviews is a common technique in qualitative-based research and according to Kvale (1996) most appropriate in a situation:

- Where a process is to be studied.
- Where exploratory work is required.
- Where factual information is to be collected and the researcher knows in advance the type of information that the participants will be able to provide.

The initial stage of the knowledge acquisition process concerns obtaining knowledge from experts, the second stage concerns knowledge elicitation and the third stage concerns knowledge representation and writing the knowledge in a computer system (Elizabeth, 1989). Part one of the process of Knowledge Acquisition for this project took place in Saudi Arabia and utilised a structured interview method. It included preparatory work, searching for experts and holding interviews.

The preparatory work resulted in a first proposal for the interrelation of the project manager's tasks along with the proposed definition of the project manager's tasks.

A list of the project manager's tasks was produced which were then verified by interviews with experts and was found to be very satisfactory in establishing the project manager's tasks

Each task was typed on to a separate label (these labels resemble mailing labels but are two centimetre square stickers and were placed on tracing paper for ease of removal and replacement). Tasks were presented to experts to define their relationships.

The initial information link model is intended to show the relationship between the tasks. Developing this relationship between tasks was an iterative process where continuous advice and suggestions were sought through discussions with a small number of experts. This step took a considerable time and required more than 40 consultation sessions with experts. Based on the result of a consultation session a refinement may be required. The result of this step is a preliminary/ initial definition of the interrelationship between the tasks.

The main format of the initial information link model is a square, which holds the title of the task and an arrow to show the linkage between the tasks, it is an extension to a traditional project network but the earlier represent information flow rather than technical constraints.

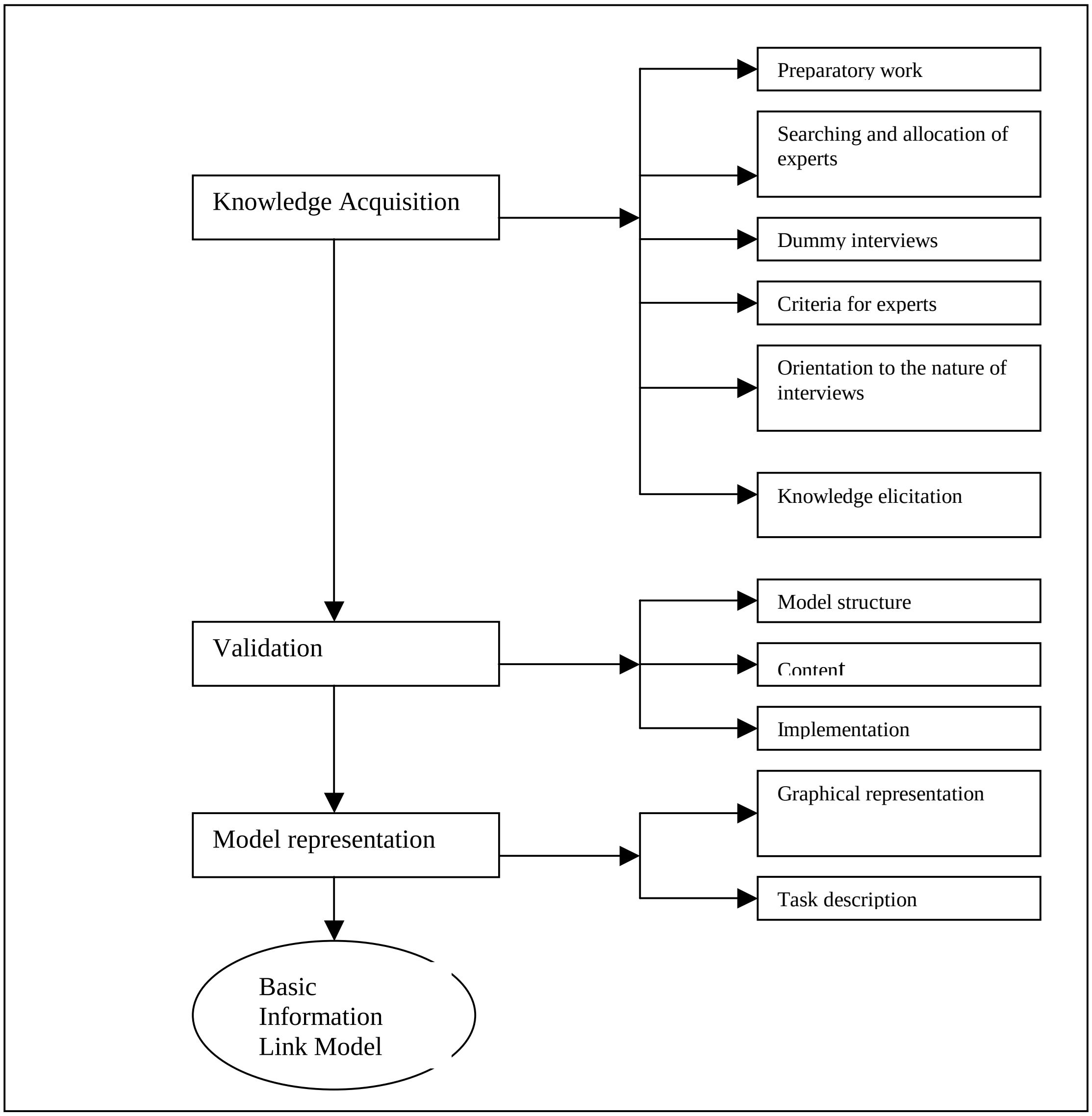

Figure 1: The Development of the Basic Model

2.2 Knowledge Elicitation

Interpreting knowledge gained from experts is termed knowledge elicitation, see Elizabeth (1989). The interview mentioned in the previous section resulted in describing each task in terms of inputs and outputs. Mapping out the tasks was done on the basis that a task generates an output, and if this output is required by another task or tasks, then the tasks are said to be interrelated. This allows all tasks to be linked by this information into a network.

The resulting model produced a chart which, when drawn out, is physically very long. (3 metres long) Although such a chart might seem a disadvantage, there are many benefits to be gained from a graphical representation on one sheet. This allows the actual user of the chart to grasp the entirety of the project with ease.

The production of the information link network was an iterative process. It includes validation of the initial information link model through experts' interviews. This resulted in some refinements and suggestions concerning the initial information link model.

The final interview took the form of a workshop and aimed to validate the basic information link model and discuss its generality. It is noted that to maintain the generic nature of the model a learning facility is included by which particular information can be specified in more detail (if necessary) by the user organisation to meet their specific practice. For example, in tasks related to the authorisation of permits and approvals each organisation has to deal with specific government authorities. (regarding the fund approvals). The nature and location of the project dictate what permits would have to be obtained and from what authorities. Another example related to the tasks involved in organising the project.

2.3 Validation of the Model

The final validation of the tasks' interrelationship was performed in two workshops of three hours each. This workshop brought together seven experts who were engaged at that time in the design of numerous projects of various types. These experts were an architectural section head, mechanical section head, electrical section head, and structural section head, a design manager and a planning manager.

In the first workshop experts were provided with the graphical diagram of the interrelationship of the project manager's tasks and a hypothetical project was considered.

The workshop started with an orientation to the diagram of the interrelationship, followed by a brief of what was required. The group generated written comments about the diagram. Following the receipt of the comments, an open discussion was held with the same group in order to clarify some issues. Comments considered less important were studied later and in general all participants in the workshop thought the structure suitable.

It was predicted that an individual expert could not remember all the detailed characteristics of all tasks (e.g. input, output), though it was planned to elicit the knowledge at a second stage by interviewing more experts, to produce one form for each task. The form produced listed more than what one expert thought of as input and output. The method adopted has a good deal in common with Delphi technique as it is based on eliciting and refining knowledge in different locations in a repetitive manner and has the advantage of acquiring knowledge in a repetitive manner for validation purposes. Two high-grade experts made themselves available for consultations. One of them had 44 years of experience and worked with the American Corps of Engineers on Saudi projects. At this time he was working as one of the senior staff to the project director. The other worked for more than 25 years, 15 years of which were with UK government construction projects. He is currently the senior engineer in a project director's office.

A brief meeting was arranged between these two experts for them to add all their thoughts to the forms produced. Both preferred to take the same document and record their thoughts. Finally, a workshop enabled the two experts to match up their comments, including minor observations. These were then incorporated into the information link model.

3. DEVELOPMENT OF THE INTELLIGENT SYSTEM

A prototype intelligent system has been developed based on the model described above. The developed prototype intelligent system is composed of two main subsystems; the knowledge-based system, and the database subsystem. The knowledge-based subsystem constitutes the information link model, which is built using decisions tree. A report generator and explanatory text are also provided within the knowledge-based subsystem. The knowledge-based subsystem is integrated into the database subsystem., which is built using Microsoft Access and Microsoft Excel. Figure 2 shows the architecture of the prototype.

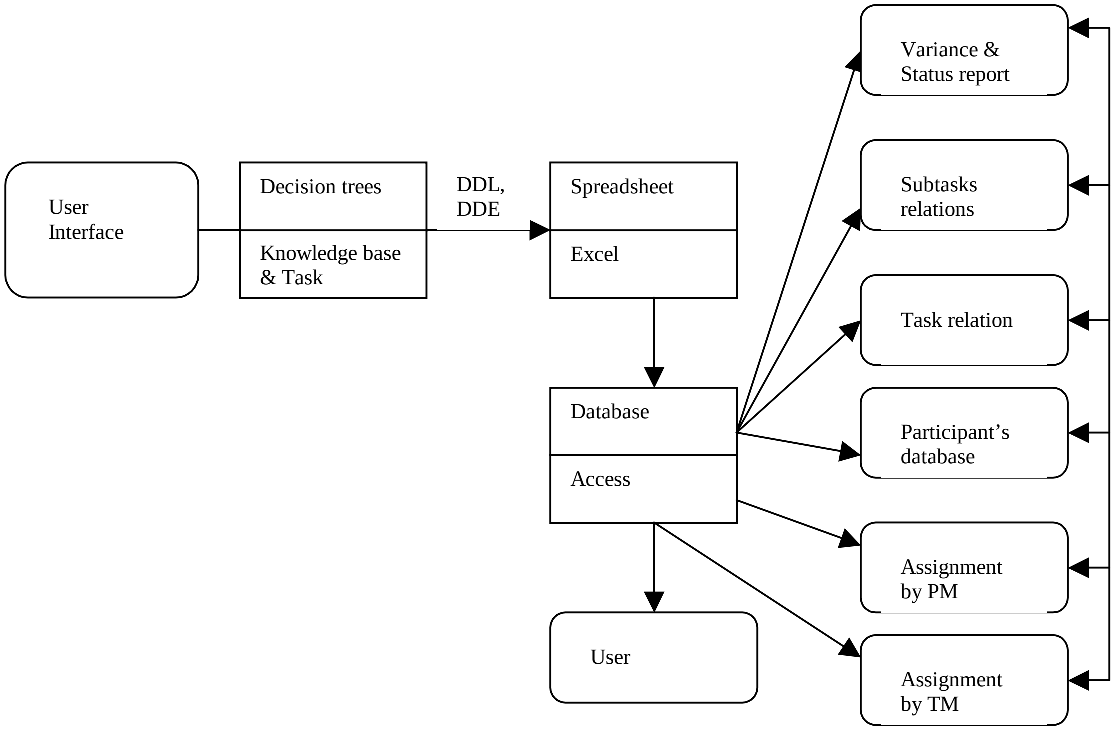

Figure 2: Intelligent System Architecture

3.1 The Knowledge-Based System Component

The basic information link model is extended to a knowledge-based system that utilises simplified decision trees. As mentioned earlier the strength of the model rests in its ability to show the links between the information. The initial question asked is to enable the user to specify whether the session will be used for task generation or for monitoring and control. An important aspect of a project manager in planning projects is to define the tasks that have to be performed, task requirements in terms of their information need and what the task generates in terms of information. An important aspect in monitoring and controlling is the follow up of the transfer of information. Whenever a stoppage of the transferred information occurs, several steps are required.

Defining the tasks and their requirements (input and output) that need to be performed can be done by finding where the stoppage of the flow of information is occurring. This is done based on the following:

- To find the causes of this stoppage manually by using the information link model, requires a backward tracing of the path of the flow of the information until the root of the cause is identified. In order to find the missing information, it is necessary to identify the root cause of the stoppage.
- A problem with the flow of the information does not mean stoppage of work. In reality it opens up the opportunity to look and seek what information can be generated that is not constrained by the identified stoppage.

One function of the knowledge base system component is to fill the two points above. Developing the KBS is done based on the following:

- Grouping related information as shown in Figure 3. The figure shows how the information is grouped for the outline stage of a project.
- Utilising the simplified decision trees and structuring these.

The system starts asking questions of the user, who has to give only one answer to each question being asked. However, it is possible to go backward to the answers and modify them. The answer to the question relating to the information in the project follows a YES/No format.

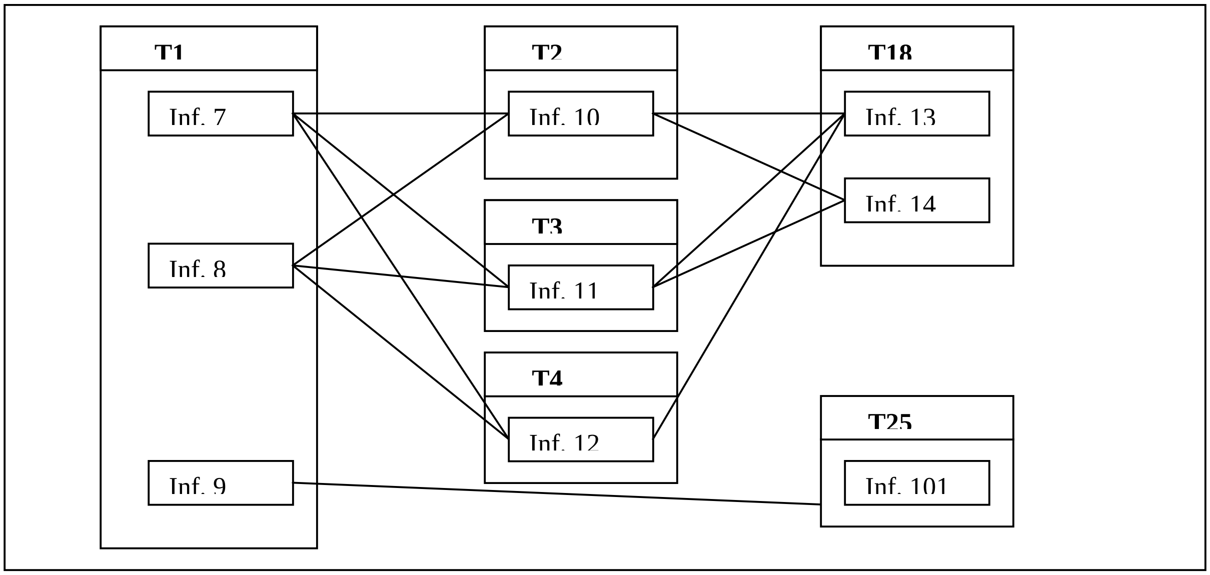

Figure 3: Grouping Related Information

According to the first question answered, sequential questions are asked of the user automatically. The sequence of questions is based on the type of connection between the tasks. Once the entire question is answered a report is displayed to the user. The report consists of the question asked to the user, the tasks that are ready to be performed and the recommendation of the ready to be made tasks.

The user can go back as many as is desirable to change answers to questions. The knowledge-based subsystem is very easy to use, even for those who are not computer users. Furthermore, it does not require reference to comprehensive manuals.

3.2 The Database Management Subsystem

The database management subsystem has been developed using Microsoft Access 97 and Excel 97. The knowledge-based subsystem interacts with Excel through what is called Dynamic Data Library (DDL) and Dynamic Data Exchange (DDE) techniques. Excel is used as a server for the knowledge base and as a client for the databases. The database subsystem is executed only through the knowledge-based subsystem. When first executed, the system asks the user if he wants to go to task generator or if he wants to go to task monitoring and controlling. If the user chooses to go to task generator by the end of the consultation session, the system will prompt the user if he wants to go to task monitoring and control. When the user chooses this option, a main switchboard that has several options will appear. The user then chooses one of the options; task assignments by the project manager; task assignments by the task manager; variances; task links and exit.

4. USES OF THE INTELLIGENT SYSTEM

The developed system provides users with many features that allow them to control a project. It is designed to assist the project manager to control construction projects through all stages from concept until completion. The system can be used at the beginning and during the project. It provides the user with many features, which have been tested by an experienced project manager and a system development expert. An overview of the tasks performed by the prototype is described below.

4.1 The Task Generator

The current state of a project is the main issue that the project manager assesses before deciding on what tasks need to be undertaken. In planning, a major role of the project manager is to identify the tasks that will need to be done. Controlling and monitoring are through continuous assessment of what tasks have been performed, and what tasks and subtasks are ready to be performed.

The objectives of the ‘Task generator’ component are as follows:

1. To capture the status of the project by investigating what tasks have been done.
2. To identify tasks and subtasks that are ready to be performed
3. To identify tasks that will have to be performed.

4.2 The Task Controller

This part of the system is based on the output of the first component ‘The Task Generator” described above. It highlights the tasks and subtasks. It allows the user to investigate the dependency between tasks and shows the requirements of each individual task that has to be performed. It also allows the user (the project manager or the task manager) to define the attributes of the subtasks (activities), their duration, start time, finish time, and as the project progresses, other information that is required, such as the actual start of a subtask. The objectives of the task controllers are as follows:

1. To show the relationship between tasks
2. To show the relationship between information
3. To allow the project manager and task manager to define the attributes of subtasks (e.g. start times)
4. To provide the user with a progress and status report.

In general the system can be said to have the following main features:

- It provides the user with the tasks that are ready to be performed. It provides the user with a report of what tasks are ready for execution. In the report, the questions asked to the user are listed and the rationale of how the tasks are chosen is detailed.
- It provides the project manager with the subtasks that have to be done in the project. It also asks the Project manager to assign responsibilities to subtasks by choosing the assignee from a predefined list of project participants, whether contractors or the project manager’s own team members.
- It provides the user with an option to choose a task. Once a task is chosen, the task requirements will be presented to the user together with the information that the task requires and those that the task generates.
- It allows variance tracking by providing the project manager with information related to the planned estimates and those that are provided and reported by the task manager.
- It allows responsibility tracking by providing the user with a dialog box that allows him to enter a name or choose a name from a list to investigate what are the tasks/subtasks that an individual is responsible for. This feature is needed when a task or subtask is encountering difficulties and the user wants to find what other tasks/subtasks are the responsibility of the same manager.

5. TESTING OF THE SYSTEM

Many dimensions exist in testing the effectiveness or utility of a decision support system. Testing normally relates to the performance of the system, its completeness and accuracy, the utility and benefits of the system, and the feedback to the knowledge engineer during development stages.

Since the purpose of the intelligent expert system developed here is to aid project mangers it was important that testing covers the following two major areas:

- The correctness of the Information within the knowledge-base
- The usability of the system

Experts from both academic and industrial sectors carried out informal test cases. The test cased resulted in certain suggestions for some additional work.

The testing of the system in both of the above areas has produced very satisfactory results in terms of the correctness of the information and the system's performance and usage. Also ideas for extending the system 's capabilities were suggested. The suggestions were not seen as limitations of the system but rather as improvements for future work. Improvements, such as for example adding an automated knowledge acquisition facility to the system, that will allow users to include new knowledge that is not currently in the system.

6. CONCLUSIONS

The Information model and the system described in this paper have wide applicability.

The basic link information model is extended to an intelligent computer system that can take advantage of the usefulness of the model and be used as a control tool for the project manager. The other benefits of using the intelligent system are:

- It presents the task requirements to the project manager; the information that a task requires and that a task generates based on the state of the project.
- It presents to the manager the ready to be performed tasks.
- It presents to the manager the tasks required to finalise a project.
- It allows the manager to assign tasks that are required to finalise a project.
- It allows the task manager to assign tasks that are required to finalise a project and to report on the task's progress.
- It allows its users to present the tasks that are assigned to them.

7. REFERENCES

Abdul-kadir, M. and Price, A.D (1995), " Conceptual Phase of Construction Projects", *International Journal of Project Management*, Vol. 13, No.6, pp 387-393.

Assaf , S.A, Al-Khalil, M., Al-Hamzi, M. (1995), " Causes of Delay in Large Building Construction Projects", *Journal pf management in Engineering*, Vol.2, No.2, pp 45-50.

Elizabeth, S. (1989), *Knowledge elicitation techniques for Knowledge-based systems*, in *Knowledge Elicitation principles, techniques and application*, Edited by Dan Diaper, Ellis Horwood limited.

Kahkonen, K.E. (1994), "Interactive Decision Support System for Building Construction Scheduling", *Journal of Computing in Civil Engineering*, Vol. 8, No. 4, pp 519-535.

Kvale, S. (1996), *Interviews- An Introduction to qualitative Research Interviewing*, Sage Publication, London

Makarand, H. (1994), "Decision Support Systems for Project Cost Control-Strategy and Planning ", PhD Thesis , Purdue University, USA.

Usmani, A. and Winch, G. (1993), " *The Management of the Design Process, The Case of Architectural and Urban Projects*", A Barlett research Paper, University College of London.

Yates, J.K. (1993), " Construction Decision Support System for Delay Analysis", *Journal of Construction Engineering and management*, Vol. 119, No. 2, pp 226-244.