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Building Information Modelling Project Decision Support Framework

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Building Information Modelling (BIM) is an information technology [IT] enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry. BIM enables improved inter-disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management. Despite the apparent benefits the adoption of BIM in practice has been slow. Workshops with industry focus groups were conducted to identify the industry needs, concerns and expectations from participants who had implemented BIM or were BIM "ready". Factors inhibiting BIM adoption include lack of training, low business incentives, perception of lack of rewards, technological concerns, industry fragmentation related to uneven ICT adoption practices, contractual matters and resistance to changing current work practice. Successful BIM usage depends on collective adoption of BIM across the different disciplines and support by the client. The relationship of current work practices to future BIM scenarios was identified as an important strategy as the participants believed that BIM cannot be efficiently used with traditional practices and methods. The key to successful implementation is to explore the extent to which current work practices must change. Currently there is a perception that all work practices and processes must adopt and change for effective usage of BIM. It is acknowledged that new roles and responsibilities are emerging and that different parties will lead BIM on different projects. A contingency based approach to the problem of implementation was taken which relies upon integration of BIM project champion, procurement strategy, team capability analysis, commercial software availability/applicability and phase decision making and event analysis. Organizations need to understand: (a) their own work processes and requirements; (b) the range of BIM applications available in the market and their capabilities (c) the potential benefits of different BIM applications and their roles in different phases of the project lifecycle, and (d) collective supply chain adoption capabilities. A framework is proposed to support organizations selection of BIM usage strategies that meet their project requirements. Case studies are being conducted to develop the framework. The results of the preliminary design management case study is presented for *contractor led BIM* specific to the design and construct procurement strategy.

Keywords: Building Information Modelling, Diffusion adoption.

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INTRODUCTION

Building Information Modelling (BIM) is an IT enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry. BIM enables improved inter-disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management (Ellis 2006, Popov et al 2007, Haymaker and Suter 2007, Fischer and Kunz 2004, Haymaker et al 2005). There are selected examples of successful BIM usage in the industry (Campbell 2007), and the number of commercial BIM applications is increasing rapidly (Khemlani 2007a). Despite this, the adoption of BIM in practice has been slow (Bernstein and Pittman 2004).

Results of a study currently being conducted in Australia are presented in this paper. The aim of the study was towards action oriented research towards the development of implementation management tools which would support both increased adoption of BIM in the AEC sector in Australia by firms at the "tipping" stage of adoption and also improved decision making by those already immersed in the environment. Towards this aim the following research objectives have been developed:

1. develop an inventory description of the current IT software commercial applications and map key features
2. alleviate technological concerns and in particular analyse current collaborative platform servers towards developing a requirement specification as an industry guide.
3. map future work practices and decision making for specific project phases from the perspective of selected BIM project champions and identify extent of change to current practices.

We initially conducted two focus group interviews with representatives from different sectors of the AEC/FM industry. The data collection, analysis methods and results have been reported in detail elsewhere (Gu et al 2008). However, some of the key findings are presented in this paper to provide the context for the next phase o f this study. The FGIs involved leading organisations that have adopted BIM to some extent, and identified the industry needs, concerns and expectations. In summary, the FGI discussions revealed that the level of BIM awareness and knowledge across the different disciplines differed; nevertheless the main issues inhibiting BIM adoption were revealed. This was preliminary data collection to refine the research objectives. The third research objective was suspected but it was not part of the initial considerations in the project and it emerged as a significant underlying theme from these FGIs that had to be explored simultaneously to the technical aspects of the first two objectives. Two follow up FGIs were conducted to explore in detail current work practices in relation to non BIM design management processes and BIM design management processes for contractors in design and construct procurement strategies. Further FGIs shall be conducted to explore the validity of the framework proposed and to refine the framework. In these follow up FGIs data shall be collected to develop further rich descriptions of the participants will be asked to map similar types of roadmaps, flowcharts and/or matrices as presented. Research objective 1 and 2 are the focus of this paper.

BACKGROUND

A critical literature review and a comprehensive desktop analysis of available commercial applications was conducted (Singh et al 2008). The BIM tools and applications report was important to the industry participants as the question arose: What should we be really using when? The report described the features and applicability of the various software applications. It also discussed characteristics of two servers available – one which focussed on data storage and management for the facility management type client during operation and use phases and the second focussed on design and construction phases. The matrices developed contribute to the understanding of the extent to which current work practices may change.

It is well understood that the development of Object-oriented (O-O) CAD packages has allowed greater intelligence in the CAD models. This enables associativity, modelling constraints and relationships within the objects and the object properties (Ibrahim and Krawczik 2003, Lee et al 2003). These constraints and relationships have been used to develop tools and features for performance and cost analysis, clash detection, conflict resolution, scheduling and intelligent documentation (Bajzanac 2005, Mitchelle et al 2007).

A wide range of commercial applications supporting BIM are available. The range of products varies from product suites (e.g. ArchiCAD, Revit and Bentley) that can be used by multiple disciplines across different phases of the project lifecycle to products for specific disciplines and applicable to a particular phase of the project. Only a few of these products are IFC (Industry Foundation Class) compliant. This inhibits their use with other packages that cannot read the data format.

Web-based product services can be very useful (Ibrahim et al 2004, Campbell 2007) and their numbers are increasing. Commercially available web-based products include product libraries, document management systems and BIM model servers.

RESULTS

Lack of initiative and training (Bernstein and Pittman 2004), the fragmented nature of AEC industry (Johnson and Laepple 2003), varied market readiness across geographies, and reluctance to change existing work-practice (Johnson and Laepple 2003) have slowed BIM adoption. In an industry where most projects are handled in multi-organizational teams the lack of clarity on responsibilities, roles and benefits in using a BIM approach is an important inhibiting factor (Holzer 2007).

Surveys conducted recently (Khemlani 2007b, Howard and Bjork 2008) suggest that collaboration is still based on exchange of 2D drawings, even though individual disciplines work in 3D environment and the demand for object libraries is growing. These surveys reveal that tool preference varies with firm size, and there is a greater demand for technologies supporting distributed collaborative works across all firm sizes. However, there is a lack of confidence in standards such as IFC.

The barriers to adoption can appear insurmountable as they include culture, industry fragmentation, existing work practices, procurement strategies, regulation, legal and contractual issues, ownership of intellectual property, data security fears, cost of implementation, client support, business processes… and the list continues - it appears overwhelming (Bernstein and Pittman 2004, Holzer 2007, Johnson and Laepple 2003).

Though surveys have been conducted which have tended to focus on barriers to adoption, there appears to be lack of comprehensive discussion with involvement of all major disciplines towards implementation. FGIs with participation of representatives from different disciplines involved in the AEC industry were conducted which began with the underlying question "…tomorrow you start a project using a BIM what would your firm/work unit have to do?... The first two FGIs provided a forum for these disciplines to exchange their expectations, concerns and needs from BIM and involved twenty one participants in discussion for approximately 2-3 hours. The second two FGIs were focussed and involved three industry participants and the research team meeting for 3-4 hours. Discussions were recorded on tape and analyzed in detail using a coding scheme. For details see Gu et al (2008) and Singh et al (2008). Key themes identified are listed in Table 1.

Table 1: Key themes discussed in FGIs

ISSUES	BRIEF DESCRIPTION
Data organization	Data management, grouping, sub-sets and usability
Version management of project data	Data integrity and concurrency
Validation	Trust and confidence in CAD models and the process of design review
Standards	Data format and interoperability.
Communication and information exchange	Instant messaging, notifications, flagging and communication logging.
Security	(1) Network security (2) Intellectual Property (IP) and protection of copyrights
Data exchange between civil and architecture models	Compatibility and data exchange between a GIS (Geographic Information System) model and BIM model.
Roles and responsibilities	Emergence of new roles and responsibilities. E.g. BIM managers are employed in large-scale projects. What was "Architects and drafters" is now "Architects and modellers". Procurement strategies require different approaches. New BIM contract clauses.
Training support	Training and awareness on BIM applications and current tool availability. Training modules for practitioners as well as curriculum in schools were discussed

Apart from the key issues discussed by the workshop participants, the analysis of the data revealed the following:

(a) O-O model development requires a different approach than using traditional CAD packages. The importance of the initial set-up phase of the model is often not realized, leading to inaccuracies, conflicts, frustrations and disappointments in latter stages.

(b) Though there is a general agreement on the potential benefits of BIM for all disciplines, the actual benefits and usability of the approach is not clear. There is lack of clarity on how BIM can be integrated with the work practices on projects.

(c) There is a common misconception that the entire work-practice has to be changed for the BIM approach to be adopted. This is primarily because the users fail to realize that the BIM approach can be used for only parts of the project lifecycle. Although the ideal is full implementation the most important aspect is that in the initial stages a clear statement of the purpose and scope of the BIM model is required. That is, users do not realize the flexible scope of BIM in an AEC project.

(d) Participants acknowledge the need for standards such as IFC. However, from the usability aspect of facility managers and clients all they expect is a simple and intuitive interface. They are hesitant to understand the underlying concepts. These discussions echo the findings reported in literature (Howard and Bjork 2008).

(e) Different business models will be required to suit varied industry needs (Wakefield et al 2007). BIM model can be maintained in-house or outsourced to service providers. In the latter case additional legal measures and agreements will be required to ensure data security and user confidence.

In summary the implications of BIM adoption require changes to four key domains including; work processes, resourcing, scope/project initiation and project life cycle and tool mapping. For example in relation to existing work practices data and document version management, workflow, decision points and design and document review methods are all matters which take BIM from an idea to a reality. Resourcing is critical as it not only relates to design consultants being able to develop the models, but the level of interaction that they have and shared understanding of building models. The capability assessment does not rest with the design team as specialist subcontractors will also contribute to the building of models. Ideally product suppliers and all other subcontractors will contribute to BIM however in many cases it is more than likely that many firms involved in BIM projects will tend to use models rather than contribute to building models in the first instance. Underpinning BIM implementation is the need to consider the scope and purpose of the model and to embed roles and responsibilities within procurement strategy and contractual relationships.

New roles and responsibilities such as the BIM manager are emerging and an examination of current workflow and resourcing capabilities would begin to highlight whether this would be an internal or externally resourced role. There was much diversity in the first two FGIs and it was agreed that the scale and business models of the different players in the industry means that organizations need to develop strategies that suit their requirements and practices, contingent upon the capabilities of their current firms that they work with.

Industry participants suggested that they did not have a structured approach to evaluating their project requirements, particularly in terms of tools, tool usage pattern, capabilities and compatibility across their project partners. Hence, a framework is proposed to allow organizations assess their internal practice, their relationship to the clusters of firms that they typically work with, and then evaluate BIM applicability to their organization. In summary four key elements underpin the development of the BIM decision framework : (a) work process roadmaps (b) tools and applications (c) scope, roles and relationships (d) resource capabilities.

DEVELOPING THE FRAMEWORK

The following discussion summarises the four key elements and the associated steps involved in BIM usability analysis for a given project are considered. In each of these steps a series of questions need to be asked. Some of the basic questions are discussed below:

1. Work process Roadmaps: understanding, defining and describing work process within and across organizations
    a. What are the project phases the organization is involved in?

b. What are the activities in each of the phases? e.g. modelling, visualization, detailing, design review, etc.

c. What are the dependencies between the activities? This can be evaluated using a simple version (Figure 1) of the design structure matrix (Yassine and Braha 2003). Activities can have mutual dependency (inter-dependent), asymmetric dependency (one activity is dependent on the other but not the other way round) or no dependency (independent).

	A	B	C	D	E
A		•		•	
B				•	
C					•
D	•				
E			•		

Asymmetric dependency: A (B) is dependent on B (D) but B (D) is not dependent on A (B)

Mutual dependency: A (C) is dependent on D (E) and vice versa.

No dependency: A and C are mutually independent

Figure 1: DSM to identify activity dependencies

d. Resources for each of the phases. Who are the actors? e.g. Design manager, Architect, What are the required resources? e.g. tools, knowledge. The list of actors (people) and resources needed in each of the phases must be identified and their dependencies noted. This allows checking the possible work flows and requirements for information exchange and data transfer.

2. Tool Availability: A comprehensive knowledge of the available commercial BIM applications and their capabilities is important. Firms can hire consultants to perform such desktop audit. Alternatively, government agencies inclined to promote BIM adoption in the AEC industry can maintain such audit reports that can be availed by the industry practitioners. The report can be summarized as a look-up chart as shown in Figure 2.

Proprietary tools/ Activities	Phase 1			Phase 2			Phase 3	
	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8
Product 1	√							
Product 2		√	√					
Product 3	√	√	√					
Product 4				√	√			
Product 5				√				
Product 6								
Product 7							√	√

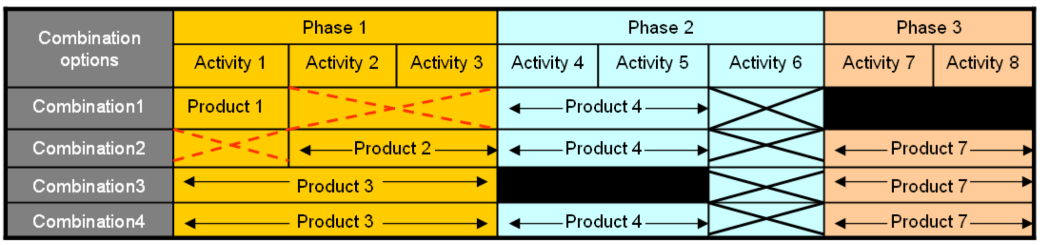

Figure 2: (a) Tool-activity matrix (b) BIM Tool compatibility chart

a. Knowledge of scope of BIM: What are the phases in which the BIM applications can be used? What activities in each phase are supported by BIM applications? Which proprietary tools are compatible to be used in the same project?

The Tool-activity matrix lists the activities that are supported by the tools listed in matrix. For example, In Figure 2, Product 2 can be used for both the Activities 2 and 3, while Product 1 can only be used for Activity 1.

BIM Tool compatibility chart shows different combinations that are compatible. Cells with regular cross (Activity 6) means there are no BIM tools available for these activities. Cells with dotted cross (Activity 1 in combination 2) means that given the other tools being used (Product 2 for Activities 2 and 3) in the same project, there are no BIM tools for Activity 1 that is compatible with Product 2. A blank cell (Activities 4 and 5 in combination 3) simply means that in that combination the given activity was not considered to be performed using a BIM application.

The chart should demonstrate that different combinations are possible and the scope of BIM usage is flexible in terms of project phases. i.e. some phases and activities may not be considered for BIM usage at all.

3. Purpose of BIM (specific to project): Which activities and phases the organization intends to support using BIM applications? Do the selected activities confirm to the activity-dependency requirements? In general, the following rules can be applied:
    a. IF there are plans to use BIM for one of the mutually dependent activities THEN all of those mutually dependent activities should be done using BIM
    b. In case of asymmetrical dependency
        i. IF there are plans to use BIM for non dependent activity THEN related dependent activity can be done with or without BIM
        ii. IF there are plans to use BIM for dependent activity THEN related independent activity should be done using BIM

    For example, Modelling is not dependent on design review but design review is dependent on modelling. Hence, if it is decided in the project that a BIM tool will be used for design review (e.g. automated clash detection) of specific disciplines then the models for the relevant disciplines must be developed using a package supporting BIM integration. However, if we decide to use BIM applications for modelling, we can still do the design review in the traditional way; though that means some of the benefits of an intelligent model are not exploited.

    c. IF activities are perfectly independent THEN use of BIM application is entirely optional.
4. Evaluate capability (current/ potential): What are the project partner capabilities in BIM usage? What tools they currently possess, and what can be procured for the given project? Can the BIM approach be adopted in-house or will an external consultant be required? What has been the past experience working with each of the project partners, if any?

The following figure 3 provides an example of a preliminary roadmap for BIM implementation for the Design Manager of a construction firm aligned with their current design management processes during the project life cycle.

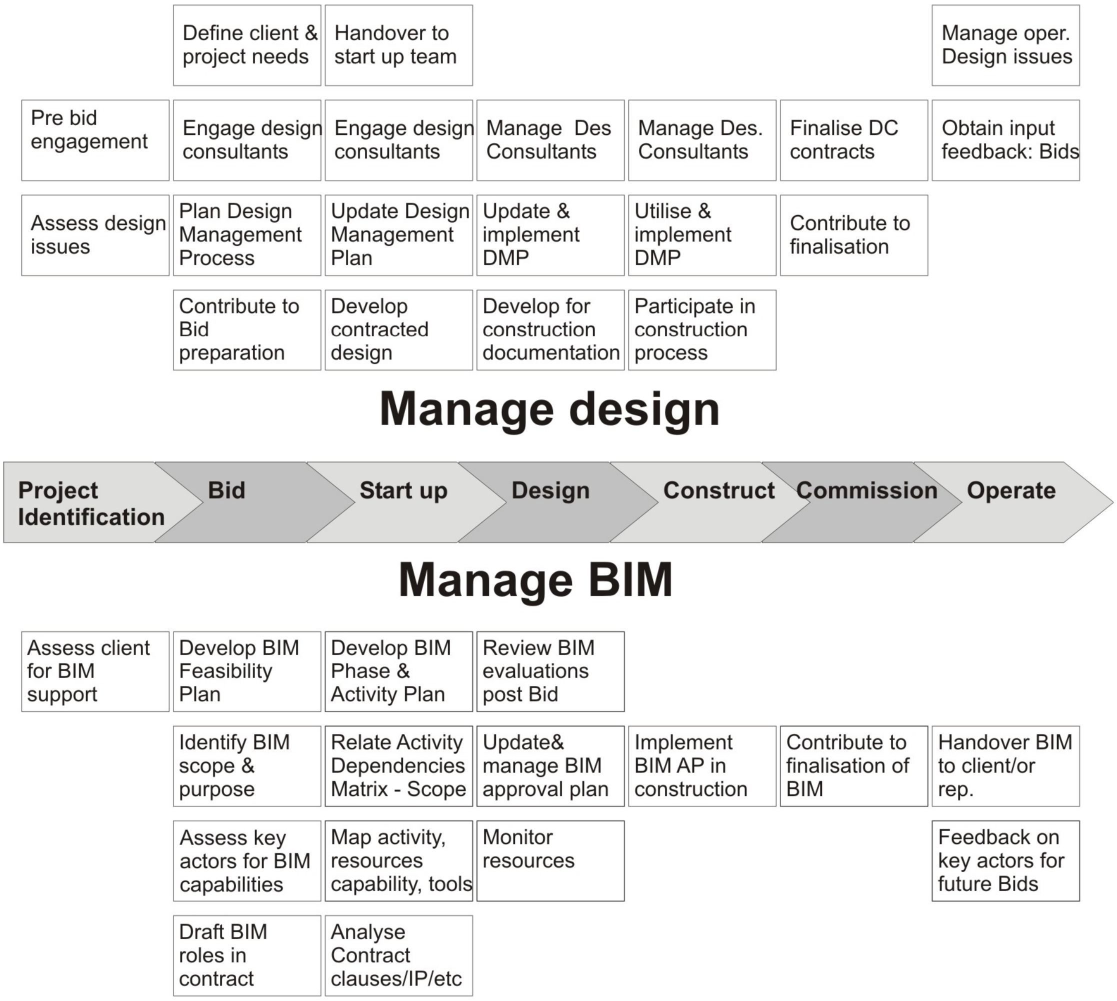

Figure 3: Manage Design Process Roadmap: BIM Implementation

The roadmap illustrated in figure 3 is specifically suited to a contractor led BIM scenario. There are two key issues to consider; first that other project champions and actors would have their own process map depending upon their involvement and the type of procurement relationships and associated roles and responsibilities required. Second that there are additional layers of detail for each individual project phase major processes identified in the roadmap in figure 3 which would involve descriptions of step by step activities, players, deliverables, resources and tools, risks and indicators for success.

CONCLUSIONS

A number of BIM applications are available that can enhance performance across different phases of the project life cycle. Despite the apparent advantages the adoption rate has been slow. A number of factors such as lack of training and awareness; fragmented nature of construction industry; reluctance to change existing work practice; lack of clarity on roles, responsibilities and distribution of benefits; and hesitations to learn new concepts and technologies have inhibited BIM adoption. Key issues that need to addressed if BIM is adopted include version management; data organization; 3D model validation; communication and information exchange; standards and data format; new roles and responsibilities; security; and training support. BIM does not have to encompass all phases of the project life-cycle. Organizations need to assess their requirements, capabilities of available BIM applications and their own business model for informed selection of tools. A framework has been developed based upon four key elements of work processes, resource capability assessment, tool availability and mapping, and purpose and project scoping aligned to deliverables.

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