A KNOWLEDGE-BASED MODEL FOR COORDINATING DESIGN THROUGH VALUE MANAGEMENT

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ABSTRACT: The design and construction of building projects is an extremely complex undertaking, which involves people from many different professional backgrounds having different commercial interests. This complexity has led to greater interdependency between specialisations, which produces a consequent need for strong integration of the independent professions and skills. It is clear that the success of the design process, to a large extent, depends upon the way in which the architects, engineers, quantity surveyors and others work together. It depends upon them perceiving the same objectives for the project and recognising that what each of them achieves depends upon what the others do. This paper explores how design can be co-ordinated through the uses of knowledge-based systems and value management. A knowledge-based model for co-ordinating building design through value management is given to demonstrate the viability. The model enables a number of people to work together on a project, or in large chunks than is possible with the more solo methods it replaces. The limitations of the model are also discussed.

1.0 THE NEED FOR DESIGN CO-ORDINATION

The design and construction of a building project is an extremely complex undertaking, involving people from many different professional backgrounds having different commercial interests. Each party is likely to give primacy to certain aspects of the whole entity, and economic studies are usually conducted by an individual engineer or architect. The results of the individual studies are that, each discipline, from its own points of view, generates and reviews requirements, establishes and modifies its particular criteria, and even modifies client's standards and criteria. This sub-optimisation approach tends to sacrifice the overall performance in maximising subsystem performance. The narrow viewpoint at a subsystem level can lead to apparently sound local solutions which create problems for the system as a whole. As Duffy (1991) stated, "many of the problems of today's buildings are due to ineffective co-ordination between different disciplines".

The complexity of construction projects has led to greater interdependency between the specialisations, which produces a need for strong integration of independent professions and skills. Although the interdependency of the contributors to the design and construction process has long been recognised, it is often regarded as sequential interdependency. It should be interactive, however, and the process should move forwards following decisions to which all appropriate elements of the system have made a contribution.

As a result of technological developments, uncertain economic conditions, social pressures, and political instability, the construction industry's clients place increasing demands upon the industry in terms of the performance of the project, the capital and running costs, the time required from conception of the project to occupation, and after all the value for money of the project (Walker, 1989). Buildings, however, are particularly complex entities involving such things as social, physical, aesthetic and environmental factors, some of which contain no reasonable way of measuring the benefit and cost (Brandon, 1984). Without proper methodologies and techniques, it is very difficult for the designers to satisfy clients' requirements at lowest overall life cycle cost.

It is of paramount importance that the objective of the project is identified and understood by all contributors. The traditional design process, however, has been often performed on an intuitive basis, rather than through a systematic approach, which identifies needs but often fails to specify objectives. The importance and the greatest opportunity of co-ordinating design is recognised by the experienced clients. Inexperienced owners, either through optimism or failure to understand the total design process, may omit this aspect.

2.0 VALUE MANAGEMENT FACILITATES DESIGN CO-ORDINATION

It is clear that the success of the design process, to a large extent, depends upon the way in which the architects, engineers, quantity surveyors and others work together. It depends upon them perceiving the same objectives for the project and recognising that what each of them achieves depends upon what the others do. Value Management (VM) is one of the most promising methods in co-ordinating professionals from different disciplines. Instead of seeking sub-optimisation, it organises all relevant parties together as a team, explores the functional requirements of projects, seeks overall optimisation accordingly. As Kelly et al (1991) argued, VM provides a method of integration in the building process that no other management structure in construction can provide.

VM, which is also known as Value Engineering (VE) and Value Analysis (VA), was first introduced by Lawrence D. Miles of General Electric in the 1940s. In

1963 this technique was introduced into construction industry (Dell'Isola, 1982). Over the past four decades, VM has been widely used in the USA, and has made great contributions to cost savings and the enhancement of project value.

Value management, by definition, is an organised function-oriented team approach directed at analyzing the functions and costs of systems, supplies, equipments or facilities, for the purpose of enhancing the value of the objects, usually through achieving the required functions specified by the clients at the lowest possible overall cost, consistent with requirements for performance, including reliability, delivery, maintainability and human factors.

Value Management (VM) as a methodology can make valuable contributions towards a better solution to the problems facing the designers. It has been widely used in the USA, Japan, and most of the member states of the European Community. It has made a significant contribution to the provision of cost savings and enhancement of performance in various areas. The European Community's Strategic Programme for Innovation and Technology Transfer has regarded VM as a powerful tool to achieve one of its three objectives, i.e. improving awareness of the innovation mechanism and promoting the convergence of national and community innovation policies.

It is the VM programme which organises all relevant disciplines e.g., architect, structural engineer, electrical engineer, and client, together as a team to explore the overall optimisation of the system. This group thinking process, as Jones (1983) argued, enables a number of people (specialists and non-specialists), to work and think together on the project as a whole, or in larger chunks than is possible with the more solo methods they replace. Clients and users of a project are often called in to attend a few sessions of the VM study. This participation makes the design process sufficiently visible and discussable, for customers and clients to contribute to it the experience and insight which can only be obtained at the receiving end, but not in the design office.

3.0 A KNOWLEDGE-BASED MODEL FOR DESIGN CO-ORDINATION

Until recently, VM studies were mainly a manual process with little computer assistance. There is little literature about how computer systems could help designers in their design practices. The system is designed to co-ordinate the design professionals by helping them to clarify client's requirements, to identify client's objectives, and to set up a clear and precise project definition of the building project through the use of VM techniques. It utilises a FAST (Function Analysis System Technique) diagram as an intelligent checklist to navigate the designers' thinking, and to remind them not to overlook any important issues concerning the design of an office building. A considerable amount of effort has been devoted to the development of a comprehensive FAST diagram.

The system is to be used in the early concept design stage. The concept design is the phase of a building project that clarifies clients' objectives, identifies their requirements, conducts conceptual investigations on how the objectives and requirements can be achieved economically. It is an interactive process among the designers and the clients/users, which starts from the project inception and precedes the start of actual design work, encompassing the briefing process.

An overview of the system structure can be seen in Figure-1. The processes involved in this system are very similar to those undertaken by the VM consultants manually. It is not the intention of the system to direct the users in every single step, but to give clear and concise information regarding functions and costs of the available design options.

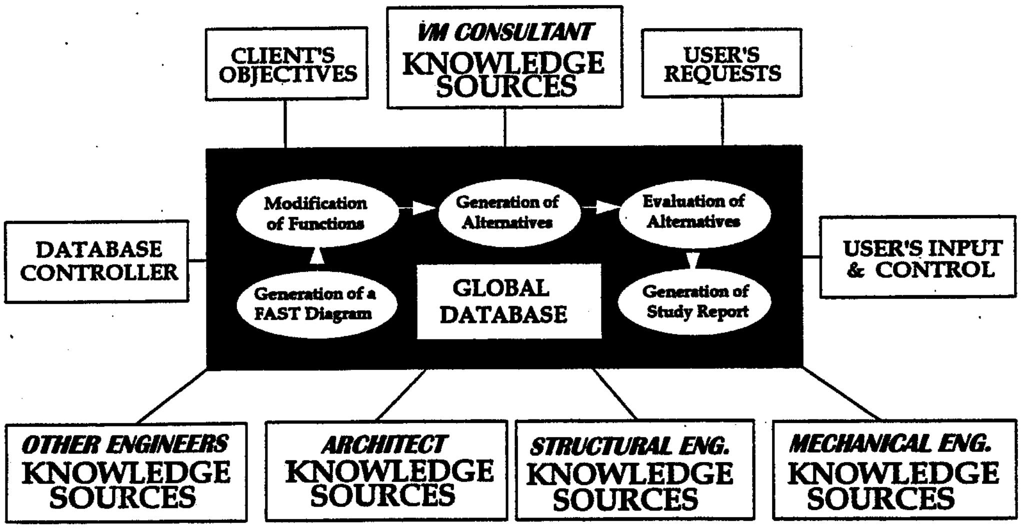

Figure 1 - Structure of Knowledge-Based Model for Design Coordination

Within the structure, a global database is used as a medium through which interactions among different knowledge sources take place. Solutions are built up incrementally into the database. This structure provides a means for storing information that is common to this system and other systems to be integrated, and facilitates communications and co-ordination among these systems.

The controller linked to the blackboard acts as an inference engine, it decides which piece of knowledge or expertise should be loaded to the database. Most instructions given by the controller can be updated by the users who also perform the role of a controller, and form an integral part of the system.

It is essential for the designers to distinguish between client's needs, wants and objectives. What a client wants might be quite different from what s/he really needs in order to achieve his/her objectives. For instance, a client's objective might be to increase his company's profit by 20%, which creates the need to employ extra 300 staff and 3000m2 more space. This does not necessarily mean a new project. It is vital for the system to suggest that there are many ways of achieving the need for extra space, e.g., leasing new space and relocating staff, remodelling and possibly expanding in currently leased space, developing a new facility specifically to satisfy space requirements etc.

Step 1 - Generation of a FAST Diagram

If a new building project is the best solution to the space needs, the system will generate a FAST diagram to organise user's thinking in a structured way. Based on the type of the project being analysed and the requirements from the client, the system will generate a generic FAST diagram to define the project in functional terms which, as the value specialists suggested, could lead users into deeper thinking and better understanding of the project.

Since a FAST diagram is usually structured to include not more than four levels of functions, functions within this system are divided into four classes, they are: level1_functions, level2_functions, level3_functions, and level4_functions. Each class of functions has its own specific memberslots. Functions within a class are represented as instances of the class. Figure-2 shows the attributes of function "establish office facilities", a function in the first level of the diagram. This representation makes the dynamic generation of functions possible, which is essential to the success of building an open-ended system.

```
         Name: Establish_Office_Facilities
     LongName:
         Type: Text
        Value:
    Certainty:
  DerivedFrom:
          IsA: level1_functions
  MemberSlots:
         cost:
 includestate:
         code: 3
 functionname: Establish_Office_Facilities
 subfunctions: Satisfy_Operability,
               Undertake_Building_Design,
               Create_Internal_Environment,
               Create_External_Environment,
               Provide_Furnishings, Provide_Services,
               Satisfy_Regulations
```

Figure-2 Frame for a Level1- Function: Establish_Office_Facilities

The inference process in the system is through the management of functions and alternatives to achieve them. The generic rule for managing the inference is shown in Figure-3. It is this kind of rule which controls the flow of information during the execution of the system. For example, if "provide image" is selected as one major function of the building, the system will ask the user "what kind of image are you talking about?"; "for what reasons do you want this image, is it for staff or for customers, or for other?" etc. The system also provides facilities to help the user in generating alternatives, and suggesting solutions.

The Generic Managerial Rules:

if	the subfunctions of the overall function are determined
and	the value of its subfunctions are analyzed
then	overall function is analyzed
if	a function is a subfunction of a higher level function
and	the subfunctions of this function have been determined
and	the values of each subfunction are analyzed
then	this function is analyzed

Figure-3 The Generic Managerial Rules in Controlling Functions

After identifying that the client's objective is to "provide an office block", an introduction to rules and principles based on which the FAST diagram is constructed will be displayed. This is because one major objective of the design staff is to provide good design solutions. To achieve this objective, they need first to "define the project properly", "generate alternative design solutions" and "optimise design solutions". To define the project properly, for instance, one needs to "clarify client's objectives" and "identify site conditions".

The design problem set by the client's brief is often vague. As Cross (1990) argued, it is only by the designer suggesting possible solutions that the client's requirements and criteria become clear. The designer's very first attempt to conceptualise and represent the problem and solution is therefore essential to the procedures that will follow, such as the alternatives that may be considered, the testing and evaluation of alternatives, and the final design proposal.

Step 2 - Modification of Functions and Generation of Alternatives

Having confirmed the functions in level-1 of the FAST diagram, the system will deal with those functions one by one through the process of giving suggestions and allowing the user to modify them, until the overall FAST diagram has been confirmed. The main purpose of this process is to guide the user to modify the suggested FAST diagram, make it appropriate for the user's specific project, and to provide necessary help. It is observed that users can be stimulated by ideas suggested by the system and use their knowledge and experience to add functions necessary for their specific projects. Users can modify the suggested functions using facilities provided by the system. These facilities include:

1) Display of current FAST diagram -- A global database is used to record the FAST diagram suggested by the system and any modifications subsequently undertaken by the user during the consultation. The database is continuously updated as the consultation goes on and the latest version of the FAST diagram structure is always available to the user.

2) Retrieval of historical archives -- Users can review previous VM documents on similar projects stored in the project database which have been well organised in a hierarchical structure. If necessary, a number of quite different projects will be retrieved to get cross-fertilisation.

3) Stimulation of user's creative thinking -- The system introduces a number of methods of creative thinking and encourages users to create new ideas by using these methods. It also suggests alternatives to perform the required functions. A checklist with expert suggested trigger words is provided to stimulate user's creative thinking and creative ideas. This self-questioning method was proved to be a very useful technique in stimulating deep and systematic thinking.

4) Information on interactions of building elements -- The system will also point out the interactions of building elements i.e., how the selection of an element may influence the selections and costs of other elements. For instance, if the quality of the building has been determined as prestigious, the selections of alternatives for other elements such as plan shape, external walling, and external environment may be affected in order to achieve the quality level. The system provides suggestions on alternatives, but not fixed instructions.

5) Suggestion of verb/noun combinations -- In VM studies, it is essential to think a project in functional terms, rather than in elemental terms. Verb/noun combinations are often used to guide team members to think functionally. The system will provide some verb/nouns combinations to help users to describe functions. The following are the possible verbs/nouns combinations suggested by the system, users may use their own words not included in the list.

With the help of the above facilities, a complete FAST diagram with a number of alternatives to achieve those functions required by the client for the specific project is available to the end users. Other facilities such as explanation of key glossaries and user-friendly interface will also help the above process. A what-if facility is then provided to allow the user to modify the FAST diagram until it is appropriate to represent that specific project in functional terms.

Step 3 - Evaluation of Alternative Solutions

There are many occasions when there is no clear decision available and the matter rests on subjective judgement. The following facilities are used in the system to expedite the evaluation and selection of alternatives:

(1) Weighted Evaluation

Most decisions made by the VM team require an analysis of several alternatives in regard to a number of criteria, each having a certain degree of importance. The system uses weighted evaluation to support this kind of complex decision-making problem. When it is difficult to choose the best alternative solely based on this method, further analysis should be undertaken using methods (2) & (3).

(2) Quick Cost Estimate

The ELSIE Budget Module, which has been proved to be reliable in giving a quick cost estimate for office buildings at very early design stage, is frequently used to compare the costs of design alternatives. A special interface between the system and the ELSIE Budget Module is therefore designed.

(3) Life Cycle Cost (LCC) Analysis

LCC analysis is a tool for comparative analysis of design alternatives. Instead of merely considering the initial cost of a building, it takes the overall costs of a building project over its life-span into accounts including costs of acquisition, maintenance, operation, alterations, and disposal. LCC analysis is conducted by the system to give a more reasonable and reliable comparison of alternatives.

Step 4 - Generation of Study Report

With the assistance of the above facilities, a final FAST diagram with the best alternatives of achieving each required function can be produced. A clear, specific and precise picture of the project definition is therefore available to those who have impacts on the scope of the project. A report summarising the analysis will be prepared at the end of consultation. It includes participants of the study, functions specified for the project during the study, alternatives generated and the alternative evaluation processes.

4.0 POTENTIAL BENEFITS OF THE PROPOSED SYSTEM

The potential benefits exhibited by the proposed system are as follows:

1) Improvement in efficiency - With the assistance of the system, the overall time spent on a VM study can be significantly reduced. Participants can find more time to concentrate on more creative sections of the studies. Because of the awareness of the VM concepts and principles prior to a formal analysis, users can more actively participate in the formal study and concentrate on the already focused difficult tasks.

2) Increased accessibility of expertise – Because the number of qualified value specialists is limited, it is often difficult to find them to conduct a VM study of the project when necessary. The system makes the scarce expertise more widely available and easily accessible when it is required. It will also reduce the risk of producing an abortive or expensive design.

3) Consistency in VM studies – The proposed system can provide more consistent results than that of an ordinary VM team. The final report and the VM change proposals provided by the system are organised in a standard format, which will become valuable historical data in succeeding VM studies, because various formats used by different experts for similar problems may cause serious conflicts and inefficiencies.

4) Reduction of study cost – The cost for a VM study can be a large expense when the project is relatively large. Because of the increased efficiency brought about by using the system, the time spent on a project can be reduced, as can the cost. Alternatively, the time spent on a study could be virtually unchanged, but a larger proportion of time will be available for creative tasks.

5) Training of relevant staff and storage of expertise - Users of the proposed system can learn VM concepts and principles as well as expertise of human experts, so that they can participate in the VM studies more easily and actively. The system can store the valuable VM expertise in the knowledge base which may otherwise be lost through staff movement or retirement.

5.0 CONCLUSIONS

Until recently, VM studies were mainly a manual process with little computer assistance. There is little literature about how computer systems could help designers in their design practices. Newly-established Information Technology have not attracted enough attention from researchers in the VM field.

VM is a useful tool in co-ordinating relevant design disciplines and achieving clients' required functions with the lowest overall cost in the design and construction of a building project. The proposed system has represented the knowledge and expertise in organising a VM possessed by VM specialists. The research has also demonstrated that the use of KBSs in co-ordinating design through VM can significantly improve its efficiency and accessibility. Most of the obstacles which inhibit VM implementations could therefore be overcome.

While it is true that the system has successfully demonstrated the viability of using VM to co-ordinate design via the aid of a knowledge-based system, two important issues relating to VM i.e. creative thinking and interpersonal skills need to be addressed in the future development of the system.

The system described in this paper does not intend to replace the human value specialists, rather, it attempts to provide assistance to the study by undertaking some of the tedious jobs and providing supporting techniques, so that the team members can concentrate on more strategic and creative issues.

REFERENCES

Brandon P. S. (1984), "Reference Points for Building Cost Planning and Control", Third International Symposium on Building Economics, W-55, CIB 84, Vol 3, Canada.

Cross N. (1990), "The nature and nurture of design ability", Design Studies, Vol 11, No 3, July, Butterworth-Heinemann Ltd, pp 127-140.

Dell'Isola A. J. (1982), "Value Engineering in the construction industry", Van Nostrand Reinhold Company, Third Edition.

Duffy F. (1991), "Building Needs 2000 - a study by experts on the future of building and information technology presented on a hypertext database", CERCI, London.

Jones J C (1983), "Continuous Design and Redesign", Design Studies, Vol 4, No 1, Butterworth & Co (Publishers) Ltd, pp 53-60.

Kelly J. R. and Male S. P. (1991), "The Practice of Value Management: Enhancing Value or Cutting Cost?", Royal Institution of Chartered Surveyors, London.

O'Brien J. J. (1976), "Value Analysis in Design and Construction", Mcgraw-Hill Inc.

Osborn A. F. (1963), "Applied Imagination", Charles Scribner's Sons, New York, Third Revised Edition.

Walker A. (1989), "Project Management in Construction", BSP Professional Books, A division of Blackwell Scientific Publications Ltd, Oxford.