

ABSTRACT**EXPERT SYSTEM TECHNOLOGY IN CONSTRUCTION MANAGEMENT**

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This paper describes the development of a micro computer aid driven by a suite of programs which allow the design identified solution for a given building project to be transposed into information reflecting the construction solution.

The 'modus operandi' of the computer aid is the use of an Expert System which can access and manipulate data contained in a data base and to submit back to a data base, for subsequent user retrieval, information about the particular building project under consideration at various stages during its realization.

The system is initiated by the creation of a design situation model which is held in a relational data base in the form of information concerning the descriptions and quantities of the finished work required to achieve the building project. The Expert System, through the logic contained in the inference engine, organises the design stated situation model describing the construction solution in terms of construction activities, the resources needed and their cost implications.

Thus the system is intended to provide an interface between the product related design solution and the process related construction solution and has the aim of aiding the following:

- 1 Resource and financial management by design team
- 2 Resource and financial management by the construction team

KEY WORDS : EXPERT SYSTEMS, DATABASES, CONSTRUCTION MANAGEMENT



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INTRODUCTION

The aim of this research is to develop a computer aid to help bring about more effective management of the resources needed in the construction of a building project.

The quantity surveying process is charged with ensuring that the finite resources available to the construction industry (1) are made best use of and therefore there is a continuing need to develop tools and techniques which can bring about improvements in meeting this objective.

The quantity surveying expertise is ideally placed to assist in resource management in that one of its areas of activity is a distinct competence in the measurement, description and quantification of construction work within the context of a legal and economic framework. (2)

Quantity Surveying has built up this competence by being primarily responsible for the production and use of tendering documentation aimed at managing the financial implications, and indirectly the resource implications, with regard to construction projects.

However, this competence has mainly been developed around the needs of lump sum tendering as a means of selecting, in competition with others, a particular main contractor to execute the construction task. Concentration on this particular important aspect of the design management process has tended to dominate the way in which the tendering documentation has developed and has not been aimed at satisfying the needs of the selected contractor in terms of implementing the construction project solution.

It is argued that such a role of the tendering documentation is not to assist the contractor in this way but primarily to aid the tendering process. However, such an hypothesis is at best short sighted and at worst hindering the identification of the most optimal construction solution as the following limitations can be identified:

- I The successful contractor has to build a resource and cost model by translation from the design stated model in order to provide a plan of construction and when construction commences control of construction. (3)
This translation is necessary because the design stated model does not correlate with the needs of the contractor for the following reasons:
 - i) The use of the unit of finished work
 - ii) The failure to reflect the differing locations of construction activity in the construction project and thus a disregard of the time dimension.
 - iii) Poor data co-ordination between the differing documentation arrangements produced by the design team thus making identification and establishment of appropriate information by the contractor difficult and error producing. (4)

- 2 The contractor's planning and controlling model built in (1) above thus may often be erroneously constructed because of the difficulties involved in the translation outlined above.
- 3 Even if correctly established the model so built provides an essentially non-heuristic statement to those concerned with the identification of the resource implications of the particular construction project under consideration. Clearly this makes the resource optimization process by those concerned with the development of the design solution and by implication, the construction solution, subjective due to an inadequate data base of resource implications being available to the design team.
- 4 The tendering process itself tends to discourage the contractor from identifying his construction solution at the correct time. This is because, due to the limited tendering period available (5) and the costs associated with the tendering process which may go unrewarded, the tender bid, and thus the financial basis for the management of the project, is based upon a brief appraisal of the intended construction solution, derived by the production of a method statement, rather than a detailed development of the intended construction solution through for example the use of network analysis. Clearly the establishment of the tender sum through the estimation process should be derived from a detailed consideration of the construction solution and the resources needed rather than developing a detailed construction solution after submission of a successful tender.
- 5 Due to the disparity of the way costs are reflected in the design produced cost model and the contractor produced cost model the payments to be made to the contractor and the actual costs incurred by the contractor are not directly related to each other. This makes effective financial management by both designers and contractors not entirely realistic due to the differing cost profiles generated by the two cost models.

Thus it is suggested that if an interface can be created which facilitates the transposition, without translation, of the design produced model into the contractor produced model as a basis for construction planning and control then the contractor will be provided with an enabling device for the execution of his construction solution and the designer will be provided with a more heuristic view of the resource and cost implications of a particular design solution.

Until the advent of micro computer technology in the early 1980s the provision of such an interface has not been realistic because of the frailty of manual endeavours. Thus there has been, and continues to be so, the production of information which attempts to satisfy a number of purposes but is driven by the prime requirement of aiding the selection of a contractor in competition with others. Underpinning this basic requirement has been, and continues to be so, the unit of finished work as it provides a convenient device for carrying costs as the recipient of such information (for example a tendering contractor) can readily comprehend what is required and thus can allocate unit rates purporting to reflect the financial implications of construction.

Thus the bill of quantities has provided, and continues to do so, a convenient interface between the design solution and the construction solution by enabling the completion of the cost model through the tendering process.

With the advent of micro computer aids in the 1980s advances have been made in the production of bills of quantities and their subsequent manipulation to provide specific requirements, for example work section presentations for tendering and elemental presentations for subsequent design cost control.

The advances made can be broadly classified as follows:

- 1) Automation of the 'working up process' thus enabling the manually prepared dimensions from the Architects drawings to be processed into the final bill of quantities in a variety of formats. (6)
- 2) The automation of the preparation of the dimensions from the Architects drawings by conversion of such information into a digital form from which, by appending appropriate descriptive information, the quantities can be generated. There are currently two major commercial developments in this area. (7) (8).
- 3) Although still very much at the feasibility stage the application of CAD techniques whereby models, both iconic and symbolic can be stored and manipulated within the computer aid. (9).

Clearly the derivation of bills of quantities, together with other models should become a realistic proposition especially as low cost 3 dimensional iconic modelling systems become a reality.

Associated with these advances have also been the development of estimating systems designed to integrate with the computer aided bill production systems in order to facilitate both the estimating process and the subsequent manipulation of cost data for various requirements such as adjustments for fluctuations, interim valuations, elemental cost analysis etc. Thus the computer aid has become an integral feature in the production of tendering documentation based on bills of quantities and no doubt its use will continue to increase in the future. Further, the process of physical measurement from drawings by the quantity surveyor will probably continue to decline as CAD systems become more sophisticated in their ability to model, in 3 dimensions, construction projects.

Advances have also been made in the use of low cost micro computer aids in the area of construction management with a plethora of optimization models designed to aid the identification of the most appropriate solution to the task of construction. (10)

Latest advances in micro computer technology have been the introduction of expert system technology in order to capture the expertise of recognised experts thus enabling the decision making process leading to an appropriate judgement to be captured within the computer aid.

Such technology has recently been applied to the construction industry and also to the quantity surveying function through the Alvey initiative resulting in three distinct, but inter-related applications in the fields of feasibility, procurement and time. (11)

The quantity surveyor is uniquely placed in that he produces and manages the interface between those responsible for the design solution and those responsible for its production where competitive, lump sum tendering strategies are employed and therefore should be in a position to develop such an interface that transcends both the requirements of both the design process : the identification of the required product : the building and the construction process : the identification of the required processes to achieve the product : the building.

Examination of advances in computer aids, as described above, indicate that such aids are generally discreet sub-sets concerned with either improving the efficiency of producing the tendering model or aiding the establishment of the contractor's construction management model. Designers have also built both inductive and deductive models to aid the identification of the most optimal design for a particular requirement as set out in the client's anticipated performance requirements. Where such models are designed to identify the cost implications of design proposals then clearly they are intended to reflect what is likely to happen when the contractor establishes his own cost model.

Design cost models generally make use of data derived from a successful tendering model: the priced bill of quantities which can then be manipulated to form a variety of data bases for subsequent cost modelling exercises.

Such data bases, although now more and more being underpinned by computer aids, to facilitate more accurate and efficient manipulation of their contents, because of their reliance on priced bills of quantities means that their reliability for use in subsequent cost models is questionable. (12)

Recognition of the limitations of priced bills of quantities as a basis for tendering and subsequent cost control has long been recognised and various proposals and developments have been attempted with varying degrees of success.

The first serious attempt was the Operational Bill and its subsequent derivative the Activity Bill which was developed by the BRS. (13) This attempt produced a bill of quantities structured in accordance with the design teams notion of how the project would be carried out by the contractor. It suffered by being perhaps ahead of its time as without the use of the computer aid it was a complex and laborious model to manage manually. However, there is no doubt that its philosophy was sound as manifested by the fact that subsequent developments in tendering documentation ape some of its recommendations as discussed below.

Some other less radical proposals were also put forward, the most well known being the ideas for construction activity derivation developed by Nottinghamshire County Council under its Building Industry Code and Research into Site Management Initiatives. (14) (15)

The DoE also proposed a solution, at a strategic level, which attempted to link design and construction through the use of Construction Planning Units. (16) In recent years a further radical approach, the use of which has been somewhat limited, has been the introduction of the British Property Federation System. (17) This proposal, amongst other changes, recommends none use of bills of quantities as a basis for contractor selection but the use of drawings and

specifications as the basis for selection. The system also suggests the use of the contractor's cost model: a schedule of activities, as the basis for cost management during the construction stage. The objective of this proposal is to set up the cost control system for the project on a more realistic basis ie that used by the contractor as a basis for executing his construction solution.

The Standard Method of Measurement Development Unit has also recognised the need to produce bills of quantities which more closely model how the contractor incurs his costs but has only made certain superficial changes in this direction under the latest proposals for bills of quantities. (18) These changes include : a) improved data co-ordination by means of the Common Arrangement; b) the introduction of more work practice related work sections thus reflecting more closely the divisions of sub-contractor expertise within the industry; c) the introduction of method related charges in order to allow the identification and establishment of costs which are not necessarily quantity related.

Despite the above improvements the latest proposals leave more to the contractor than under SMM6, in the task of quantifying construction work as fewer items are now identified for separate measurement and quantification. Thus the design produced cost model generated under SMM7 will have less cost detail than under its predecessor SMM6 which will have the effect of 'locking up' more cost information than is currently the case which may lessen further the ability of the quantity surveyor to manage construction costs.

A radical improvement in the use of bills of quantities as a basis for providing a more effective cost model has been achieved by the introduction of the 1976 CESMM and its successor the 1985 edition. (19) This document was developed in order to produce bills of quantities which aimed at satisfying two objectives:

- a)as to enable tenders to be prepared efficiently and accurately.
- b)to provide for use of the priced Bills of Quantities in the valuation of the work executed. (20)

Thus this particular standard method has contributed much in aiding the production of a more realistic cost model for use in the cost management of civil engineering projects.

However, despite the various improvements in the approach to the information to be included in the bill of quantities together with the advances in the application of micro computer technology in the generation and management of construction costs it is suggested that there is a need to generate a cost model for use at the design/construct interface which enables both the product and the processes needed to achieve a building project to be modelled.

The hypothesis put forward in this research is that such an interface can be produced which can provide an effective cost model for use by both designers and constructors within the context of lump sum competitive tendering.

THE DESIGN/CONSTRUCT INTERFACE

The interface is supported by a micro computer aid and makes use of relational data base management techniques and expert system technology to provide and 'intelligent' resource based cost model which can be used as a basis for resource and cost management embracing the following applications:

- 1) Design resource and cost management
- 2) Contractor selection
- 3) Construction resource and cost management

The computer aid that is being developed (PROPPROC) comprises a suite of programs, as illustrated in Systems Analysis flow diagram, which allow the design identified product to be transposed into the processes necessary to achieve its construction. The essence of the system is the facility for the Expert System component of the program suite to access and manipulate data from the data base component of the program suite and to submit back to this data base for subsequent user retrieval information about the particular building project under consideration at various stages during its realisation.

The system is initiated by the generation of the design situation model by inputting design data with the following structure:

A	Elemental Criteria Constructional Criteria Location Criteria	eg eg eg	External Walls Brickwork 1st Floor Level
B	Task Description in Quantity and Unit	eg eg	Half brick walls in commons c/m (1:1:6) 50 m ²

A above are necessary for activity assembly as they describe what, how and where and indirectly how long.

B above are necessary in order to define the precise identity of how, together with how much.

Rather than uniquely creating the above situation model for each building project a general data base will be provided containing information from which the unique project description can be created by appending the appropriate quantities and locations. Where such information is not available within the general data base then any unique information requirements can be additionally input.

It is also feasible, although not envisaged as forming part of this research, to input unique information to create the design situation model through the application of CAD technology, or at a less sophisticated level the use of digitizing systems.

The design situation model thus created is now accessed by the expert system which contains, within its inference engine, logic rules which allow the assembly of construction activities together with their sequence. The expert system also carries out validation checks on the design situation model to identify any omissions within it. Also the logic contained within the system can be overwritten by the user, for example the contractor, where a different approach is required. On completion of activity derivation and sequence the expert system further interrogates the design situation model and derives the finished quantities which are then converted into:

- 1) Resource types : materials, labour, plant and supervision
- 2) Quantities of each resource type
- 3) Productivity data where appropriate
- 4) Cost information

Again the user can overwrite any assumptions within the system where disagreement occurs.

The final process the expert system carries out is to identify the activity durations having interrogated the user as to appropriate limits (time and/or resource type).

The completed construction situation model can now be output to give a statement of the envisaged plan of the construction task and when construction commences be used as means of control, the expert system responding to any changes from the originally identified plan by producing a revised plan.

Thus the interface described above is designed to avoid the error producing duplication of effort that is currently required in order to translate the design stated solution into a construction solution. The interface acts as a transposing mechanism hence converting the design stated solution into a construction solution. The benefits that should accrue from such an approach are summarised below:

- 1) The design team should become more aware of the implications of their design solutions on the construction solution.
- 2) The construction team should be directed towards a construction solution without the need to assemble their own construction solution from the design information.
- 3) Act as an implementation device for executing the construction solution on site by providing a management tool for use by those concerned with realizing the construction solution.

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