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ABSTRACT: Building Information Modeling (BIM) is an IT enabled approach that is expected to enable improved inter-disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management. While the potential benefits of the BIM approach in design data management and project co-ordination and collaboration are near to obvious, the adoption rate has been very slow. This paper discusses the findings from an ongoing research funded by Australian Cooperative Research Center for Construction Innovation (CRC-CI), which aims to identify these gaps and develop specifications and guidelines to enable greater adoption of the BIM approach in practice. This paper reports on the findings from a detailed analysis of Focus Group Interviews (FGIs) with industry focus groups for their inputs and feedbacks on changing work practice, role of technology, current perception of BIM and industry expectations. FGI discussions were recorded on tapes and analyzed firstly using an open-ended approach to identify the main themes. Based on these main themes a coding scheme is developed for in-depth analysis. The key issues that emerge include version management, data organization and structuring, data exchange, data ownership and control, activity co-ordination and protocols for 3D model validation. While many issues discussed echo our findings from the literature review, the FGIs give greater insight into the causes for the inhibitions to BIM adoption. This paper presents the observations from the FGI data in detail. Plausible future research on BIM and it’s relevance to existing technologies and tools are discussed.

KEYWORDS: Building Information Modeling, perception, adoption.

1. INTRODUCTION

BIM (Building Information Modeling) is an IT enabled approach that allows storage, management, sharing, access, update and use of all relevant project data through out the project life-cycle in the form of a data repository. The information maintained and produced in the BIM approach includes both geometric as well as non-geometric data. Geometric data includes 2D drawings, 3D models, dimensional and spatial relationships. Non-geometric data could
mean annotations, textual data, reports, tables, charts, freehand illustrations, graphs, images, audio-visual data, and any other forms of information generated during the project. BIM is expected to enable improved inter-disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facility management (Ellis 2006, Popov et al 2007, Haymaker and Suter 2007, Fischer and Kunz 2004, Haymaker et al 2005).

While the potential benefits of the BIM approach in terms of knowledge sharing, design management, project coordination and collaboration seem evident, the adoption rate has been rather lethargic. Hence, a comprehensive understanding of the current perceptions of BIM in the AEC/FM (architecture, engineering, construction and facility management) industry is essential, if measures are to be developed for promoting BIM in practice. In this research, Focus Group Interviews (FGIs) with experts from various disciplines involved in the AEC/FM domain are used to collect the data. A coding scheme was designed to analyze the FGI data. A comprehensive background study of BIM literature and current BIM related applications was conducted before hand. 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 been identified as major barriers to BIM adoption in the literature. The background study provides a benchmark for the FGI discussions. Through FGIs, this paper identifies and discusses the key issues that need to be addressed if BIM is to be adopted. They include version management; data organization; 3D model validation; communication and information exchange; standards and data format; new roles and responsibilities; security; and training support.

2. RESEARCH DATA

A comprehensive background study was conducted followed by FGIs for industry needs analysis and assessment of current perception, awareness and expectations from BIM. Background study involved a critical review of available BIM literature along with a comprehensive desktop audit of currently available BIM applications.

2.1 Background Study

Key findings of the literature review and desktop audit are summarized as below.

**Technological development**: The development of Object-oriented CAD packages has allowed greater intelligence in the CAD models. This enables associability, modeling 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 (Khemlani 2007a). The range of products varies from product suites 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.

**BIM model server**: 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. In general, BIM model server hosts the building data and does not include any application apart from the database management operations. Each discipline can use its own native applications to work on the data.

**BIM adoption**: 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 been discussed as some of the reasons for slow adoption of BIM. In an industry where most projects are handled in multi-organizational teams the lack of clarity on responsibilities, roles and benefits in using the BIM approach is an important inhibiting factor (Holzer 2007). Some of the surveys conducted recently (Khemlani 2007b, Howard and Bjork 2008) suggest that collaboration is still based on exchange of 2D drawings, even though individual disciplines are working in a 3D environment and the demand for object libraries is growing. These surveys reveal that a 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 (Industry Foundation Class).
2.2 Focus Group Interviews

Two FGIs have been conducted with active participation of representatives from all sectors of the AEC/FM industry including architects, engineers, project managers, contractors, consultants, academics, vendors, and delegates from government agencies. The main goal of the FGIs is to uncover and analyze the industry perceptions of BIM adoption. Discussions in the FGIs and the earlier BIM literature review suggest that the reasons for low adoption of BIM in the industry are not only technological. Other factors that influence BIM adoption include: work practice, organizational structure, business interest, user training and so on. It has been recognized that the introduction of BIM would require a different approach to data organization and structuring. Some legal/contractual measures will also be required to deal with safety and work practice related issues.

The FGI discussions were recorded on tapes and then segmented. The segmented data and background study were analyzed firstly using an open-ended approach to identify the main themes. Based on the main themes identified a coding scheme has been developed and applied to the FGI data for detailed analysis.

The design of the coding scheme reflects on the importance of various factors affecting BIM adoption. The coding scheme has five categories: discipline, context, type, content and keyword. Discipline, content and type categories are used to cluster the data such that we can identify the pattern of BIM awareness, interest and knowledge across different disciplines. Keywords allow identification of major issues.

**Discipline** category is used to classify the data based on the disciplinary and functional background (roles in the industry) of the speakers. Marking of each segment, based on the disciplinary background of the speaker, gives useful information about the importance of the different aspects of BIM (in terms of the content) within each discipline.

**Type** category is used to classify the data based on the perceived purpose of the statement. Possible values for Type category are: suggestion/ideas, concern, opinion/viewpoint, observation/analysis, query, inform, strategy and wish-list.

**Context** category is used to mark the circumstances under which a given segment of data has been discussed. Classifications within Context category include: “initiated” (if the segment of data was for starting a new subject of discussion); “reply” (if the segment of data was for answering a question); “follow up” (if the segment of data was in continuation of an ongoing subject initiated earlier in the discussion); and “chair” (if the segment of data was a statement to control the flow of discussion, and in general was often given by the moderator).

**Content** category classifies the segments based on the subject of discussion and identifies the dominant topics. Accordingly, there are eight classifications within the content category: technical, cultural/work practice, structural/data organization, training, legal/contractual, organizational-team, process/method, and business case.

**Keywords** allow identification of major issues across the different categories, and we can set priority for keywords by evaluating the frequency of occurrence in the data.

Examples of coded segments are shown below in Table 1 to demonstrate the use of the coding scheme:

<table>
<thead>
<tr>
<th>Comment/segment</th>
<th>Discipline</th>
<th>Context</th>
<th>Type</th>
<th>Content</th>
<th>Keyword</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frustrating part is having different regulations across states ...</td>
<td>Design manager</td>
<td>Initiated</td>
<td>Observation</td>
<td>Legal/contractual</td>
<td>Regulations</td>
</tr>
<tr>
<td>How do we get one agreed standard?</td>
<td>Contractor</td>
<td>Follow-up</td>
<td>Query</td>
<td>Culture/work-practice</td>
<td>Standard</td>
</tr>
<tr>
<td>Force them to do that.</td>
<td>Design manager</td>
<td>Reply</td>
<td>Opinion/strategy</td>
<td>Culture/work-practice</td>
<td></td>
</tr>
</tbody>
</table>

The design of the coding scheme allows a detailed analysis of FGI data. For example: **Discipline vs. Content** mapping indicates what contents are the dominant issues to specific disciplines; **Type vs. Content** mapping indicates awareness, interest and knowledge about the content; and **Discipline vs. Type** mapping indicates awareness, interest and knowledge across specific disciplines. Similarly other correlations can be mapped to plan...
future research and strategies can be planned for specific disciplines and issues. A statistical analysis of the collected
data has been presented in an earlier paper (Gu et al, 2008). In this paper we focus on the discussion of the key
issues identified. They are discussed with details in Section 3.

3. OBSERVATIONS FROM FGIs

BIM technologies and processes are the most prominent points of discussion in the FGIs. While some issues
discussed in the FGIs are similar to those found in the literature review, the FGI discussions and the data analysis
give greater insight into the issues, as well as their causes and possible solutions. Key issues that emerge from the
FGIs are:

- **Validation using 3D models:** Over the years, even though 2D drawings are increasingly being
generated out of 3D CAD packages; the *lack of trust on completeness and accuracy of models* has
remained a major concern for the practitioners involved. This despite the fact that within the
AEC/FM industry some disciplines like steel structures, in some cases rely completely on model
accuracy as their outputs that are CNC (Computer Numerical Control) fabricated. The development of
intelligent model checkers has done little to alleviate the concern. Some work practice-oriented
measures like standard evaluation and validation procedures need to be put in place to generate
confidence amongst the users. As Bernstein and Pittman (2004) suggest, it is important to create
awareness amongst the practitioners about the greater computability of the digital designs created by
the available applications.

As the building industry moves towards greater use of pre-fabricated building components and
advanced on-site fabrication technologies that can directly take computer-generated data, the accuracy
and completeness of models will become a critical issue. In such scenario, automated checking of the
model, and agreed processes and protocols for 3D validation will be required for design approval.

- **Standards for data exchange:** Though the AECbytes survey (Khemlani 2007b) suggests that
interoperability is not a burning issue, the participants in the FGIs spent considerable amount of time
discussing the need for standards across proprietary tools. Accordingly, IFC, International Alliance for
Interoperability (IAI) and Geographic Information Systems (GIS) have been frequently discussed.

Interoperability issues, due to the availability of different commercial software that may not have a
common format remain a dominant topic during the FGIs. At present, the IAI’s certification of IFC
compatible applications is not stringent. Hence, for practical purposes there are many limitations with
IFC data conversion and exchange. This is a serious concern for managing an integrated database at
the model server using IFC standards. Most product libraries and specific BIM applications that are
commercially available, target specific commercial applications with a wide market base, for example,
Autodesk Revit. This means that such libraries cannot be shared or used by other packages. Besides a
standard format for data exchange, there is a greater need for standard vocabulary for the consistency
of data when exporting from one package to another.

- **Version control** is another important factor:
  - When application vendors develop a new *version of the application* sometimes there are significant
differences from the previous versions. This brings in problems such as data loss and compatibility
issues if different versions of the software are used by different team members.
  - *Version of project data:* If BIM is to be adopted using an integral database where each discipline
maintains, modifies and updates the data, then technical measures, work procedures and methods
need to be put in place to ensure data integrity, allowing different versions of the project to be
managed throughout the project life-cycle.
  - *Version of IFC:* At present the IFC standards are still evolving, and the format has changed
significantly in the last few years. Service providers who maintain IFC data for the clients may have
to update the stored data’s format for the clients accordingly. Such updates may not be easy if the
changes are significant.
• **Data management and organization**: Concerns have been raised by the participants that as more and more building data are managed and stored electronically; standard practices and procedures need to be put in place to deal with data organization, storage and security. Ability to manage different sub-sets of the project, which relate to compatible sets of data for different purposes at different stages of the project, will be useful.

While the ability to constantly update the data gives unprecedented flexibility it also adds to the complexities related to version management, data explosion and usability. Some of these issues may have been addressed in Database Management Systems (DBMS), but from a technological perspective, and not from an organizational perspective for the AEC/FM domain. This poses a new challenge involving strategic decision making which need to be taken up early in the project planning stage.

Digital data management provides new alternatives different from the traditional paper-based file management system, but at the same time losing stored data can be a click away. A new set of CAD drawings can easily overwrite the earlier versions. History of the actions taken and the digital data itself should be maintained. Clients and users will need to decide which stage(s) of the data need a backup.

**Public space and private space**: Individual disciplines generally work on local machines. At some stage of the project, when they deem appropriate they share the data with the rest of the team. The model server should not prevent individual disciplines from storing their own data on the model server that are not shared in the team. A mechanism is needed to support both private and public spaces within the model server. Private spaces can be at individual level, sub-team level or discipline level. For instance, if a group of people need to interact on a daily basis for the project, but this group is not ready to share the data with the rest of the team, then such private spaces for sub-teams should be possible on the model server. We are planning case studies to enable these issues be tested by collaboration with the service provider.

**Register communication and information exchange**: Information exchanged between the BIM users through different media is not captured in a BIM model. Participants suggest that BIM servers should allow message flagging and notifications between team members. Though not explicitly discussed, some of the ideas discussed are similar to the concepts of Enterprise Wiki (Kalny 2007).

**Training in design schools**: CAD courses taught at design schools do not complement the present industry needs. In most architecture schools CAD courses are separated from the design studio, and the design methodology taught in schools often fails to integrate CAD in the design phase. Although some alternative approaches such as parametric design have been introduced as digital means to conceptual design, such cases are still limited. The FGI analysis also indicates the lack of teaching staff with knowledge and experience of modern CAD packages and the reluctance of adopting new technologies and their use in the design curriculum.

Students also need to be trained in applying computer-supported collaborative tools in team projects to appreciate the collaborative processes as well as understand and experience the potential benefits. In practice, architects work in a team and often coordinate team activities. In architecture schools although students also involve in team projects, the coordination of team projects is normally manual, face-to-face and within the single design discipline. Students need to be trained to explore state-of-art computer-supported collaborative tools and to collaborate across disciplines.

**Key drivers**: The FGI analysis and successful examples of BIM implementations in practice suggest that there has to be a strong driving force to bring about the change. In most cases BIM usage has been enforced by the dominant partners in the project. In general, in a collaboration project there is variable power status, and often, the more prominent players determine and control the work practice. For example if a world-learning engineering firm decides to change their work practice then they are in a greater position to convince other smaller partners to change. Bigger organizations have greater incentives to put new systems in place. In general, for them the large scale of the project requires more efficient approaches to project data handling. These organizations are more willing to invest in measures with long-term benefits.
Government and regulatory authorities can play an important role in BIM adoption. Changes made in regulations and processes at the government end will force the entire industry to adopt the new systems. Government and regulatory authorities can set the benchmark for technological capabilities and competencies of the parties working on government projects. Government organizations are also at the position to make the mandatory and regulatory processes smoother, which can provide greater incentives in the forms of reduced project approval time, simpler submission processes, reduced paperwork, etc. CORENET in Singapore (Tai Fatt: http://www.corenet.gov.sg) is one such example that allows electronic submission of approval drawings.

New roles and team dynamics: As new technologies are being adopted in the industry, new roles and relationships are emerging. 3D modeling has already become common practice, and since 2D drawings can be generated out of 3D models, the modelers have increasingly taken the place of draftsmen. What used to be “architects and draftsmen” is changing to “architects and modelers”.

Dedicated roles like BIM managers will be useful for improved project collaboration and coordination, particularly in large-scale projects. At present with collaboration tools in place a lot of coordination activities are still manual, and hence a dedicated person with relevant experience and training will be required. In some of the ongoing large-scale projects the roles of BIM managers have been created and appointed.

Importance of as-built data: Ability to support facility management is considered as an important value-added feature for the BIM approach, making a strong business case. The information stored and maintained during the project is useful for later access and retrieval. This database is useful in updating and identifying the information needed for maintaining the building facility. However, in most construction projects changes are made during the construction phase. Hence, the final output may have some variations from the initial design, represented in the form of the BIM model. At present there is no process in place of updating the designed model to incorporate the changes made during construction. This is particularly important because it is the actual as-built information, which is required for facility management.

As-built drawings may become important for regulatory purposes like sustainability assessment and other performance measures. Once the BIM model is updated with the as-built data, it can be used for comparison of projected building performance against actual performance to evaluate design quality. These types of comparisons will allow more accurate analysis tools by providing more effective and detailed evidence. Quality of as-built data is important. When the surveyors provide data for the built facility, the BIM managers need to register the quality of the surveyed data. Measures like grouping sets of data as sub-models for different parts of the model, based on the quality of the survey can be adopted. These measures are closely related to version and data management.

A number of large projects have involved significant overlaps of both civil as well as architectural works. For effective collaboration supports this will require the BIM applications to be compatible with GIS. At present they are not compatible and in the FGIs it is reported that Open GIS Consortium and IAI are working together to resolve this issue.

Data security: Apprehensions exist about data security of model servers. These include concerns about Intellectual Property (IP) and protections of copyrights. Some concerns relating to network security may have technical limitations, but other concerns on design protections and access may be alleviated by greater awareness and legal measures. For instance, the access to data on model servers can be controlled through secured log-in. Data check-in and check-out can be registered for each interaction. Service providers may also manage the data under a contractual agreement with the data owner, and the terms and conditions of data management and operation can be laid in advance.

4. ANALYSIS OF OBSERVED DATA

Expectations from BIM vary across the disciplines. Design disciplines see BIM as an extension to CAD, while contractors and project managers expect BIM to be a more intelligent DMS (document management systems) that can take-off data from CAD packages directly. However, for both the design and non-design disciplines
visualization is an important part of the BIM applications. Users such as designers, with CAD background, are expecting BIM servers to support integrated visualization and navigation that is comparable to the native applications they use. Users such as contractors and project managers, with DMS background, expect visualization and navigation to be an important feature of BIM servers that is missing in existing DMS solutions.

Discussions in the FGIs suggest that users are hesitant discussing new and technical jargons. They emphasize the significance of standards such as IFC. However, from the usability side all they expect is a simple and intuitive interface. These discussions echo the findings reported in literature (Aranda-Mena and Wakefield 2006, Howard and Bjork 2008). With the increasing number of applications supporting BIM, standard data formats will become inevitable for compatibility across the different tools.

BIM adoption would require a change in the existing work practice. An integrated model development needs greater collaboration and communication. A different approach to model development is needed in a collaborative setting where multiple parties contribute to a single shared model (Lee et al 2006). Standard processes and agreed protocols are required to assign responsibilities and conduct design reviews and validation. In addition, users developing an object-oriented model (which is a pre-requisite for the BIM approach) need to be trained in actual build and construct process. The BIM approach can facilitate involvement of contractors and construction managers in early design stages. This will allow modelers to get feedback on their model development, aligning it to actual construction process. At present, the importance of setting-up the model has often not been realized, leading to inaccuracies and conflicts in later stage. Users need to be aware the potential pitfalls and risks involved in using traditional practices with new tools. In the training modules it will be useful to discuss the common mistakes made in intelligent model development.

A BIM model has the potential for a virtual representation of the entire project life cycle, which is found to be the expectation from the FGI participants. As seen in literature (Fischer and Kunz 2004) simulation tools are being developed not only for the building data but also for the project teams and organizations. Since, BIM approach envisages an integral database accessible by different compatible applications, the same BIM model and different versions and parts of it can be used for running a virtual project before it is commissioned in the real world. Such simulations can facilitate efficient project management, planning, scheduling, conflict resolution, performance analysis and cost reduction.

Desktop audit shows that the number of product libraries is increasing. This allows model developers to use pre-existing objects. At present, most of these libraries are entirely built for modeling purpose. It may be useful to have product libraries from the actual product suppliers and manufacturers. These libraries could also serve as the product catalogue. This will allow a virtual model with every detail same as the available products in the market and enable early decision making on supply chain management and procurement.

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 later case additional legal measures and agreements will be required to ensure data security and user confidence. New roles and relationships within the project teams are emerging. Dedicated roles such as BIM manager will be inevitable for large-scale projects, as already seen in some real world projects. Team members need appropriate training and information to be able to contribute and participate in the changing work environment.

For BIM to succeed in the industry all stakeholders have to be informed about the potential benefits to their disciplines. Experiences from the FGIs suggest that unless the users are able to map the BIM approach to their current practice and their roles, it is difficult for them to gauge the applicability and usability of BIM across the different phases of the project. Hence, a framework is required to allow organizations assess their internal practice and their relationship to the clusters of firms that they typically work with and then evaluate BIM applicability to their organization.

5. CONCLUSION AND FUTURE WORK

BIM technology is rapidly improving and a number of commercial applications supporting BIM are available in the market. Though there have been a few examples of successful use of BIM in the industry (Campbell 2007) the adoption rate has been slow. Main reasons for the slow adoption of BIM include: 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. There is significant difference across the different disciplines in AEC industry in terms of their knowledge and awareness about BIM. Most of the research reported on BIM has focused on specific disciplines. This study reveals that user-centric BIM research has to be more inclusive since the success of BIM adoption lies in collective participation and contribution from all the stakeholders in a building project. Such discussions allow greater clarity on roles and responsibilities. Strategies and work-processes can be developed with collective agreement and can be adopted in practice. Greater adoption of BIM can be achieved through multiple measures that include: (1) improved awareness through trainings and demonstrations, (2) new protocols and processes suitable to BIM approach, (3) government and regulatory initiatives, (4) robust standards and their acceptance amongst software vendors, and (5) greater adoption of pre-fabrication and automation in construction.

The industry adoption of BIM requires strategic planning, especially regarding the emergence of BIM technologies and various existing digital tools and applications. The scope and implementation of BIM approach need to be clearly understood. For some experts BIM is purely a building project database that can be accessed using other applications. Others consider object oriented CAD packages as BIM applications, which is a limited approach. With object-oriented models it is now possible to develop a number of intelligent applications for various functions not available with regular CAD packages. Such plug-ins and add-ons are vital to BIM. Hence, using proprietary CAD packages for limited BIM usage can at best be a temporary solution. For effective utilization of the different commercial applications they need to have compatible data format. In such a scenario standards like IFC are indispensable. At present, the lack of trust in such standards is limiting the scope of BIM.

Innovation in the AEC/FM research and development influenced by BIM includes:

- New process models will need to be developed, considering new members and dynamics of the project team to include clients; new design requirements and constraints; new tools and resources and so on due to the adoption of BIM in different project stages.

- Since the BIM approach envisages a central database with different applications accessing and using the data, it is possible to extend the BIM usage beyond the project life-cycle and facilities management to routine functions of the built facility. For example, while discussing the case of a landmark building in Sydney it was suggested that some part of the model could be accessible to the visitors, who should be able to check the current shows, location of theatres, and so on. The facility manager expressed that some part of the model could be made interactive for the user/audience visiting the premises.

- Organizations need to change their work-practices, project development processes and methodologies to adapt to the BIM approach that allows benefits such distributed access to data and greater concurrency in multi-disciplinary collaboration.

- Focused research is needed to develop measures for various data management issues that include project data version management, data sub-sets and grouping, history and pruning, and data representation and usability.

- An integrated model of the entire project would generate a large amount of data. In order to avoid information overload innovative data representation and information visualization techniques must be used that are user friendly and effective. It may be useful to classify the data based on factors like frequency of usage, significance to performance of the built environment, importance to safety and security of the built environment and the users, etc.

- Training modules in design schools and industry must be updated regularly to include modern technologies and tools, which are constantly improving. Educators and trainers need to train users not only in the use of tools but how they can fit in with the design process and within the team environment. In addition, training modules should not only be prescriptive (what “to do”) but also demonstrate the pitfalls of not using the tools properly (what “not to do”). Interactive training guides are being developed that have proved useful, but at present these are limited to tool usage. It may be useful to develop different scenarios of team and project environments in virtual worlds such as Second Life (http://www.secondlife.com), where the trainee can use the application tools for developing a dummy project and experience the entire project development process.
Most immediate steps required in advancing BIM adoption are:

- Since the AEC industry is diverse in terms of the project team's size, composition and capabilities the BIM requirements may differ from project to project. 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 models for informed selection of BIM applications. Further research is needed to develop such a framework for project BIM requirement evaluation.

- A BIM usage-project phase matrix is required to evaluate the cost implications of BIM application in different phases of the project. Such research will allow development of value analysis tools for the potential users. Such an analysis will also be useful for stakeholders to clarify their roles, responsibilities and benefits, thereby facilitating greater adoption of BIM in practice.

- Commercial BIM model servers that are IFC compliant are available in the market. These model servers can host the model data, which can then be accessed through native applications. The servers by themselves have very few functions. Since the model servers are not yet used widely a number of issues such as usability, interface and applicability have not yet matured. Further research is needed to develop BIM server specifications to identify the areas of improvement in the technology and its usability in collaborative work environments.

- Though BIM technology is not yet matured, even in its present status it can be used for improved project collaboration and performance. As part of the ongoing research software specifications of BIM model servers and industry guidelines are being developed to prepare the potential users to adopt BIM in practice.

6. ACKNOWLEDGEMENT

This project is funded by Australian Cooperative Research Center for Construction Innovation (CRC-CI).

7. REFERENCES


