DATA RICH DIGITAL ARCHITECTURAL ENVIRONMENTS

Managing Rich Information Flows in Architectural Practices of Australia

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SUMMARY

The development of data rich digital environments for the construction industry has been problematic despite the initial optimism when their application to design and construction was first considered. This paper reviews the current state of the art research into the application of information technology in design and construction and identifies the more critical issues in its adoption. In conclusion the paper then proposes a preliminary theoretical model being developed as a research tool for investigation into highly detailed information flows in a case study building renovation project. This investigation aims to track the detailed information flows and knowledge system used by the stakeholders in the building project.

INTRODUCTION

Although there has been much discussion about how to improve productivity, cost control and client satisfaction in the building industry, little progress appears to have been made. The promise of the gains which could be made by utilising the capabilities of information technology has been limited at best. In implementing IT, organisations have generally applied computing to pre-existing organisational processes which were developed prior to computers being utilised. Furthermore these internal processes as well as those which link one organisation to another are fragmented and have not been well described at a detailed level. This is the foundation of the application of IT to the construction industry. The recent move from the focus on the development of the building product model to that of identifying organisational processes reflects an increased level of understanding of the various factors which influence the take up and efficiency of IT use.

THE BUILDING PRODUCT MODEL

The conventional method of distributing design and construction documentation within the AEC industry has been paper-based. Although the industry often prepares 3D models for visualisation and presentation, it has yet to fully integrate 3D modelling into design and construction. According to Eastman (1999), this will change within the next few decades as the shift towards digital representation increases in demand and popularity.

The building product model may be seen as a digital information repository describing the objects making up the building, capturing the form, behavior and relationships of the parts and assemblies within the building (Eastman & Siabiris 1995; Eastman 1999). Rich data stored in the model permits support for architects, construction managers, engineers and others who are directly involved in the total building project from the initial design through to demolition. Architects who design non rectilinear building forms where two dimensional drawings provide limited support, should support the advancement of 3D modelling tools for complex architectural arrangements (Laiserin 2001).

The possibilities perceived by Eastman (1999) include detailed planning of construction during design, building analysis during the design stage (eg thermal, acoustic, lighting, HVAC system applications) and support for the building's ongoing operation. Anecdotal discussions regarding the development of Virtual Reality as an aid in the planning and visualisation of construction techniques prior to their application on site claim to reduce production time, control costs and minimise errors. This has yet to be conclusively demonstrated.

The growing diversity of industry disciplines has resulted in difficulties in current technology meeting the diversity of needs. This has encouraged industry fragmentation. One of many solutions is to develop agreed standards by which industry groups adhere (Eastman 1999). There is also a "need for a data management system focusing on information to the object level rather than files and layers is important … and will allow greater control but raises liability issues regarding ownership of data in computer terms” (Laiserin 2001). Computer and communication technology, particularly with the establishment of the Internet, has opened new opportunities for information to be transferred across multiple formats and platforms. This places increased importance on data management and standardisation.

Being able to distribute design information worldwide has made it a unique infrastructure for inter-disciplinary integration, information sharing, collaborative and concurrent working (Wang et al. 2002). For this to be effective the decomposition of large scale problems is required which has been anticipated by researchers such as Anumba et al. (2002). It is evident from the work of Jeng & Eastman (1998), that the WWW has influenced the shift of computer use in architectural design, from replacing and supporting manual drafting, to a network device for co-ordinating distributed design activities.

PROCESS MODELLING

With industry fragmentation, support tools have become consultant specific to deal with the complexity and specialised nature of many of the design and construction processes. Other industries such as automotive, electronics, manufacturing, and shipbuilding have developed many industry wide processes to an advanced level. Reports such as Latham (1994), Egan (1998) and the Commonwealth of Australia (1999) have indicated that adopting manufacturing processes and their supporting technology will enable the construction industry to save up to forty percent of the total project cost (not to be confused with the *net* building cost). As a result, the need to adopt inter and intra industry leaning is vital (Latham 1994; Egan 1998; Kagioglou et al. 1998; Australia 1999).

Jeffery Huang and colleagues at Harvard University (Huang 1999; Huang et al. 2000), argues the need to systematically question existing design processes in order to invent new methods of collaboration.

Process mapping is recognised as an important management tool for understanding how value is delivered to customers (Winch & Carr 2001; Kagioglou et al. 2002). There are two approaches for process mapping. The first is often referred to as the engineering approach which involves the implementation of IT and focuses upon information flows. Secondly, the business approach deals with the actual flows of information between the different stakeholders within an organisation (Winch & Carr 2001). The current transition in the construction industry from paper-based to digital information transfer suggests further consideration needs to be given to the relationship and distinction between information content and format in the production and utilisation of documentation (Leeuwen & Harry 1998; Leeuwen et al. 2001; Coulson 2002). Winch and Carr (2001) stress that research efforts should look into “establishing good practice in the resolution of project processes, to reduce resource generating, transmitting and interpreting unnecessary information, while retaining full definition of the information flows that are required”.

Initiatives by Froese (1995a), Aouad et al. (1998), Aouad et al. (1999a) and IAI (1999) have presented generic processes and information transfer protocols to support business structure, design, construction and post completion stages at a macro level. It appears however, that the defined inter-relationships between activities are not sufficiently directly applicable to industry to gain their strong interest and subsequent implementation.

The Generic Design and Construction Process Protocol is perhaps the most detailed and thorough process model proposal and potentially influential for the Australian construction industry. On the other hand, like many other process model attempts, the model presented is linear in its description of building process. There is evidence that these models acknowledge the inter-relationship between activities within the process. In spite of this, very little is known about who has what information, when, where, and in what form? Winch and Carr (2001) argue that the construction industry needs to develop a widely accepted “methodology for creating maps and protocols which can provide the baselines for shaping project-specific processes, and communicating to the client the merits of competing protocols” rather than generic process protocols.

CROSS-INDUSTRY LEARNING

Efforts to apply process mapping to the construction sector are evident (Construct_IT 1995; IMI 1995; Gann 1996; Hinks et al. 1997; Aouad et al. 1998; Aouad et al. 1999a; Lee et al. 2000; Thorpe 2000; Winch & Carr 2001). Recent reports from the UK and Australia (Egan 1998; Australia 1999) have indicated that the industry needs to identify construction as a manufacturing process to enable a productive future for the industry. However, fragmentation of operational activities between industry stakeholders and the architect's perception of uniqueness of architectural designed projects have accounted for the slow uptake of new technology (Aouad et al. 1998) as a means of facilitating the adoption of new processes.

Research has identified the tangible benefits the adoption of more efficient processes bring with a decrease of project duration, wastage reduction and improvement in communication methods and channels (Aouad et al. 1999a).

Discussions of new product development have indicated that it is conventional for product developers to be involved during the early stages of the design including the client's briefing stage (Culbreth 1989; Gann 1996; Fox 2001; Pratt et al. 2002). Project progression points are explicitly scheduled for various prescribable decision points. Scope for the concurrent process planning and professional input is included in such process philosophies. The outcome of such adaptation has enabled projects to be systematically conceived, developed, and revised whilst retaining the option to vary or cease the process within the prescribed process management protocol (Aouad et al. 1999a; Kagiolou et al. 2000). Ongoing reviews of the product's life cycle after its completion allowed product developers to revise and improve subsequent product versions.

If such process application is adopted by the construction industry, it has the potential to offer extra scope for pre and post production consultancy and evaluation roles allowing the industry to generate and use feedback in improving the product and their own production process (Aouad et al. 1999a). This is currently lacking.

The latest research efforts have indicated that IT, process management and communication are interdependent (Froese 1995b, a; Hinks et al. 1997; Aouad et al. 1998; Froese & Rankin 1998; Aouad et al. 1999a; Froese 1999; Bjork 2002). Such indication has led to the need to integrate and communicate interdisciplinary expert information and define the terms and content (when, what, and where) of the communicated information. The 'fuzzy', 'soft' or unstructured nature of the early design stages will pose difficulties.

Impact of IT

Installation of IT in design and construction organisations has been evident for the past thirty years. During this period the industry witnessed many companies investing in the wrong IT technologies without addressing the importance of their business structure.

Post 1990, the industry witnessed the shift from employing IT driven solutions to implementing IT as an enabling technology (Aouad et al. 1999b). Incorporating the development of IT systems that support business processes taking into account process, people, and cultural needs are the latest endeavours to rectify previous problems (Aouad et al. 1999b). Aouad et al. (1999b) discussed several hazards of using IT as a driver and suggested two approaches utilise IT to enable solutions to the fragmented industry. These include firstly the integration of process and IT in parallel focusing on process as a driver and IT as an enabler tool and secondly the phenomenon of co-maturation of IT and processes is necessary.

Aouad et al. (1999a) proposed an ideal theoretical process model, which they believed would ensure the proper and effective use of IT. However, the extent to which the model reflects industry practice is open to discussion.

STAKEHOLDER COLLABORATION

Collective and joint efforts in design, often known as Collaborative Design, Co-operative Design, Concurrent Design, Multi-disciplinary Design or Interdisciplinary Design is a recent research focus in

Computer Aided Architectural Design (CAAD) and computer use in the AEC industry (Kalay 1998; Pena-Mora & Ali-Ahmad 1998; Stouffs et al. 1998; Huang 1999; Snyder & Flemming 1999; Faraj et al. 2000; Lottaz et al. 2000; Aspin et al. 2001; Han & Turner 2001; Anumba et al. 2002). Computer use in the AEC industry has been primarily utilised to evaluate final design solutions and produce graphical representations. Efforts to improve the data flow between disciplines have resulted in some enhancement of communication. However, facilitating collaboration for joint decision-making among stakeholders involved in the design and construction has yet to be addressed in detail.

As reported by Kalay (1999), the implementation of joint decision-making will deliver a better overall product. However, such collaboration is difficult to achieve in the fragmented industry environment. Typically, a construction team will comprise of a number of organisations formed into a temporary project team (Aspin et al. 2001) from a much larger number of independent or semi-dependent organisations (Kalay 1998). Such organisations may be geographically separated with requirements to monitor project progress. This may be achieved by setting up integrated communication infrastructures and developing shared models to work efficiently (Aspin et al. 2001).

Current conferencing tools have assisted the process of the traditional physical meetings between principals of each design discipline. However, it has yet to mature into facilitating Asynchronous Distributed Collaboration (ADC), where participants are located in different places at different times as described by Snyder & Flemming (1999) and Anumba et al. (2002). Anumba et al. (2002) proposes the potential use of artificial intelligence and presented various key features of agent-based systems for collaborative 'peer to peer' interaction and negotiation between design applications for the design of portal frame structures.

Cooperative Collaboration

Another proposed approach to resolve the problematic sociological inhibiting issues is through education (Kalay 1998). Kalay (1998) recommends the 'world view' approach, where individual adversarial approaches are reconciled to concentrate and appreciate the overall project initiatives. Known as P3 (Product, Performance and Process) the model was introduced to facilitate a unified multi-disciplinary design environment that promotes knowledge sharing (Kalay 1998; Penoyer et al. 2000).

There have several been efforts aimed at developing group participation in a web-based environment including the Information, Communication, and Collaborative System projects established by Stouffs et al. (1998) and Lottaz et al. (2000), the Web-based IFC Shared Project EnviRonment (Faraj et al. 2000), and the Distributed Virtual Workspace for Enhancing Communication within the Construction Industry - Information Society Technologies project number 13365 (Aspin et al. 2001). Despite this, face-to-face communication between people has remained the preferred method when interaction is required (Johnson 2001). However, technology will eventually couple with tools to support unfocused communication to assist group awareness for team members who are geographically distant (Johnson 2001).

DATABASE RESEARCH

To facilitate rich design information flows and large heterogeneous formats in design, the requirement of database technology is essential to enable the data management competency. The development of digital Building Description Systems was initiated three decades ago with the works from several organisations in the UK and the USA. These computer programs were designed with the capability of describing buildings at a detail to facilitate design and construction (Eastman 1976).

More recently, the key functions of database systems has been identified (Jacobsen et al. 1997). These functions include the storage of large amounts of heterogenous data and transaction management allowing concurrent access and update of data while managing the data's integrity.

Research efforts have allowed engineering professions to successfully implement database technology into their business structure (Saad & Maher 1996; Shah et al. 1996; Wood III & Agogino 1996; Jacobsen et al. 1997; Dong & Agogino 1998; Jeng & Eastman 1998; Eastman 1999; Liang et al. 1999; Xue et al. 1999; Sun & Aouad 2000; Amor & Faraj 2001; Dawood et al. 2001; Katranuschkov et al. 2001; Kazi et al. 2001; Giannini et al. 2002). The current issue is the reliability of integrated project databases to support collaborative and concurrent design procedures. As discussed by Amor & Faraj (2001), there have been many project attempts to promote its benefits but has yet to deliver its early promises.

Of particular interest is the Distributed Project Database concept (Amor & Faraj 2001), where the project data repositories are dispersed, held at various locations supported by individual disciplines and accessed via a common neutral interface such as COBRA or DCOM. The effectiveness of this concept is potentially very high (Amor and Faraj 2001). Integrated databases are also being investigated as an information resource base for four dimensional virtual reality construction process simulation. The Virtual Construction Site: a decision support system for construction planning aimed to design a comprehensive database of building components integrated with current tools such as AutoCAD 2000, Microsoft Project and with a graphical user interface to deliver a meaningful 4D model (Dawood et al. 2001).

At present however, it appears that a neutral format (eg IAI 2000) project database will be slow to be adopted across the AEC industry. Therefore, it is suggested that a process modelling study of the activities performed within each industry consortium, should form the basis for the software specification and later data models (Eastman et al. 2002).

DISCUSSION AND CONCLUSIONS

The evidence suggests that the initial emphasis on information technology as a means of increasing productivity and quality in the construction industry was misplaced. Even the recent research into the development of building product models appears to simplify what are in reality far more detailed structures both in terms of information complexity and organisational interaction. The more recent discussion of the significance of process model development and the necessity to move from an adversarial to a collaborative model for the industry shows a better understanding of the issues involved.

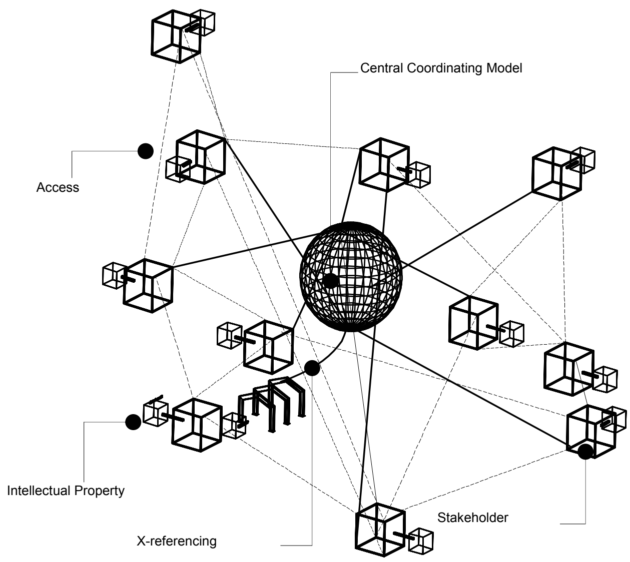

Figure 1 3D Distributed Information Model

The researchers are developing a theoretical process model which endeavours to reflect the complexity of information, stakeholder interaction and intellectual property concerns which are currently seen in the construction industry (Figure 1). This is being developed and tested against a case study project at Deakin University. The case study project will show the detailed information flows and interactions between such the stakeholders such as designers, project managers, client, contractors, subcontractors and suppliers. This will then provide a micro view of the processes and interactions which will then be compared against the theoretical process model. From this a detailed system model will be prepared as a means of identifying a detailed information structure which may required to support efficient information flows in the construction industry.

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