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Building Information Modelling: An International survey

Building Information Modelling (BIM) appears to be the next evolutionary link in project delivery within the AEC (Architecture, Engineering and Construction) Industry. There have been several surveys of implementation at the local level but to date little is known of the international context. This paper is a preliminary report of a large scale electronic survey of the implementation of BIM and the impact on AEC project delivery and project stakeholders in Australia and internationally. National and regional patterns of BIM usage will be identified. These patterns will include disciplinary users, project lifecycle stages, technology integration–including software compatibility—and organisational issues such as human resources and interoperability. Also considered is the current status of the inclusion of BIM within tertiary level curricula and potential for the creation of a new discipline.

Keywords: BIM, AEC Industry, implementation, survey, integration, project delivery

1. Introduction

No one would dispute that we are living in a 3-dimensional (3D) world. If time or money is included one could even say that our world encompasses four or five dimensions. Extending this approach, we can think of a world of up to n-dimensions. However, the building industry has been trapped in the 2D-3D realm for decades (Campbell 2007), first on paper, and more recently using Computer Aided Design (CAD). Recent advances in technology have allowed the Architecture, Engineering and Construction (AEC) Industry to keep up with the multi-dimensional real world. The tool that has allowed them to do this is Building Information Modelling.

Building Information Modelling (BIM) is now considered the ultimate in project delivery within the AEC Industry (Azhar et al. 2008), and has the potential to revolutionize the industry (Gerrard et al. 2010). It is a process involving the generation and management of digital representations of physical and functional characteristics of a facility. The resulting model becomes shared knowledge-resources to support decision-making about a facility from the earliest conceptual stages, through design, construction, operational life and eventual demolition (National Institute of Building Sciences buildingSMART alliance 2012). Thus it is a singular central system suitable for the entire project process. It involves the co-ordinated efforts of all consultants being combined within one highly detailed model with all elements required for a building project (Azhar et al. 2008). This breakthrough technology is responsible for the complex collaboration systems now in place within many organisations who have integrated BIM as their preferred project delivery method.

Building Information Modelling has been under considerable scrutiny over this last decade. A number of papers have been published outlining challenges and limitations but it seems there has been little progress over the years as the same concerns are repeatedly mentioned. These concerns include interoperability, irrelevant data, integrated design, and legal issues around intellectual property and data ownership.

One of the most common items of discussion is software interoperability. Where there is a market, there will be competition. With competition, these competing software vendors continuously try to out-do each other and to maintain a hold on the market through individuality, resulting in a large number of different software packages (see Çetiner 2010 for examples). Programs like Autodesk Revit and Graphisoft Archicad have created their own file types, with the idea that if one software developer developed a new tool that had substantial benefit over the competition, a user couldn't then just open their project file into another program. Users are then limited to one program, unless they were to spend twice the time to develop the project in both programs. A lack of comprehensive BIM standards mean that multiple BIM software products lack the ability to produce interoperable files" (Smilow 2007), and therein lies the problem. Often professionals who utilise different software cannot fully collaborate on a BIM project as even though there are methods of using third party programs to convert to a common file type to be able to move from one to the other and back again. Typically this process strips most of the information from components, and may degrade parts of the 3D model so that they may not appear as a smooth curve anymore, or polygons—building blocks of a 3D model—may disappear altogether. While this competitive behaviour by software developers is expected or promoted within a free-market economy, it can hinder consultants and project teams, and in turn the uptake of BIM by industry.

Furthermore, many disciplines that require the processes of analyses then face the issue of BIM models containing too much of the wrong sort of information. Poerschke et al. (2010) express concerns regarding the sheer volume of irrelevant data that needs to be processed even when only “particular, abstracted information" is needed for modelling tools.

Another point to consider is the limitations of the design phase within BIM. Some significant drawbacks stand in the way of a fully integrated project. Coates et al. (2010) argues that BIM “…concentrates rather too much on providing means of representing the final form of the design, whereas designers also need a continual stream of abstraction, advice and information…”. Most designers still prefer to use pen and paper to sketch out ideas and many prefer the freedom of physical model building as current BIM tools fail to allow "personal nuances in the design process" as well as accommodate for the "ambiguities of early design" (Coates et al. 2010).

However, beyond the software realm itself, BIM has raised many more issues in terms of legalities (Smilow 2007), with concerns over who has legal ownership of the digital models of collaborative projects, and whose intellectual property it may be. As BIM leads into a new method of team collaboration, team dynamics must make developments and new definitions for individual responsibility and liability (Boos 2010). As the use of BIM increases, these issues may continue to grow in importance, although some claim that as use has increased, fears of these issues have become less (Young et al. 2009).

There have been a number of surveys in recent years that have attempted to quantify just how much impact BIM is having, and how widely adopted it has become. A US survey (Dean 2007) found that as many as 70% of industry participants are either using BIM, or plan on adopting it in the near future. A survey of American architects, engineers and contractors indicated that 62% of BIM users claimed they would use BIM on at least 30% of their projects in the following year and 45% of users said they expected to use BIM on at least 60% of projects (SMART 2008), while a 2009 survey found the US uptake rate at 48%, compared to 28% in 2007 (Young et al. 2009, 5). In contrast, Gerrard et al. (2010) found that in 2007 only 25% of Australian firms were using BIM. This is far less than the literature on BIM seems to intimate. But is BIM used the same way by all these professionals?

The question remains of what practitioners understand BIM to be and to what degree BIM is utilised. For some time, many considered BIM to merely be a 3D model of the project as an improvement over 2D drawings, but little more. The industry started to see 4D modelling and as such, the limits of what was possible grew.

Technology has advanced significantly in the past five years. Take for example the rise of Facebook, iPhones (and other smart phones), and tablet computing. These technologies have been disruptive in their adoption, and increased from a zero base to become ubiquitous. It is conceivable that other technologies, such as BIM, may have undergone similar rapid transformations. Use of BIM in the USA appears to have risen from 28% to 48% between 2007 and 2009. It is possible that similar rises in use have occurred in Australia and other countries since 2007.

To gauge how much the use of BIM has changed a research project has been initiated that has as its first objective an update of the level of adoption of BIM in Australia. Beyond this, the project also plans a similar worldwide survey, something that appears to be missing from the literature. The project ultimately aims to gain a thorough understanding of BIM with regards to its functionality, extents of its strengths and weaknesses, and identify its opportunities and threats. The intent of the surveys is to develop a coherent picture of the professional practitioner’s point of view of the technology, as well as update and benchmark the level of use of BIM within Australia and on a wider global scale. These data will also be broken down to identify the areas where BIM is utilised within a project lifecycle by each discipline. The study is particularly designed to address the impact of BIM with regards to the first principles of project management, namely time, cost and quality.

At the time of writing, preliminary data only have been collected from the surveys. This paper therefore reports on the methodology being adopted, the rationale and expected outcomes from the work, and in particular attempts to present a coherent conceptual framework for the potential utility of BIM based around a first principles analysis of literature from the perspective of project time, cost and quality.

1.1 Uses of BIM

The uses of BIM can vary through wide scope of works. Current BIM modelling can function to an *n*th dimension of works – these progress more as technology evolves and as the BIM process is refined. A preliminary list of BIM uses may include:

- Design Visualisation
- Design assistance and constructability review
- Site Planning and Site utilisation
- Scheduling and Sequencing (4D)
- Cost Estimating (5D)
- Integration of Subcontractors and supplier models
- Systems coordination
- Layout and fieldwork
- Prefabrication
- Operations and Maintenance (including as-built records)

(Campbell 2007)

One of the strengths of the approach is the reduction in tedious computation from 2D drawings for many tasks (Smilow 2007), obviously a 'step in the right direction' for building project delivery. Such a change is likely to have a significant impact upon the time for any project.

1.2 Time

One crucial question is what effect has BIM implementation brought on project delivery time? There is no doubt that this question cannot easily be answered without first hand case study analyses conducted on BIM. Reddy (2008) examining a number of case studies, and Azhar et al. (2008) based on 32 major projects that employed BIM both found that that BIM can influence time management with a 7% reduction in time for project completion. There is a perception that it helps to deliver projects on time (Suermann and Issa 2009, 2007), but it is not clear that this is actually the experience of the industry. Some claims of time savings are from vendors of BIM technology (Carroll 2007), while others derive from extensive surveys of industry practitioners in the USA (Young et al. 2009). This same study also reports potentially significant cost savings.

1.3 Cost

Most authors tend to point out the theoretically viable economic benefit of BIM implementation. Nonetheless, there is very little empirical evidence within current academic literature of project cost savings. Some authors attempt to attribute figures, such as an "average BIM return on a given investment [of] 9.486%" (Azhar, Hein and Sketo 2008) or reports that "…a cost differential as small as 2% in increased construction costs results in savings of more than 10 times that investment in reduce energy consumption, waste management, and other costs of operation. This doesn't even factor in the reduced waste of both time and materials during the construction process" (Reddy 2008).

Azhar et al (2008) reports that a 2007 study by the Stanford University Centre for Integrated Facilities Engineering (CIFE), based on 32 major projects that employed BIM, found cost benefits including a reduction of unbudgeted change by 40%, accuracy of cost estimation brought to within 3%, time taken to produce a cost estimate reduced by 80%, and clash detections resulting in savings of as much as 10% of the contract value.

Perhaps the most compelling evidence for the cost effectiveness of BIM comes from a 2009 US study (Young et al. 2009), with two thirds of over 1,000 BIM users seeing positive return on investment (ROI). Most telling from this study, businesses that actually measured their ROI found substantially greater benefits than those who simply estimated the benefits; 57% of companies who directly measured the benefit found a ROI of 10 percent or greater, compared to 36 percent of companies who simply estimated ROI (Young et al. 2009, 4).

If these benefits are repeated across the industry, BIM would appear to be a sound investment. Two obvious questions are: is this benefit being seen in markets outside of the USA, and are there similar impacts being seen on project quality.

1.4 Quality

The importance of an integrated design system within BIM is continuously emphasised and proven through current academic research. Benjaoran and Sdhabhon (2010) detail the BIM's integrated design tools which identify project-specific safety hazard and provide best practices to eliminate corresponding hazards and design clashes. "Traditionally, safety is managed separate from the construction" (Benjaoran and Sdhabhon 2010). Construction management is thus fragmented from safety management and tends to disregard safety constraints within the construction process, ultimately leading to a disjointed planning phase. "The 4D CAD model is an innovative integration tool between construction and design. It combines two separated information sources – a construction scheduled and a 3D CAD model into one integrated system." (Benjaoran and Sdhabhon 2010). This is achieved through the development of a holistic and automated systems tool that integrates safety into design planning and control processes. The system is supported with database that encapsulated and accumulated safety knowledge including both in explicit and implicit form. Its unique ability to "represent construction activities as virtual 3D objects can effectively convey space information" (Benjaoran and Sdhabhon 2010) and assist designers during the Schematic Design (SD phase to plan accordingly, continuously re-iterating the planning schemes.

According to the planners, the 4D CAD visualisation of the workflow allowed subcontractors to make early decisions to avoid congestion and work space conflicts; thus planning the workspace effectively between different construction trades. It was further mentioned by planners that 3D-4D modelling, unlike 2D drawings, does benefit the planning for the work tasks performed at height, thus helping the contractors to plain into the production adequate lifting aid devices of heavy materials as well as the lifting of workers themselves in order to perform their work tasks at a proper working height (Rwamamara et al. 2010). Such issues highlight the potential of BIM to mitigate planning errors and reform the project delivery process, thus improving project quality.

Rwamamara et al. (2010) state that "construction work activity is information-intensive and the number of documents increases proportionately with the project size." As project size increases, so does the complexity. Waly and Thabet (2003) made use of "advancements in computer graphics to develop 4D tools that enable graphic simulation and visualization of the construction process."

In addition, Popov et al. (2006) states that usually an "architecturally – design part of a design is dissociated from an economic one strictly therefore a designer (Architect or Constructor) having no tools and often even no possibilities (for instance due to time restrictions) for unbiased pricing of a structure and comparison of variants, simply makes no price evaluation at all." Therefore it can be stipulated that a designer (from the Schematic Design (SD) phase) will be able to design within realistic constraints and provide economically viable solutions. This information can therefore be exported about operations and resources from estimates and scheduling applications such as Microsoft Project – therefore creating a smooth transition (Popov et al. 2006).

Contrastingly Coates et al. (2010) argues that although significant potential lies within the BIM implementation and its relation to design, huge developments are required for better alignment with architectural tools and the design process. "For an Architect BIM concentrates rather too much on providing means of representing the final form of the design, whereas designers also need a continual stream of abstraction, advice and information to facilitate in the move from information to the distillation of knowledge" (Coates et al. 2010, 58). Nonetheless Coates et al. also acknowledge the advantages of BIM to the architectural design process such as the use of the BIM for 3D printing of physical models as well as the creation of animations and virtual environments. Coates et al. (2010), however concludes strongly with a detailed list on the areas for developments with regards to improving the misalignment of BIM with the design process:

- Better alignment with the architectural thought processes
- Improved intuitive operation, reduce the mental overhead of using the system
- A building method of information collection, evaluation, structuring and sharing
- Further develop of BIM linking it more effectively to real world capture and feedback and customer feedback technologies
- Providing a greater range of models and abstractions to assist with the creative process
- Further development of BIM using total emersion technologies
- A built in learning and error correction system
- A better system of tailoring issued information to meet the needs and capabilities of the recipient
- Better integration with other practice business systems, combining, aggregating and visualizing business data
- Better integration with contextual information and GIS systems

(Coates et al. 2010)

It seems clear that BIM has the potential for improving project quality for some disciplines more than others. One of the things that needs to be assessed is whether practicing professionals actually see these quality improvements on their projects. This can really only be assessed by asking them directly.

2. Methodology

This research is a part of a larger BIM study conducted by the same research team (QUT ethics committee approval number 1200000555). It intends to combine data gathered through this survey with data collected from face-to-face interviews. Extensive literature analysis has shown both these approaches valid for gathering data on the use of BIM. This immediate research consists of an electronic survey that is conducted online with invitations emailed directly to individual within construction firms, initially within Australia and then internationally, including Korea, China, Indonesia, the UK, Canada, Brazil, India and the USA. Translation of the survey from English means email invitations will be sent out in stages as translations are complete.

The literature review and analysis has been integrated into the research methodology to form a strong basis of knowledge as well as to identify knowledge gaps in the overall knowledge base of BIM's theoretical knowledge. In addition the qualitative information acquired from the literature analysis has been influential towards presenting a theoretical frame working model (see Figure 1) which outlines the overall system's integration of BIM's functionality within the AEC industry professionals. This has effectively identified the differences between theoretical BIM notions to real world scenarios and relative BIM performances.

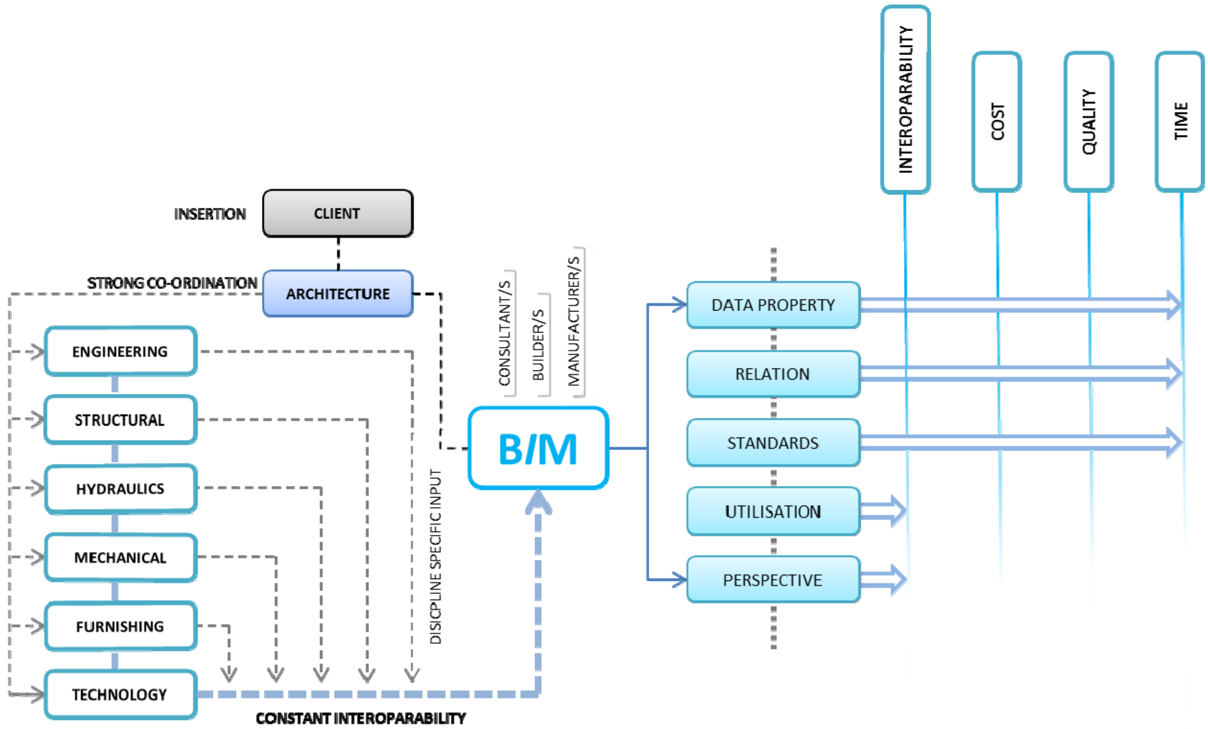
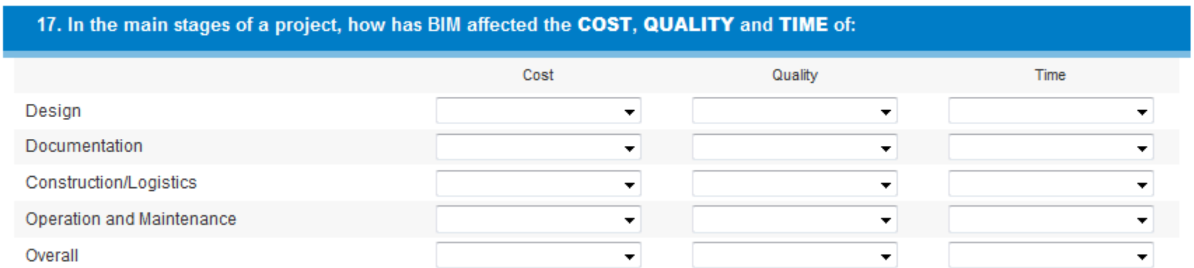


Figure 1: Conceptual framework of BIM as a tool connecting disciplines with project outcomes

The discrepancies identified within the literary analysis as well as the lack of current information on BIM (especially within Australia) are the basis for the nation-wide electronic survey. There are and have been a number of surveys and studies of BIM. The Royal Institute of Charted Surveyors (RICS) are currently conducting in-depth BIM research which includes a survey released on October 2012. RICS's survey presents more emphasis on the overall systems of BIM with regards to surveying and housing markets. Consequently, neglecting the overall understanding of BIM's influence on the entire AEC industry. This knowledge gap is effectively covered by this research. Therefore justifying the primary aim for this research study and establishing the potential contribution that can be made by this research study.

This survey seeks to obtain information from all AEC related disciplines (architects, engineers, surveyors, contractors, project managers etc.) on their *current* use of BIM. This will allow the study to encompass a broad view point and identify the effects of BIM on the AEC industry. The structure of survey is designed to collate data from both BIM-Users and Non-Users. The start of the survey contains general questions put in place to gather demographical information from the participants. The survey is then broken into two sections; BIM Users and Non BIM users, with many more questions for BIM users. It includes a range of qualitative and quantitative questions that allow the consenting, voluntary participants to provide information on issues such as – the duration of BIM use; scope of works with BIM use; building types that BIM has been utilised for; identification of strengths, weaknesses and potential improvements. Most questions have emphasis put on project lifecycle phases, such as: Design; Documentation; Construction Logistics and Operation and Maintenance, as shown in Figure 2 . This broad range of questions will allow this study to identify the extent of BIM use within the current AEC industry with relation to project delivery.


17. In the main stages of a project, how has BIM affected the **COST**, **QUALITY** and **TIME** of:

	Cost	Quality	Time
Design			
Documentation			
Construction/Logistics			
Operation and Maintenance			
Overall			

Figure 2: Example of question layout of online survey

The Non-BIM users section contains questions which allow this study to draw justified conclusions on the lack of BIM integration for various reasons behind this as well as their willingness to adapt for the BIM revolution.

This extensive questionnaire is currently within its Phase 1 of data collection (230 participants engaged). At the completion of data collection this survey will reach more than a 1000 participants world-wide. This method of data collection is intended to provide valuable information to feed into the literary qualitative analysis. The survey also complimented the integration of qualitative research with a series of 'open ended' questions to allow the participant to provide responses which were not restricted. This can be used to gain an in-depth understanding on to the quantitative data collected as well as to draw conclusions between the pre-survey qualitative analysis.

The aim of this approach is not to reiterate existing systems of BIM use, but to gain a more in-depth understanding on the use of BIM and provide up-to-date information on its overall systems relationship with the AEC industry. The fundamental reasons for using a combined, qualitative and quantitative research methodology is due to its ability to base factual up-to-date data (quantitative) collected while integrating the concepts and knowledge base acquired from the qualitative literary analysis. This can further assist in comparing the up-to-date qualitative information gathered from the survey in identifying the line between the theoretical potential of BIM to real world scenarios.

3. Results

At the time of writing only very preliminary results have been obtained, with a total of just ten completed surveys, with another 35 people who have 'clicked through' the survey without completing any responses. Part of the rational of this survey was to canvass all construction firms and individuals to get an appreciation of total use within the industry, not just the opinions of those who use BIM. Of the 10 respondents almost half have identified as not using BIM. This is consistent with the pattern reported by Young et al. (2009) It will be very interesting to see whether this pattern continues as more responses come in. There has been a lot of excitement about the potential of BIM, but the reality might not match the rhetoric (Gerrard et al. 2010), at least in Australia. These responses have come from eight different professions, including: steel detailer, building designer, tradesman, quantity surveyor, interior designer, structural engineer, draftsman architect and construction manager. All have more than ten years experience in their profession.

With this low number of responses, drawing sensible conclusions is difficult. However some responses are consistent with patterns already seen in the literature and are likely to be reiterated by further respondents. These are shown below.

- Software most used is Autodesk Revit, Autodesk Navisworks, and Tekla Structures.
- Three of four BIM users find it highly effective compared to 'traditional methods'
- Estimated costs of implementing BIM are between 2 and 15% of total project costs
- BIM is used most during the documentation stage of the project
- The most consistent improvements in Time, Cost and Quality of a project are during the construction/logistics phase.
- During the Design phase, BIM is most effective for visualisation
- During the Documentation phase, BIM is most effective for modification and overall accuracy.
- Most BIM training is Company Funded, and focuses primarily on Software

- Of the four BIM users one apparently had a bad experience, and commented that there was a "...Significant addition of time" to the project, significant organisational costs "...with no immediate benefits", "Significant cost in hardware and poor performance of software", and that "genrally [sic] the BIM process is done poorly by most ".

- This same respondent feels that "More integration is required between software manufacturers - especially Autodesk products", and that "Due to the additional planning stages of BIM projects onsite operations are generally overtaking the BIM process in construction program".

- This user concluded with advice to others: "Understand the process is HUGE and you are not an expert". Other users had slightly difference advice: "Never give up. It makes sense and will be adopted. Be patient and concentrate on data [not on] the tools. Do not let yourself be cornered into exclusive propietary [sic] solutions." and "It works".

- Of non-BIM users, one had never heard of it, while two others stated there was no demand for it.

More extensive results will be presented in due course, including results from international respondents.

Ideally BIM should be regarded as "the entire process of exchanging, re-using and controlling project information being generated during the lifecycle of a building project and not just a simple information model" (Ham et al. 2008). This notion is illustrated within Figure 1. With plenty of room for improvement, BIM has currently affected the organisational structuring of many building project processes. The BIM approach provides architects with the opportunity to regain lost ground in respect to their traditionally status as leaders (Khemlani 2007), as it enables enhanced control, co-ordination and management of building projects. Having said that, the BIM process is still at a very young stage and just like organisations in the retail sector before them, BIM adopters will need to go through a managed process of change which encompasses not only their internal organisation but also the way they interface with their external supply-base and clients (Dawood and Iqbal 2010). Currently the majority of the UK market is still working lower level processes, with the most significant benefits experienced by moving to higher levels of BIM adoption (Dawood and Iqbal 2010, 7-14), something reiterated by in the USA (Young et al. 2009).

4. Conclusion

A wide range of institutions and industry bodies are conducting BIM research. This research project has the ability to stand out from the rest and effectively contribute to the overall body of knowledge, as it will update the knowledge of BIM use in Australia, last assessed in 2007 (Gerrard et al. 2010), as well as making an international assessment of current industry practice. While data do exist for the US and UK as recently as 2012, this study extends the knowledge of use across international boundaries and across disciplinary boundaries. Dta collection for this project is still within its preliminary stages, but over the early months on 2013 a substantial amount of data will be gathered and analysed.

5. Acknowledgements

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6. Appendix—Survey Questions

1. PRELIMINARY

What is your profession? (Please check all that apply)

How many years of experience have you had in your profession?

Where is your current workplace based?

Have you used BIM on any projects you have worked on?

2. BIM USERS

What is your current definition of BIM?

How long has your organisation been using BIM?

How often have you had external requests to use BIMs?

From who have you had requests for BIM?

On what percentage (%) of projects have you used BIM in the last year?

Within these project types, what is the average project size on which you have implemented BIM? Nominate all types that apply

Which BIM software have you used?

How effective has BIM proven to be in comparison to utilising more traditional methods (CAD, Hand drawings etc.)?

What aspect/s of BIM do you use?

What project changes/results have you experienced having used BIM?

What are the estimated costs of implementing BIM on your project (of total project costs)?

What is the extent of BIM's involvement/implementation within the main stages of a project?

In the main stages of a project, how has BIM affected the **COST**, **QUALITY** and **TIME** of:

Within the **DESIGN** phase how effective has the implementation of BIM proven to be?

Within the **DOCUMENTATION** phase how effective has the implementation of BIM proven to be?

Within the **CONSTRUCTION/LOGISTICS** phase how effective has the implementation of BIM proven to be?

Within the **OPERATION AND MAINTENANCE** phase how effective has the implementation of BIM proven to be?

What is your overall level of satisfaction with your BIM experience?

Who is mostly responsible for co-ordinating the BIM on a project?

Which discipline/project party has intellectual property ownership of the BIM in a project?

With all building projects there are legal concerns which impact the process. With regards to BIM integration were there any legal concerns?

Were there any organisational issues involved in the BIM process?

What is the competancy level of BIM users within your organisation? (Total must add up to 100%)

Do you have any BIM training systems in place?

What is your BIM training focussed on?

How often does your organisation provide training?

To what extent should BIM be integrated into Tertiary Studies Curriculum?

Were there any challenges with the initial take up of BIM?

Any suggested improvements to:

What advice would you pass onto to new BIM users?

Would you recommend implementing BIM on building projects?

To what extent would you recommend the implementation of BIM within the building types below?

To what extent would you recommend the implementation of BIM within the Project sizes listed below?

To what extent would you recommend the implementation of BIM within the Project lifecycle phases listed below?

Any Additional Comments?

03. NON-BIM USERS

What is your current definition of BIM?

What are your reasons for not employing BIM?

Are you considering the implementation of BIM within your organisation?

What aspects of BIM do you plan on utilising?

Have you had any external requests for BIMs and from whom?

Any Additional Comments

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