The Limitations of Current Working Practices on the Development of Computer Integrating Modelling in Construction

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ABSTRACT

For the Construction Industry to improve its processes through the application computer-based systems, traditional working practices must first change to support the integrated control of design and construction. Current manual methods of practice accept the limitations of man to process a wide range of building performance and production information simultaneously. However when these limitations are removed, through the applications of computer systems, the constraints of manual methods need no longer apply.

The first generation of computer applications to the Construction Industry merely modelled the divided and sequential processes of manual methods i.e drafting, specification writing, engineering and quantity calculations, estimating, billing, material ordering data-bases and activity planning. Use of these systems raises expectations that connections within the computer between the processes modelled can actually be made and faster and more integrated information processing be achieved. "Linking" software is then developed. The end result of this approach was that users were able to produce information faster, present it in an impressive manner but, in reality, no perceived improvement in actual building performance, production economy or efficiency was realised.

A current government sponsored Teaching Company Programme with a UK design and build company is addressing the problem of how real economic benefit can be realised through improvement in, amongst other things, their existing computer applications. This work is being carried out by both considering an academic conceptual model of how "designing for production" can be achieved in computer applications and what is immediately realisable in practice by modelling the integration of a limited number of knowledge domains to which computers are already being applied.i.e. billing from design, estimating and buying. This paper describes each area of work and how they are impacting on each other.

1. BACKGROUND

For European construction companies to remain competitive in world markets it is essential that they employ the techniques and technologies that support engaging new and keeping existing clients, reacting faster to design, tendering and production requests to meet clients or end users requirements in the finished building and to return estimated profits for the participating organisations. Construction and computer specialists have been working towards this for decades but the majority of the above requirements have yet to be met and the corresponding benefits realised.
This is because construction specialists requested computer systems to emulate their individual manually driven information systems based on divided working practices to which, computer programmers responded with what they thought was really required.

This meant that the basis for the computer system was the specific implementation of working practice which, was not necessarily correct but from which user requirements were identified. Computer specialists did not necessarily appreciate the relationships in the practice models and how they could be achieved through using computers. This lead to programme designs being those of the programmer and not the user. This in turn resulted in computer systems that failed in application. The introduction of "Systems and Software Engineering"(1)(2) widened the boundaries of programming to include the concepts behind the models of practice, the models themselves, their implementation and supporting software, hardware and wetware.

Initial application concentrated on meeting the requirements of very narrow domains, emulating manual processes without considering how they might be linked together to pass or exchange information. Construction industry computer systems accept the concept behind the current practice models to firstly consider building design, construction planning and construction operations(3) is correct and that the original perceived benefits can be realised if correctly implemented, that is linking the stages in the process together. The benefits from this approach are increased speed, due to reduced information handling and duplication, and traceability in documentation due to the relational nature of the data. Apart from the method of processing and the economic use of information nothing has really changed and therefore the overall outcome in terms of economic benefits to the participating organisation and improvement to the buildings will not have changed either.

Industry is beginning to question its' methods and models in collaboration with research institutions (4). Research indicates that future construction industry computer systems will be based on practice models whose concepts support a wider view of "engineering buildings"(5). These models will cover the design and construction of the building integrated with the design and construction of its method of production(6). In essence these new approaches accept that a buildings production has to be designed and that this must be in close association with its design as a product due to the common data models (7) between them. This means that all design work must be simultaneous and start from the briefing phase of a project. These approaches have been designed to realise the original perceived benefits, using computers will help yield them more quickly.

2. INTRODUCTION

Early computer systems could only address small parts of narrow domains due to speed and capacity limitations of the hardware. Developments of faster and increased capacity machines, more flexible operating systems and programming languages, removed these and in doing so revealed a new ones. These new limitations were as a result of how information was handled within a domain and between domains, that is the architecture of the information system and the nature, order of use and need for the information, that is the method of practice.

In construction organisations there are systems in use that are based on application to parts of and narrow domains. These are simple applications requiring extensive manual data input resulting in hard copy output, that is manually entered into the next stage. Current work is focused on linking domains in order to remove data handling and duplication and replace it with a common data philosophy and free flow of information. This work reviews the architecture of the implemented information system against a model of the ideal system, based on accepted practice, to plan the changes needed to remove information bottle necks and correct information deficiencies.Current research shows that if all the domains are linked together the benefits will be limited to those of speed and documentation.

Current research proposes new working practices based on a common goal of delivering a building to the customer and being able to demonstrate that all requirements have been met and that cost and time and grade are always under control. For this, information to achieve the common goal is defined and used as the basis of practice processes and information system.
For the perceived economic benefits to the organisation and quality improvements to buildings to be realised from the use of computer systems the traditional practices of project participants must undergo a fundamental change. The focus must change from that of islands of responsibility for parts to total responsibility and common goal of delivering a building.

3. CURRENT PRACTICE

A UK design and build company whose work is evenly divided between traditional contracting and design and build has an active programme of implementing information technology to improve their business. This now includes a teaching company to bring closer collaboration between the industries needs and research findings and ideas.

3.1 INITIAL APPLICATIONS

Initial implementations were based on the requirements of isolated users and existing manual methods of working. The question of whether the manual methods were a correct implementation of currently accepted models of practice or whether the computer systems were based on a strategy for the use of information technology in the business were not an issue.

The purpose of this was to show a small piece working utilising computers to stimulate interest for further applications and developments.

Applications to localised areas of the business has given speed and traceability benefits to those areas but has not resulted in any overall improvement to the buildings produced or the economic performance of the company. For example the use of CAD systems by the design department has meant that impressive detailed images of the proposed building can be produced with alternative feature variations and views to order. To be able to see a buildings spatial arrangement in three dimension and change the interior decorations is an important benefit and without CAD would have been uneconomic to produce in terms of time and cost.

The use of computer aided take off systems has benefited measurement, take off and bill production in terms of speed and traceability in documentation. It is suggested that time savings of up to 50% (8) are possible over manual methods depending on the type of system and its implementation. A similar situation exists with project planning and management accounting. The theme common to these type of computer applications is that they all exist in isolation fulfilling particular functions within a department, resulting in localised benefits. These applications reflect the artificial divisions and barriers of working practice which severely limit the change over to an integrated working approach, the results of which challenge the construction industries raison d'etre.

Developing islands of computerised information required considerable capital expenditure in computer technology that failed to return the originally perceived economic and quality benefits to the company or the client.

3.2 THE ONGOING SITUATION

Through the teaching company programme several areas within the organisation are being investigated with a view to improvement. Pre contract is one where considerable benefits can be gained through the integration of estimating with schedules of work (billing) and design. This is currently based on the pre-contract design and build model in figure 1.

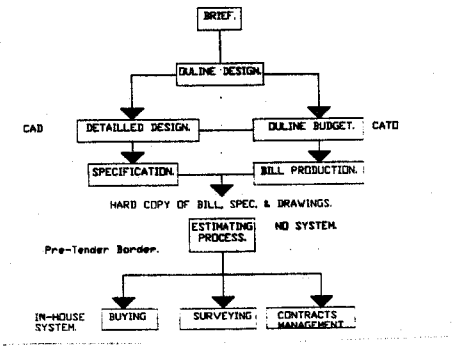

FIGURE 1 A Pre-contract Design and Build Model

The model is supported by an information system that is implemented through a combination of manual and computer based tools. It is basically a manual system with islands of computerised information.

The computer systems take hard copy input and produce hard copy output which means there is considerable information duplication and poor traceability between stages.

A combination of manual and computers methods are used for outline design. CAD is used for the detailed design, CATO for bill preparation whilst spread sheets support subcontractor tender analysis. A in-house data base is used to maintain subcontractor supplier procurement information and assist in order production. Manual systems are used for budgeting, estimating and financial site control.
However, the information system is out of balance due to "bottle necks" created by manually processing information, hard copy transfer and keyed data entry into the computerised sections. One of these being investigated is estimating due to the convergence of information as illustrated in figure1. To date a suitable estimating package has not been identified.

In order for estimating not to become just another island, an information system is being developed that supports the industries accepted models of practice and not the specific departmental ad hoc models of estimating. It is considered that by using this approach a better understanding of the information required as outputs, to be received as inputs to the next stage, will be more clearly defined and easier to interface. It is perceived that as a result of this the reduced data duplication and manual handling would effectively speed up the process and increase the traceability across domains.

When all project information, developed using the currently accepted models of practice is available and in use, current practice itself will be seen as the next limitation to integration. This is because there will be less information in circulation but a wider range of information available from the early stages of design, which will lead to the need for changes in working practice through the requirements for project participants to contribute to and use it from the start of a project. For example an estimating system connected to all information sources within the organisation and to selected external ones could mean the estimator being involved with decisions relating to the size, shape and spatial arrangement of the building during outline design. The development of an prototype integrated design, billing and estimating system (9) demonstrated that a further reduction in handling and duplication across and "what if" scenarios between domains was possible.

The next limitation to integration will be the information itself in relation to the aim of delivering a building to the customer. With the flexibility to use whatever information is required there will be no excuses for why the correct information cannot be used and processed to control the delivery of a building.

Therefore with information systems correctly implemented using the currently accepted models of practice the benefits will be limited to increased speed and traceability in documentation. Speed does not necessarily mean any economic improvement for the participating organisations or any building improvement for the client. Traceability does not necessarily mean the ability to demonstrate meeting requirements or better control over projects because nothing has change in respect of methods, processes and procedures.

4 FUTURE PRACTICE

The change in working practice from phased to parallel involvement of project participants and the search to establish the reasons for and the missing information to control building delivery is also the aims of construction research.
This common ground effectively closes the gap between them which should lead to stronger partnerships, like those of the teaching company programme, through the application of research into practice and practice into research. The conceptual approach being proposed in this paper supports the direction of change in current practice now and in the future.

4.1. DESIGN IN PARTNERSHIP WITH CONSTRUCTION

Current methods of practice are based on the concept that design is separate from construction (3) and that construction is a follow on activity, whether or not design and construction overlap as in the fast track approaches. It is a fact that the majority of decisions affecting construction are taken in the early stages of design. These relate to a range of issues from the location and spatial arrangement of the building to the selection of the elements and materials. The early decisions made in respect of these will directly impact upon the choice of labour, plant, the order of building assembly, cost and time for the project. The division between them can lead to failure during production which can increase both cost and duration of the project (6).Therefore there is natural integration between design and construction that is broken by the methods of practice.

Correcting this situation means that construction operations must be designed in partnership with building design so that the decisions made take account of the requirements and criteria for both. This is supported by the statement (10) that:-

> "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones"

Which can be interpreted as:-

> design is the intellectual activity of devising a course of action that changes existing situations into preferred ones.

Which can be reinterpreted as:-

> the existing situation **as** the existing natural and built environment
>
> the preferred situation **as** the building proposal
>
> the course of action that changes **as** construction operations.

Which means:-

> design is intellectual activity of devising construction operations that changes the natural and built environments into building proposals.

Further meaning the boundaries of design in the construction industries must include construction activities. This can be further interpreted as the proposal for the modification of the environment(6).

4.2 DESIGNING FOR PRODUCTION

In building design it is accepted that buildings are designed for performance for a given use. What this really means is that the building is designed to be part of an "in use" system. For example part of a retailing system, a manufacturing system or a home. A building can be part of many systems (6) and must be designed to part of those to which it belongs but, it is firstly part of the system that produced it, its "production system". This concept and that of environmental modification forms the basis of designing for production.

4.3. THE PRODUCTION SYSTEM

In construction design a building must be designed to perform as part of a production system during the modification of the environment. In the production system a building is considered as a resource of its own production and part of a system of resources. It comprises man, machine, material, environment and emerging building that is flexible in configuration and dynamic in operation. It is a system in which resources move or are moved to effect the modification of the environment.

The production system has to be designed and this includes the design of the building as one of its elements. It could also include the design of materials and components, plant and equipment and the education and training of personnel (the development of flexible resources), if required.

It has to be designed so that the most economic combination of resources are used to effect the modification of the environment.It is proposed that this can be achieved by considering the movement of resources conceptually as MATERIEL (7) flow because it covers the what, where, when, how and why issues for individual resources and for the system of resources. This will result in the information to configure the continuously changing production system and control construction operations to achieve the finished building.

The resulting form of a production system will depend on the design criteria and their relative priority.
For example time, cost and convenience could be design criteria but by changing their order of priority different systems would result.

4.4. MODELLING PRODUCTION

Materiel flow is a high level concept that can be satisfactorily be generalised up on but it may prove difficult to model directly. This is due the complexity, quantity and nature of the information and decision making that would be required during proposal and analysis sessions. Instead of attempting to build up one model it is proposed that a set of four integrated models are built (7) that collectively represent the modelling of flow, theses are-

FLOW

- space
- load
- energy
- resource

The model contributes the following to the study of flow:-

Space modelling addresses the provision for production spatial requirements.

Load modelling addresses the provision for production structural static and dynamic requirements.

Energy modelling addresses the provision for production energy type and level.

Resource modelling addresses the provision for production of man, machine and materials and in particular their physical, chemical and operational properties.

The study of flow starts at resource supply origins, through manufacture and finishes at the points of disposal when the building is demolished within a boundary of significance. This will include the consideration of the following issues:-

- -transportation
- -handling
- -storage
- -processing
- -positioning
- -fixing
- -protection

for:- -original construction assembly, time and cost

-repair

-replacement

-substitution

This will ensures that a buildings construction, maintenance, refurbishment and demolition are given consideration during the original design. Space ,load, energy and resource modelling for production are compatible with those for end use modelling (7) due to the commonality in information type which supports the necessary integration mechanism. For use in practice it is necessary to place a frame work around the modelling in order to control the build up of information and its use to control construction operations.

4.5. PRACTICE MODELS

The matrix of integration between and within the in use and production systems from outline to detail and the fact that buildings are part of both means that management of the design process is critical.
This is because decisions on design proposals must be share at various stages in the design process. Meaning the design processes must be in harmony with each other and run in partnership, simultaneously, if the requirements for both systems are to be identified and complied with fully. This requires very flexible project practice models to bring together "in use" and "production" system designers and managers.

Simultaneous engineering(11)(12) is practised by major manufacturing organisations such as the ford motor company to reduce the cost and time of introducing new products. It brings close cooperation between product designers and manufacturing engineers to ensure that product proposals are based on sound production methods. Figure 2 is from an interpretation for construction of a description of a pilot implementation of this at the Ford Motor Company (11).

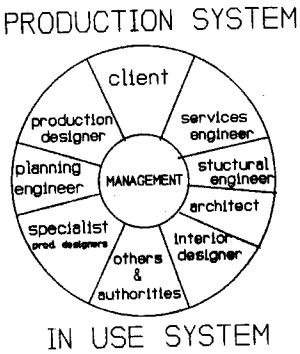

FIGURE 2 Simultaneous Practice Model Structure for Construction

Figure 2 illustrates the wider involvement in the project and the equal status of the participants. This means that all involved can consider the issues relating to the in use and production system development in partnership through equal consideration during the process of design.

The systems structure of the environmental modification model (6) was developed for this purpose, its level providing both horizontal and vertical frame work for decision making.
Figure 3 illustrates the concept of simultaneous practices applied to a pre-contract situation.

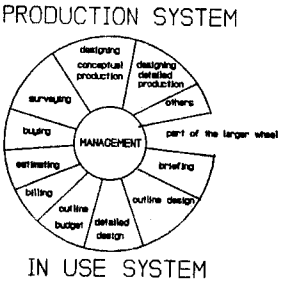

FIGURE 3 Simultaneous Practice in pre-contract Design and Build

5. INFORMATION SYSTEMS

The aims of modelling and the structure of the flexible project practice partnership model provide the outline of the requirements for the supporting information system.

The concept of the information system to meet these requirements would consider:-

the nature and information needs of the modelling

the multi-organizational nature of project practice

the need to work from briefing to detail design between the design of two systems.

This could result in a system were the information is held in levels of detail and distributed amongst the participants, based on a modified version of the environmental modification model that takes into account the systems to which a building belong.

The modelling would then be supported by appropriate modelling tools that could access the information in any of the storage locations at the appropriate level of working. This is the architecture of a flexible and open system and considered desirable for economy and efficiency in information usage (13).

6. CONCLUSIONS

Computer systems are only tools to support working methods. They only speed up processes and provide a trace of information from start to finish within the boundaries of the system. This means if the working methods are incorrect computer systems will support getting it wrong and if working method are correct they will support getting it right. Therefore computer systems will either help to get it right or wrong faster with traceability of information.

The perceived economic and quality improvements will not come about through the application of more advanced computer systems to the industries accepted methods of practice. This is because those methods do not support design in partnership with construction or the design of a production system.
This paper has proposed that:-

unless designing for production is accepted as the missing part of design no further appreciable benefits from the application of computer systems will result above those of speed and traceability.

designing for production is part of normal practice to design systems of "production" and of "in use" simultaneously.

this is view of practice will provide the platform for the development of open information systems. These will enable the original perceived benefits from computers to be achieved and possible many more that will emerge when these have been satisfied.

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