Building Information Modelling- An issue of adoption and change management

[1]Ning Gu, [2]Vishal Singh, [3]Claudelle Taylor, [1]Kerry London and [1]Ljiljana Brankovic

[1]School of Architecture and Built Environment
University of Newcastle, Australia

[2]Key Centre of Design Computing and Cognition
University of Sydney

[3]Nexus Point Solutions, Australia

Abstract

Building Information Modelling (BIM) is an IT enabled technology that allows storage, management, sharing, access, update and use of all the data relevant to a project through out the project life -cycle in the form of a data repository. 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. While the technology itself may not be new, and similar approaches have been in use in some other sectors like Aircraft and Automobile industry for well over a decade now, the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry is still to catch up with them in its ability to exploit the benefits of the IT revolution. Though the potential benefits of the technology in terms of knowledge sharing, project management, projec t co-ordination and collaboration are near to obvious, the adoption rate has been rather lethargic, inspite of some well directed efforts and availability of supporting commercial tools. Since the technology itself has been well tested over the years in so me other domains the plausible causes must be rooted well beyond the explanation of the 'Bell Curve of innovation adoption'. This paper discusses the preliminary findings of an ongoing research project funded by the Cooperative Research Centre for Construc tion Innovation (CRC -CI) which aims to identify these gaps and come up with specifications and guidelines to enable greater adoption of the BIM approach in practice. A detailed literature review is conducted that looks at some of the similar research repor ted in the recent years. A desktop audit of some of the existing commercial tools that support BIM application has been conducted to identify the technological issues and concerns, and a workshop was organized with industry partners and various players in the AEC industry for needs analysis, expectations and feedback on the possible deterrents and inhibitions surrounding the BIM adoption.

1. Introduction

A few cases of successful use of BIM approach in real world projects have been reported (Khemlani 2007b, 2007c) that suggest even if the BIM applications and tools may not have matured fully they are very much usable in their present form, and can enhance project collaboration and management in the AEC industry well beyond the current state. The study conducted so far suggests that the readiness of the AEC industry for BIM adoption in the near future varies significantly across the different geographical and political boundaries owing to variable drivers and practices across these divisions. Some of the main factors like the market distribution, amorphous structure of the AEC industry, work culture and work practices, and economic implications and factors have been discussed in this paper to exemplify their role and implications on BIM adoption in practice. This paper gives a broad overview of the present state of BIM and the issues surrounding it, and highlights the main features of the AEC industry that differentiate it from some of the other industries that have been quick to adopt a similar technology. As the industry begins to integrate BIM in practice it is likely to bring about and require some changes in the work practice, changes in the project development approach, and emergence of new roles and relationships, both at technical and management levels. While the new technical positions may replace some of the old ones there is likely to be greater impetus and need for different kinds of management skills to meet some of the specific requirements corresponding to data management, project co-ordination and quality assurance on a scale not seen before in this sector. The available case studies and pilot projects provide some evidence and glimpses of these likely changes, which have been discussed in this paper.

This paper is built around the discussions on project management issues, challenges and paradigm shifts required and likely to be shaping in, as the AEC industry prepares for a greater adoption of BIM approach in practice. The drivers and key players that are expected to lead this change are discussed and the main issues of change management facing the practitioners and drivers of change are highlighted. The discussions in this paper are based on literature review, a desktop audit of major commercial BIM applications, and conclusions of the workshops conducted with participants from the industry.

2. Research approach

In order to build the platform for developing specification and guidelines for greater adoption of BIM in practice the study was conducted in three phases.

Phase1: An extensive literature review on BIM approach and applications was conducted. These included reports and research from similar research conducted earlier (Bernstein and Pittman 2004, CyonResearch 2003, GreenwayConsulting 2003, STATSBYGG 2006), white papers and technical reports from vendors and industries involved in developing BIM related applications (AutoDesk, Bentley and Workman 2003, EPM Technology, Gehry Technologies, Graphisoft, Navisworks), papers and research conducted by academic institutions (Eastman et al 2004, Mitchell et al 2007, Pentilla 2007), guidelines and reports generated by regulatory and government institutions (AGC America, GSA 2007, Tai Fatt), and newsletters and articles (Khemlani) on the practice and trends in AEC industry.

Phase2: A desktop audit of the different types of commercial applications that form a part of BIM approach was conducted. This involved live demonstrations and trials, data gathered from product brochures and analysis of tools reported and published by other sources. The types of applications evaluated include BIM model servers, discipline specific design tools, planning tools, analysis tools, design review and viewing tools, facilities management tools, product libraries and so on. The desktop audit provided an overview of the technological capabilities and applications, their role in BIM approach and trends in development of commercial BIM applications.

Phase3: Two workshops were conducted in different cities (Sydney and Brisbane) with active participation of representatives from various sectors of international and Australian AEC industry including architects, contractors, vendors, consultants, project managers, academicians and people from government agencies. The workshops were conducted to identify the industry needs, expectations and apprehensions, and the participants shared their views and experiences. Towards the end of the workshop a moderated section was conducted to discuss the specific questions that had come up from the literature review and desktop analysis. The workshop discussions were recorded on tapes and analysed first using an open-ended approach to identify the main themes. Thereafter, analysis of tape and literature study was used to identify "axial categories" from which the "core categories" emerged clustering the main ideas.

3. Background: IT and work practice

The advancements in information technology over the last couple of decades have transformed the work practice and processes in many industries. This transformation however has varied significantly across the industry types. Understandably, the domains like media and journalism that are primarily information based and require little physical outputs were quick off the mark. In

industries like manufacturing and AEC that involve a lot of information exchange but require transformation of the digital data produced into physical product the story has been different. While some sectors like the aircraft and automobile industry have made rapid progress over this period, the AEC industry has remained way behind. In th e last few years there has been some concerted effort for developing BIM facilitating tools and standards like IFD (Information Delivery Manual) (Christensen and Gruppen 2005) and IFC (Industry Foundation Class), and the lessons learnt from similar approac hes in other industries like STEP (Standard for The Exchange of Product Model Data) model and PLM (Product Lifecycle Management) in engineering and manufacturing sector have helped the effort (IAI, You el al 2004). The fact that the underlying technology has been well tested over the years means that the main challenges that lie ahead of the AEC industry concern promoting its application and usage.

4. Adopting BIM in the AEC industry

This section discusses the main features of the AEC industry including its d istinguishing characteristics, the issues that come along with BIM usage, and the status of BIM across different physical and geographical boundaries.

4.1 What makes the AEC industry different?

To investigate the possible causes for a relative slow rate o f adoption of BIM some of the main features of the AEC industry that differentiate it from the other industries that are commonly used as a benchmark for BIM adoption have been identified. The differences are listed here to emphasize that a benchmarking with the mentioned industries may not be applicable:

Fragmented business practice: The AEC industry is fragmented into very few big and players and a large number of small and medium size players that work as collaborative networks. The financial status, te chnological requirements and capabilities, and work profile of these organizations vary considerably unlike the automobile sector which has a very few but big players and with very competitive capabilities.

Control and benefit: In the automobile industry the various phases of the product lifecycle ranging from design to delivery are often managed in -house by the various discipline units, where as in the AEC industry this is very rarely the case. Thus, while the benefits of the efforts put in by any discip line directly apply to the organization, the fragmented structure and inter - organizational collaboration in the AEC industry means that each organization involved in the project requires greater clarity on the efforts versus benefits for the participating organizations or disciplines (Holzer). At the moment the roles of the various disciplines involved in generating a

BIM model is not very clearly defined in practice. The premises on which the technological development has taken place assume that each disci pline adds the relevant data to the model, which requires additional effort. This on the other hand may conflict the economic interests of certain disciplines which may not directly see the benefit of an integrated model proportional to the required effort.

In addition, in the AEC industry at different phases of the project lifecycle the control of the project data may change hands. For example during the design phase the Architects may be at helm of the data, where as during construction this passes on to the contractor, and this may then be transferred to the facility manager for later use. In the automobile industry on the other hand changing data ownership is not an issue because of an integrated and more or less fixed organizational structure.

Change drivers: In an integrated business organization like in the automobile industries policy introduction and changes in work practice are often a matter of management decision, and it is relatively easier to re -structure the various disciplinary units within a single organization. On the other hand, in case where different organizations are involved the conflicting aspects of independence and interdependence inhibit such changes, until all the involved parties agree to such changes collectively. In such case, the organizations that often hold an upper hand or dictate terms can force in such changes. For the AEC industry such internal drivers could be in form of the big players that are high on power relationships or else the external drivers like the regulatory authorities and clients that make specific requirements.

Product type and scale of projects: The product of a single project in an AEC industry is quite often a custom one unlike the automobile industry where one model goes for mass production. However, the scale of the projects may still be the same as the realization of an AEC project may still consume high financial, infrastructural and manpower resources. The scale of the project is an important factor determining the economic and functional benefits of putting in the extra effort.

Distribution and maintenance: In the AEC industry facilities management has become a major aspect. With the growing complexity of the buildings the integrated database of the building will go a long way in supporting efficie nt maintenance and operation of the built facility. Thus facilities management makes one of the most useful and economically viable case for a BIM approach. It is important to note that this also means that the BIM model has to be updated with the as-built model, which may have some differences with the design model.

Modelling requirement: In the automobile and manufacturing industry the model is directly used to generate the physical prototype, which means the modelling precision has traditionally been an important criterion. On the other hand, the traditional use of 2D drawings in the AEC industry has meant that 3D models primarily served visualization purposes and most often models remained incomplete, or lacked precision which was never a critical factor. Over the years, even though more and more 2D drawings are being generated out of intelligent 3D CAD packages (Eastman et al 2004) 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 industry itself some disciplines like steel structures in some cases rely completely on model accuracy as their outputs are CNC generated. The development of intelligent model checkers that are an important aspect of BIM approach have helped the cause, but 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.

4.2 Issues that affect the BIM adoption

Pilot studies and some of the projects using BIM approach have identified the issues that come up with BIM adoption in its current state. As we endeavour greater adoption of BIM these issues need to be addressed:

Version management: constant upgradation of softwares has been an issue for the practitioners. While most often upgraded softwares allow using data generated from earlier versions, many a times significant changes inhibit these. This means that in order to have all the collaborating partners to be working on compatible versions often compromises have to be made on efficiency. Though measures like IFC standards have reduced the problem of interoperability (Graphisoft, Khemlani 2004) across different software packages as well, the changes in the versions of IFC specifications have also been an issue as revealed in the workshop.

Organization and data management: As more and more data is managed and stored electronically standard practices and procedures need to be in place to deal with data organization, storage and security. Managing the different versions of the project, which relates to compatible set of data from different disciplines at specific stages need to be fixed. While the ability to constantly update the data gives unprecedented flexibility it also adds to the complexity relating to version management, data explosion and usability. Some of the related issues have existed in Database Management Systems (DBMS), but rather than the technological issues, these

are more of organizational issues for the AEC domain and practitioner's and poses a new challenge involving strategic decision making.

Architectural training in schools: one of the major criticisms of the architectural education in the recent years has been the widening gap of the techniques and methods taught in architecture schools and what is practiced in the fiel d. Rather than giving separate introductory sessions on computational approaches and BIM applications there is a need for integrating the same in design studios for the students. Such approaches will go a long way in alleviating the concerns in some section that believe computational approaches to be inhibiting design creativity.

Security of data: Putting data on an integrated database in an electronic format raises some security concerns amongst the involved players. Related to it are the concerns of Int ellectual Property (IP) and protection of copyrights. While some concerns on network security from a technical viewpoint may be justified, others may be alleviated by greater awareness and legal measures. For instance, the access to data on such databases is controlled through secured log-ins, and data check-in and check-outs are registered for each interaction. Data hosts manage the data under a contractual agreement with the data owner and the terms and conditions of data management and operation are well laid out in the document. Similarly, the IP issues are legal issues, which are no different to this format of data storage and design than what exists in practice.

Readiness of the tools: Examples of the use of BIM approach in practice suggest that in th e present state as well there are tools that can significantly improve the work process in the AEC industry. However, lack of tools supporting and integrating conceptual design activity has been a major concern (Khemlani, Holzer). As more specific BIM appl ications are being developed that look at specific aspects of design process and allow integration with each other the technical support is bound to improve.

Seamless Integration and standards: Over the last few years various types of tools have come up for specific aspects of BIM application. BIM approach involves a collaboration platform, and with that there are specialized tools providing product libraries (standard products), integrated navigation and visualization, clash detection, environmental and p erformance analysis, construction and project management, fabrication and so on (Khemlani 2007 a).

These developments suggest the need for greater standardization of processes, terminologies and products, early information exchange between the different pl ayers to avoid re-work, capability to conduct preliminary analysis of project concepts, greater intelligence in tools to aid computability

of building data as they get more complex, and greater automation in construction and fabrication to leverage the benefits of a better and precise model.

4.3 Global challenges

Across different regions and boundaries the present status of the AEC and industry and its readiness for BIM adoption varies significantly, and hence different strategies may be required in different places to promote BIM usage.

In some places where the AEC industry is more organized like Singapore, Norway etc and where the regulatory authorities have taken a lead, BIM adoption is well on track. For example, the CORENET project in Singapore enable s electronic submission of models and drawings to the regulatory authorities which makes the entire process more efficient and faster, besides many other advantages (Tai Fatt). What is important here is to realize that for any changes to take place there should be very distinct incentives in place, and in practice such incentives should also have a competitive and economic aspect to it.

There are other cases where the regulatory processes have remained the unchanged, but some of the large and multi -disciplinary organizations like ARUP have adopted a BIM kind of approach within their own projects to facilitate their own project management (Bentley News 2006, BE Magazine 2004). Adoption of BIM in such projects has been possible because of the leadership taken by these organizations, and their collaborating partners had to adapt. Often, in such cases the mammoth scale of the project necessitated the need to look out for a more efficient approach of project data handling.

At the other end of the spectrum are the regions where the design detailing is still in 2D stage, and while BIM is far from the scene, even intelligent object -oriented CAD packages have not yet percolated into the market. In some cases like India, given their leadership in IT sector this may sound contradictory, but the lack of automation in construction industry, the low cost of construction labour, and inefficient regulatory authorities have hindered this progress (Khemlani 2004a). On the other hand, even here some pockets of BIM awareness and usage exists in form of outsourced modelling projects, which suggest that economic and business incentives are the main driver to bring in the process change.

5. Managing the future of BIM in the AEC industry

This section looks at the changes and measures re quired for greater adoption of BIM in practice, and the implications of such changes on the work practice in AEC industry are discussed.

Incentives and drivers: For very large projects involving large amounts of resources and very large firms the collaboration support at the design and construction phase itself is good enough incentives for adoption of BIM as seen in some recent developments. However, within these projects as well if the BIM applications become compatible with GIS (Geographic Information Systems) tools the project management and handling will become much more efficient, as most of the projects of this scale involve a high percentage of civil works, where GIS is a preferred system.

The community of practitioners, regulatory bodies and involved consultants need to deliberate upon the possible sharing of responsibilities, fee structures, and project plans to accommodate for the shift in the effort required as the BIM approach is adopted. A successful adoption of BIM is expected to lengthen the initial design process but reduce the construction cost and time.

It must be noted that effort required by the architects and other design disciplines to put in the additional information can be considerably reduced if the commercial vendors have enough incentives to provide country specific product libraries and standards. Such specifications need to be in place to allow a sustained market for BIM applications. This in turn will also facilitate the working of regulatory authorities enabling automatic code checking and building standards.

Market needs and distribution: As discussed earlier the AEC industry has a very large number of small and medium size players and quite often the incentives discussed above may not be sufficient for this segment. Emergence of a multitude of BIM applications looking at specific aspects of project requirement means purchasing and upgrading licences of such products may not be a viable option in the long run. Innovative options like project specific licence hiring of commercial applications as already available in case of server spaces can go a long way in bridging this gap. Already design teams are increasingly becoming distributed, and if the trend of internet based teaming (GreenwayConsulting) and Laubacher and Malone's (1997) suggestions are any indication for the organizational structure of the future then flexible product licensing strategies may even become a necessity.

Changing/emerging roles and relationships: Adoption of BIM approach would re-structure the data exchange amongst the participating disciplines. A large amount of data needs to be managed and some of the issues related to it are discussed above. As has been seen in case of a few ongoing projects, having a dedicated BIM manager facilitates project co-ordination and management. These trends suggest that with increased adoption of BIM the role and responsibilities of the BIM manager needs to be more defined. As object oriented CAD tools are becoming the norm 3D modellers are increasingly replacing drafters, and with the adoption of

BIM approach that relies on intelligent objects and modelling precisions drafting may become an obsolete profession in the AEC industry.

In summary, the paper identifies the critical factors that have inhibited the adoption of BIM in AEC industry. Fragmented market, multitude of specialized softwares and variable licensing capabilities (affordability) of end users in their ability to keep up with latest tools is one kind of limitation. More than the resistance to change from inertia , lack of processes and procedures to account for the additional effort put in by different disciplines, business models for data ownership and accountability, and awareness of the tool capabilities are the hindrance to BIM adoption. Innovative product lic ensing and distribution, greater automation in construction and fabrication, changes in regulatory practices and processes, and standard work practices and procedures to account for legal and contractual concerns can provide the necessary incentives and boost for greater BIM adoption. Project managers and change drivers need to make region specific strategies to bridge this gap.

6. Acknowledgement

This project is funded by a CRC-CI research grant. The authors wish to thank all the participants from the industry workshops conducted in both Sydney and Brisbane, Australia.

7. References

AGC America: The Contractors Guide to BIM, URL: http://iweb.agc.org/iweb/Purchase/ProductDetail.aspx?Product_code=2926

Autodesk: Building Information Modeling in practice (white paper), *Autodesk Building Industry Solutions* , URL: http://images.autodesk.com/adsk/files/bim_in_practice.pdf.

Bentley, K and Workman, B: 2003, Does The Building Industry Really Need to Start Over? A Response from Bentley to Autodesk's BIM/Revit Proposal for the Future (white paper), Bentley.

Bentley News: 2006, ARUP wins 2006 BE Awards, URL: http://www.bentley.com/en-US/Corporate/News/News+Archive/Quarter+3/Arup.htm

BE Magazine: 2004, Creating a Water Cube, BE magazine **1**(2), URL: ftp://ftp2.bentley.com/dist/collateral/User_20Story_3A_20Arup_20_2D_20Water_20Cube_2C_20Low_20Respdflo.pdf

Bernstein, PG and Pittman, JH: 2004, Barrie rs to the adoption of Building Information Modeling in the building industry, Autodesk Building Solutions (white paper), URL: http://images.autodesk.com/adsk/files/bim_barriers_wp_mar05.pdf.

Christensen, CL and Gruppen, S: 2005, Low friction information logistics enabled by the Information Delivery Manual (IDM) framework (presentation), *IAI Conference in Oslo, Norway*, *Government and Industry Day –June 1st*

CyonResearch: 2003 , The Building Information Model, A Look at Graphisoft's Virtual Building Concept (CyonResearch white paper), URL: http://www.cyonresearch.com

Eastman, C, Lee, G and Sacks, R: 2004, Development of a Knowledge -Rich CAD System for the North American Precast Concrete Industry, *ACADIA 22, Connecting Crossroads of Digital Discourse* , Indianapolis, IN. Ball State University, pp. 208-215.

EPM Technology: 2004, *EXPRESS DATA MANAGER™, Information* **1**(6), URL: http://www.epmtech.jotne.com

Gehry Technologies: Construction Industries Transformation (Brochure), *Gehry Technologie,* URL: http://www.gehrytechnologies.com

Graphisoft: A Strategy for Design, Construction and Management Services Collaboration, Sharing information based on the Virtual Building™ and the IFC™ object sharing protocol: IFC brochure, *Graphisoft*.

GreenwayConsulting: 2003, Revolution and Achievement: New Practice and Business Models Emerge in Study of Architecture, Design, and Real Estate, URL: http://images.autodesk.com/adsk/files/greenway_consulting_report.pdf

GSA: 2007, GSA Building Information Modeling Guide Series, URL: http://www.gsa.gov/bim

Holzer, D: Are You Talking To Me? Why BIM Alone Is Not The Answer, URL:http://epress.lib.uts.edu.au/dspace/bitstream/2100/476/1/Holzer_Are+you+talking.pdf

IAI: The EXPRESS Definition Language for IFC Development (white paper), IAI, URL: http://www.iai-international.org/Model/documentation/The_EXPRESS_Definition_Language_for_IFC_Development.pdf

Khemlani, L: 2004, The IFC Buildin g Model: A Look Under the Hood, *AECbytes Feature*, March 30, 2004, URL: http://www.aecbytes.com/feature/2004/IFCmodel.html

Khemlani, L: 2004 a, AEC Landscape and technology Adoption in Indi a, *AECbytes Newsletter*, July, URL: http://www.aecbytes.com/newsletter/2004/issue_12.html

Khemlani, L: 2006, BIM Symposium at the University of Minnesota, *Building the Future (Article) AECbytes*, February, URL: http://www.aecbytes.com/buildingthefuture/2006/BIM_Symposium.html

Khemlani, L: 2007 a, Supporting Technologies for BIM Exhibited at AIA 2007 , Building the Future (Article), *AECbytes*, May, URL: http://www.aecbytes.com/buildingthefuture/2007/AIA2007_Part2.html

Khemlani, L: 2007 b, 2007 Third Annual BIM Awards Part 1 , Building the Future (Article), *AECbytes*, August, URL: http://www.aecbytes.com/buildingthefuture/2007/BIM_Awards_Part1.html

Khemlani, L: 2007 c, 2007 Third Annual BIM Award s Part 2 , Building the Future (Article), *AECbytes*, September, URL: http://www.aecbytes.com/buildingthefuture/2007/BIM_Awards_Part2.html

Laubacher and Malone: 1997, Flexible work arrangements and 21st century worker's guilds, Initiative on Inventing the Organizations of the 21st Century, Working Paper #004, http://ccs.mit.edu/21C/21CWP004.html.

Mitchelle, J, Wong, J and Plume, J: 2007, Design Collaboration Using IFC, A case study in thermal analysis, *Proceedings of the Computer Aided Architectural Design Futures (CAADFutures) 2007* (Eds.) Dong A, Vander Moere A & Gero JS, Springer; pp: 317-329.

Navisworks: JetStreamv5 from Navisworks, URL: http://www.navisworks.com

Pentilla, H: 2007, Early Architectural Design and BIM, *Proceedings of the Computer Aided Architectural Design Futures (CAADFutures) 2007* (Eds.) Dong A, Vander Moere A & Gero JS, Springer; pp: 291-302.

STATSBYGG: 2006, Experiences in development and use of a digital Building Information Model (BIM) according to IFC standards from the building project of Tromsø University College (HITOS) after completed Full Concep tual Design Phase (report), R&D project no. 11251 Pilot project, Tromsø University College (HITOS) for testing IFC.

Tai Fatt, C: An IT Roadmap for Singapore's Construction Industry (presentation), URL: http://www.corenet.gov.sg

You, S, Yang, D and Eastman, C: 2004, Relational DB Implementation of Step Based Product Model, *CIB World Building Congress 2004*, Toronto, Ontario, Canada.