BIM IMPLEMENTATION IN A NEW ZEALAND CONSULTING QUANTITY SURVEYING PRACTICE

Curtis Harrison, Unitec Institute of Technology, New Zealand
Derek Thurnell, Unitec Institute of Technology, New Zealand

ABSTRACT

5D BIM - generating cost data via the building information modelling (BIM) process - has the potential to be used by quantity surveyors (QSs) to streamline their workflows and increase their provision of a quality service. Consultant QSs experienced in the use of 5D BIM, from the New Zealand office of a large global practice, were interviewed on their perceptions of the benefits of, and barriers to, 5D BIM implementation within their firm. Findings suggest that 5D BIM has numerous benefits over traditional methods, chiefly through the increased efficiency and visualisation that BIM provides, along with the rapid identification of design changes. However, realisation of these perceived benefits is limited to date, due to several barriers hindering 5D BIM implementation: incomplete design and insufficient model object data in the BIM model; a lack of standards to facilitate electronic measurement; legal issues, and a lack of government support. Increasing 5D BIM implementation, in tandem with increasing use of collaborative project working through integrated project delivery, will, however, facilitate these benefits being achieved to a far greater extent in the future. Further research is recommended to identify the BIM skills which QSs will need in the future to reach the full potential of 5D BIM.

KEYWORDS: Building Information Model (BIM), 5D BIM, Quantity Surveying, New Zealand.

INTRODUCTION

A Building Information Model (BIM) is "a model composed of objects that represent the different elements of a building, and data related to each object" (Forgues, Iordanova, Valdivesio & Staub-French, 2012, p.779). It is a digital representation of a building's geometric and non-geometric data, and is used as a reliable, shared knowledge resource to make decisions on a facility throughout its lifecycle (National Building Information Modeling Standard, 2010). It provides an innovative, collaborative environment, offering many opportunities to various disciplines within the construction industry, through the utilization of BIM models throughout the design, construction, and facility management of a building. The multi-dimensional nature of BIM, often referred to as 'nD BIM', allows for modelling in an infinite number of dimensions: 3D (object model), 4D (time), 5D (cost), 6D (facility management), 7D (sustainability) and even 8D (safety). Various users can extract and use the invaluable data contained in the data-rich and intelligent 3D model objects. Parametric modelling facilitates the creation of a relationship between elements, and includes the specification and properties of individual elements and objects, [potentially] enabling the extraction of comprehensive and accurate information from the model which can be directly used for costing (Eastman, Teicholz, Sacks & Liston, 2011). The 5D BIM process uses BIM model data to provide quantities in real time for cost estimating (Forgues *et al*, 2012), and 5D BIM specifically concerns the extraction and modification of cost-related data, becoming the primary source of information for quantity surveying (QS) services (Stanley & Thurnell, 2014).

However, before the potential of 5D BIM can be truly realised, the barriers limiting its implementation must be fully understood (Mitchell, 2012). The main objective of this research then is to determine the perceived benefits of, and barriers to, 5D BIM implementation within a single, large multi-national consulting quantity surveying practice in New Zealand. It is hoped that the results will inform and provide insight into the specific issues surrounding the implementation of 5D BIM, to enable the next step in the process, the development of solutions for overcoming the barriers, in order to obtain the benefits of 5D BIM within that practice.

LITERATURE REVIEW

5D BIM in New Zealand

New Zealand's only national BIM survey recently found that the proportion of BIM users increased from 34 % (2012) to 57 % (2013), with a year-on-year increase in overall BIM awareness in the construction industry, from 88 % (2012) to 98 % (2013) (Masterspec, 2012; Masterspec, 2013). BIM is expected to provide endless opportunities to the quantity surveying profession and their clients, allowing them to streamline their workflows and increase the quality of the cost services they provide (Boon & Prigg, 2012).

A common understanding of 5D BIM is that the costing application of BIM is contained within the BIM model itself; a cost dimension is added, by incorporating cost data within the BIM model objects themselves (Thurairajah & Goucher, 2013). The adoption of 5D BIM within a construction project provides an expanded range of possibilities to not only the quantity surveyor, but to many different project stakeholders. These possibilities are attributed to the significant amount of information that can be encapsulated from the BIM models and the efficiencies that can be gained (Forgues *et al*, 2012). Current practice in New Zealand is for BIM models to be "live linked" to estimating software tools, in order to automatically extract the quantities (Boon & Prigg, 2012).

Despite the increased use of BIM reported above, New Zealand's BIM maturity level remains fairly rudimentary, and most of the industry is still operating at Stage 1B ('Intelligent 3D') of the Australian Institute of Architects' BIM implementation scale (Australia Institute of Architects, 2009). There is anecdotal evidence that a few NZ construction projects are operating at Stage 2A: 'One-way Collaboration', where the (single) BIM model can be shared with other project participants for visualisation, coordination, communication, assessment, analysis, simulation or discipline design; however, the original model is updated in digital isolation from other discipline models, and feedback to the original BIM model author for design and coordination is in traditional formats and the original model is updated in digital isolation from other discipline models (Australian Institute of Architects, 2009). It should be recognized that the highest level of BIM adoption [level 3 – Integration], where there is integration of several multi-disciplinary models using model servers or other network base technologies is advocated, that contains all information and conforms to international frameworks, is not apparent within the New Zealand market (Stanley & Thurnell, 2014). Instead, projects often utilize up to three different (and separate) models, which can encompass architectural, structural and services design documentation (Boon & Prigg, 2012).

Literature on QS's use of 5D BIM within a New Zealand context is limited mainly due to the small market and reluctance to adopt its use (Tran, Tookey & Roberti, 2009). Indeed, 5D BIM is rarely being implemented in New Zealand, except on a very few large projects, which have recently used a single integrated BIM model, which can be shared with other project participants (Boon & Prigg, 2012). A recent survey of 20 quantity surveyors in New Zealand found that almost all respondents had experienced no more than 5 projects which had used 5D BIM (Karamaena & Domingo, 2014).

Nevertheless, New Zealand's use of 5D BIM technologies, whilst limited, is developing (Stanley & Thurnell, 2013, 2014). Despite the purported benefits of BIM, the adoption of 5D BIM in New Zealand and Australia is significantly slow-moving due to a number of barriers limiting its implementation within industry, which are ultimately centred around the fragmented nature of the construction industry, suggesting that a shift in current workflows is required (Masterspec, 2012).

RESEARCH METHODS

To answer the research question "What are the benefits and barriers of 5D BIM implementation in one large global professional quantity surveying practice?" a qualitative study utilising a qualitative, cross-sectional survey approach was adopted. The research aim of exploring the challenges of BIM implementation for the specific context of a consultant quantity surveying practice requires discovery of perceptions and attitudes on issues related to the topic. Qualitative, attitudinal research enables participants' opinions, impressions and experiences on a relatively novel topic [i.e. 5D BIM] to be examined in-depth (Hartman, Fischer & Haymaker, 2009).

Purposive, non-probabilistic sampling ensured that only those quantity surveying (QS) staff that had some 5D BIM experience were selected, and as 5D BIM is a leading edge, recent development in QS practice, there is a dearth of experts in 5D BIM, and so a sample of five professional quantity surveyors from the large global consulting quantity surveying practice in New Zealand was obtained.

Data were collected in two stages: initially using an emailed closed ended questionnaire with follow up semi-structured interviews used to discuss the main themes that surfaced from the questionnaire responses. The questionnaire format assessed participants' attitudes towards the benefits of, and barriers to, implementation of 5D BIM in their particular organization, by using a 5 point Likert-type semantic rating scale where: 1 = Strongly Disagree to 5 = Strongly Agree. The follow up interviews gave participants the opportunity to have the wording of questions clarified, and the interviewer the ability to ensure that the questions were interpreted as intended, and allowed participants to elaborate upon their earlier responses to the closed questions when necessary. In order to minimise the potential for introduction of interviewer bias, the interview structure and questionnaire were piloted beforehand, and all interviews were voice-recorded, which enabled post-hoc analysis of qualitative responses, in order to further reduce bias. Analysis of the questionnaire data consisted of identifying patterns or trends in the ratings given by respondents; strongly supported issues were then investigated further during the interview stage. The issues raised in the questionnaire were drawn from a wide variety of sources in the literature (Boon, 2009; Boon & Prigg, 2012; Bylund & Magnusson, 2011; Matipa, Cunningham & Naik, 2010; Olatunji & Sher, 2014; Popov, Migilinskas, Juocevicius & Mikalauskas, 2008; Samphaongoen, 2010; Sattineni & Bradford II, 2011; Stanley &

Thurnell, 2013, 2014; Tran, Tookey & Roberti, 2009). Ethics approval was sought and obtained, and all responses were kept confidential, and participants' anonymity was ensured.

Demographic information such as the job position/role of participants, how many years of QS experience they had, and the participant's level of experience with 5D BIM, was collected. The next section queried participants on their perceptions of the benefits and barriers of 5D BIM in the context of their particular firm.

The follow up interviews, which were subjective, unlimited and flexible, only comprised open-ended questions. This was designed to gain a thorough understanding of the main issues that surfaced from the questionnaire. Participants' comments were analysed by identifying any dominant themes from the respondents' responses, which were then codified, and emerging trends were then compared with findings from the literature review.

FINDINGS AND DISCUSSION

The first section of the questionnaire covered information on the participants' experience as a quantity surveyor, and with 5D BIM. All participants were qualified quantity surveyors, with one a Director (17 years' experience), 3 Senior Quantity Surveyors (between 11 and 15 years' experience), and one an Intermediate Quantity Surveyor (5 years' experience). All five participants had used 5D BIM in the past three years to generate cost plans and/or schedules (bills) of quantities, on between one and nine projects, in New Zealand, Australia and the USA.

All participants indicated that they have used 5D BIM to prepare Schedules [Bills] of Quantities (SOQ), and for cost planning. Two participants suggested 5D BIM can only produce SOQs in part, meaning the tool can only be used to extract quantities for certain items such as light fittings, structural steelwork, windows and doors, etc. All participants have used 5D BIM on projects in the last 3 years, with one participant using it on 4 projects, and one on a total of 9 projects, 4 in the USA, and 5 in Australia. All participants anticipated continuing to use 5D BIM on projects in the next 2 years, but interestingly, only 2 of 5 thought that 5D BIM would significantly change their role as a QS.

Benefits of 5D BIM

The participants were questioned on their perceptions of the benefits of using 5D BIM in a consulting QS firm, and the following themes emerged

Enhanced visualisation

Participants generally perceived that BIM's 3D function improves decision making, reduces inaccurate drawing interpretation, and reduces the assumptions the QS needs to make. This aligns with Sabol (2008), who suggested 5D BIM provides a clearer understanding of construction components which in turn reduces the chance of missing or misinterpreting vital building items. However, 2 participants commented that the QS could still misinterpret the 3D model if they were unfamiliar with how BIM operates and where common design errors were found in the models. "*If you are not familiar where the inaccuracies lie in the model, and you just trust that the quantities that you extract are correct, often you will not get accurate data*". This suggests the QS requires a thorough understanding of the underlying process of data embedment and also must be able to identify inaccuracies within the models. Monteiro and Martins (2013) suggest quantity extraction is "a tricky feature and tends to be only used by an expert" (p. 239); similarly, Boon & Prigg (2012) also suggest that an expert quantity surveyor is required to operate with 5D BIM, due to its tricky extraction and mapping features in addition to identifying incomplete design.

Efficient data extraction for early stage (preliminary) estimating

Four of the five participants felt that 5D BIM does not enable efficient data extraction for early stage preliminary estimates, which is contrary to the findings from the literature, which purports that 5D BIM can be utilized to automatically extract quantities to speed up preliminary estimating (Firat, Arditi, Hamalainen, Stenstrand & Kiiras, 2010; Matipa, Kelliher & Kean, 2008; Thurairajah & Goucher, 2013).

One participant explained: "*not at the moment, it is an experience thing, what you get out of the model is only as good as what the designer has put in, and at an early stage, the design is too inaccurate and insufficient*". However, this will improve: "*as we get better at using the tool, and the tools become more available, we will be able to use it a lot more for that type of estimating*". Another participant reported that it's hugely dangerous to use BIM models for early stage estimating due to the concept model containing little or incomplete information: "*the art and magic of concept estimating is estimating what's not there, you need to figure out all the things that will be included in the design phase like acoustics, fire, solar shades that no one has talked about but you know through experience that they will be required*".

This suggests that if QSs use the BIM model to extract quantities from a concept design, taking the quantities at face value without additional manipulation, they may not realise that what is shown will be vastly different to what the final detailed model will show; the QS could therefore easily overlook construction items not shown, producing an inaccurate estimate. However, participants did suggest that concept models are used as a bulk-checking tool of manual measurement, and anticipated that preliminary estimating will become more efficient through 5D BIM automatic generation of quantities in the future through increasing experience and awareness.

Efficient data extraction for detailed estimating

Most participants felt that 5D BIM enabled efficient detailed elemental cost plans, but only for certain building items; extensive bulk checking and identification of missing items is imperative to ensure quantities are correct, and often manual adjustments are needed. Similarly, Stanley and Thurnell's (2014) New Zealand study indicated that 5D BIM is currently used to support cost planning at the detailed design stage. Some participants suggested that in order to facilitate the measurement of more building items, the QS must work closely with the designer from the outset of the project to align data embedment with QS requirements. Roberts (2012) asserts that the QS and design consultants need to work collaboratively from project inception to enhance communication on design input.

One participant was optimistic for 5D BIM's future impact: *"as we go through, we will learn to use it more and more and better and better, and we will also have a lot of input to the designers so that they provide what we need as part of the model for detailed estimating"*.

Efficient data extraction for producing Schedules of Quantities (SoQs)

Participants generally perceived that the automatic generation of quantities enabled by 5D BIM speeds up the process of producing schedules of quantities (SoQs), but (as for detailed cost planning, above) only certain building items could be measured, and only a small efficiency is gained due to the bulk checking that is required to ensure quantities are correct, and to identify incomplete design. Boon and Prigg (2012) found similarly, describing quantities that could be extracted for items such as doors, windows, reinforcing, concrete and structural steel.

However, this is in contrast to much of the international literature; Quek (2012) reports that 5D BIM did not facilitate this type of measurement due to the many problems associated with the way the design is embedded into the model, suggesting quantities did not conform to standard methods of measurement. Stanley & Thurnell (2014) also found that currently, there is no increased use of 5D BIM for the production and pricing of SoQs during tender/bid stage. Participants, however, suggested that the more industry uses the tool, and resolve the challenges associated with design embedment, producing SoQs will become increasingly efficient. One explained how a comparison was made between a manual measure and a BIM measure of light fittings, in order to determine which method was more efficient. The result was a 2-hour time saving by extracting the quantities from the BIM model; he said "*I counted up light fittings, and it took me 6 hours, then I used the BIM model to extract light fittings, and it took me about an hour, and then it took me three hours to check the quantities, so it did save me a bit of time, but not a huge amount*". He believes that: "the time saving will get better as we understand how it can be used", suggesting that the more that industry uses BIM, the more that the challenges associated with design embedment will be resolved, leading to increasingly more efficient production of SoQs. However, Olatunji and Sher (2014) assert that although 5D BIM can speed up the identification process, to ensure the reliability of estimates, BIM models often need reconstruction and design analysis to adapt them to the idiosyncracies of construction projects.

Rapid identification of design changes

All participants agreed that design changes can be rapidly identified and updated for estimating through 5D BIM, which aligns with Stanley and Thurnell (2014), who assert "The ability to update and change quantities quickly can be a major benefit for QSs in terms of cost modelling" (p.110). Furthermore, Olatunji and Sher (2014) suggest that BIM allows professional QSs to identify factors that have economic benefit or consequence on various design options in order to select the most suitable and cost efficient proposal.

Improved accuracy, communication and access to information in the design

Participants were optimistic for the future in terms of increased accuracy from using 5D BIM automatic generation of quantities: "*as designers get better coding, there will be less incorrect information in the model, and inherently that will increase the accuracy of our estimates when we use the information*". Participants tended to agree that 5D BIM improves communication and access to information in the project team, one relating how on a recent project, due to the quantity surveyor being integrated with the designer early on, access to design information was improved and communication was significantly enhanced. As a result, the two consultants were able to work together in order to embed the data to conform to the company's standard rules of measurement, something that couldn't have been achieved if they worked in isolation.

BIM depends on a collaborative approach, ideally through the use of a centralised model, where design changes are automatically updated and coordinated amongst the project team (although this is rarely achieved to date). Eastman *et al* (2011) assert that collaboration can be achieved either by project teams utilising one proprietary software suite that contains all relevant design and cost information, or by project teams using multiple proprietary or open-source software, that contains mechanisms to ensure that data is fully exchangeable across different disciplines. This allows for real time changes to be suggested and made electronically during construction (Aranda-Mena, Crawford, Chevez & Froese, 2008). Recent research on information management through BIM highlights BIM's potential to foster greater collaboration within project teams (Demian & Walters, 2014).

Commercial advantage

All participants strongly perceived that 5D BIM gives a commercial advantage over competitors, which is supported by Thurairajah and Goucher (2013). One participant said: "*I think we are one of the few QS practices that are getting into it at this stage, therefore if we can get good at this quickly, it will provide a short term commercial advantage until our competitors get on board, however by that time, we would have still gone through everything so hopefully we would still be ahead of them*". This suggests that the implementation of 5D BIM is commercially advantageous for two different reasons: in gaining a competitive advantage over competitors through client recognition, and also in gaining a commercial advantage by discovering and overcoming all the issues associated with 5D BIM before competitors decide to implement it themselves; thus they are always a step ahead which means they can perform the service more efficiently.

Improved coordination and clash detection

There was a strongly held perception by participants that 5D BIM increases coordination through integration of specifications and clash detection, as centralised BIM models have the ability to automatically update changes and rapidly disperse this information to stakeholders. This is in contrast to traditional methodologies, where the QS had to scan through revised documentation in order to identify changes.

Popov *et al* (2008) assert that the use of 5D BIM for cost modelling encourages collaboration on projects, and as such aids the management of the project overall. In order to achieve effective 5D BIM, designers need to generate suitable 3D information, and this needs to be checked for clashes by the construction team. 5D software also has the ability to check for clash detection, and in this way a collaborative atmosphere is further encouraged (Won, Lee & Lee, 2009).

Barriers to Achieving 5D BIM

Participants were questioned on their perceptions of the barriers to using 5D BIM in their consulting QS firm, and the following themes emerged.

Software inter-operability issues

Participants perceived that BIM models are compatible with estimating software tools, on the basis that their company's in-house software tool was compatible with various BIM model formats. This is in contrast to the literature, which often suggests a major hindrance to 5D BIM implementation is due to BIM software companies using non-proprietary file types which cannot be exchanged with estimating software. For example, Olatunji and Sher (2014) explain how the data needed for cost planning sits in isolation between different software vendors and applications. Nevertheless, some participants have encountered problems associated with data exchange, e.g. the inaccurate transferring of data from Revit files to IFC (Industry Foundation Class) file types. Although IFCs are compatible with the company's estimating software, the company abandoned the use of IFCs, due to the loss of data and inaccurate exchange of information from Revit files: "*an IFC basically takes the data from a Revit file and transfers the information into an IFC file, and then when you upload the file into our IDX software (the design component of Qubit), it takes that data, messes it around, and information can be messed up*".

Also, one participant suggested that designers were now beginning to stop using IFCs because the risk of losing critical information was too great. The company mainly uses DWFX file types "*which are similar to a read-only type file and are fully compatible with the software*". IFC standards have been generated by the International Alliance of Interoperability (IAI) to help govern the exchange of data between CAD software tools, estimation software tools and other construction application software tools by creating a neutral file format. IFCs are believed to be important for cost consultants, as without complete inter-operability, items will be missed from the BIM model as they are combined, and therefore missed from estimates and schedules of quantities. However, Quek (2012) reports that a single "merged" IFC-based model "creates a layer of complexity, with the risk of redundancies because of its large file size and compromised data transfer rates and perceived lack of incremental benefit" (p. 3405). The use of IFCs for information exchange is still problematic regarding inter-operability; nevertheless, the IFC schema is still considered to be the best currently available (Pauwels, 2014).

Incompatibility with Quantity Surveying formats

Participants had a strongly held perception that the design embedded into the BIM model is incompatible with QS formats for estimating (i.e. elemental format), as well as for schedules of quantities. One said "*if you have had no input in the model, you wouldn't be able to get it at 100% complete and therefore it won't be in line with the way we produce our estimates.*" Quek (2012) contends that the risks associated with design clashes with implications such as redesign, re-work and variations are ameliorated by the more collaborative approach that BIM encourages. As one participant said "*as we go through, we will learn to use it more and more and better and better, and we will also have a lot of input to the designers so that they provide what we need as part of the model for detailed estimating*".

The Royal Institution of Chartered Surveyors (RICS) in the UK have worked with industry to develop new rules of measurement (NRM) which will facilitate 5D BIM, and are extending this collaboration with the Australian Institute of Quantity Surveyors in Australia (buildingSMART Australasia, 2012). Currently in New Zealand there are no standards that facilitate the embedment of design data to ensure extracted quantities are compliant with the quantity surveyor's SMM (e.g. NZS 4202:1995). However, a technical sub-committee of the New Zealand Institute of Quantity Surveyors (NZIQS) is attempting to revise New Zealand's standard method of measurement by proposing the use of the Association of Coordinated Building Information in New Zealand's (ACBINZ) Coordinated Building Information (CBI) classification system. The CBI classification system was created to coordinate information sources such as drawings, specifications, quantities, technical and research information and publications (Masterspec, 2012). The NZIQS sub-committee came to their conclusion on the basis that it was a similar coding system to the one used in Singapore, the Construction Electronic Measurement Standard (CEMS), a classification system established for BIM measurement that is globally recognised as being successful (Boon & Prigg, 2012).

Lack of industry standards/protocols to facilitate design embedment

All participants strongly felt that there is a lack of industry standards and protocols to support 5D BIM implementation. This finding supports the literature which suggests there is a lack of protocols currently facilitating BIM, in particular design embedment (Boon & Prigg, 2012; buildingSMART Australasia, 2012; Thurairajah & Goucher, 2013). buildingSMART (2012) reported that BIM's future progression in Australia was reliant on the government and industry coming together to develop these standards, and recently have contributed in the development of the New Zealand BIM Schedule (BRANZ, 2014) and New Zealand BIM Handbook (Building & Construction Productivity Partnership, 2014), which may help improve matters somewhat if they are adopted.

One participant raised an interesting point regarding early collaboration between designers and QSs: "*we need to be careful of how much we impose on designers, because they won't want to work with us, that's why standard coding is required*". So, if QSs keep telling designers what to include in their BIM models, they could potentially discourage designers from working with them, hence standard coding is required to provide consistency and to sufficiently manage the process.

Necessity of manually reviewing/checking extracted quantities

Participants generally perceived that the time required to check automatically generated/extracted quantities from the BIM model meant that 5D BIM was not significantly faster than manual take offs. Stanley and Thurnell (2014) also found that a lot of bulk checking still needs to be done, but that in the future, the efficiencies of 5D BIM would improve; this is echoed in the literature: Bylund and Magnusson (2011) suggest that through BIM it is possible to gain accuracy and speed up the process of take-offs, and Shen and Issa (2010) found that gains in speed and accuracy are achievable when using 3D models when compared to traditional 2D.

Lack of Government intervention

All participants perceived a lack of government intervention to set up the required protocols to facilitate 5D BIM (e.g. standardisation of use of IFC's, etc.). They also felt that there was a lack of drive, and support, from the New Zealand government for BIM development and use. Masterspec (2012) also report that a lack of government intervention was currently limiting BIMs implementation in New Zealand. Kraatz, Sanchez and Hampson (2014) highlight the need for a ‘steering agent’ for BIM in a ‘peak body’: a not-for-profit umbrella organization that provides “information dissemination services, membership support, coordination, advocacy and representation, and research and policy development services” (p.462). However, as previously mentioned, the New Zealand BIM Schedule (Building Research Association of New Zealand, 2014) and New Zealand BIM Handbook (Building & Construction Productivity Partnership, 2014) have recently been published, and so it seems that the NZ government (through the auspices of the Building Research Association of NZ, and the Building and Construction Productivity Partnership respectively) is (somewhat belatedly) starting to move towards supporting the use of BIM in the NZ construction industry.

Lack of context for construction methods

All participants perceived that 5D BIM lacks ‘intelligence’ of construction methods such as wastes, jointing and lapping. One participant opined that wastes and lapping were not as much of an issue, as they can easily be built into the rates used, but items associated with joints were more problematic, as they are not physical objects incorporated within BIM models: *“...so if you have a beam that butts into a column, that’s not actually an object within the model, it’s a ghost if you like, but there is definite cost to that junction*”. Shen and Issa (2010) support this view, contending that BIM models do not contain ‘Process Construction Quantities’, for items which are dependent on construction processes, as opposed to ‘Product Procurement Quantities’, which are design components which are present in the BIM model, and thus can easily be quantified e.g. volumes of concrete, or mass of steel.

Training issues

Participants perceived the cost and time implications associated with training staff in 5D BIM were not a disincentive for owners/directors to invest in 5D BIM. However, a common theme was that in order to operate in the BIM environment, experts in 5D BIM are essential, and such expertise is scarce at present. Investment in 5D BIM was thought to be worthwhile and advantageous for QS consultancies, due to the commercial benefit which BIM provides, and thus owners were willing to pay for training in 5D BIM. However, it should be noted that the participants all work for a large, global QS practice; smaller, more localised QS consultancies may find that training costs for 5D BIM are a significant challenge to overcome; Karamaena and Domingo (2014) found that around half of NZ quantity surveyors surveyed were currently undergoing 5D BIM training, which bodes well for the future.

Cultural resistance

Most participants perceived that there is still a cultural resistance to change to 5D BIM from traditional quantity surveying techniques. A recent case study in New Zealand related how several BIM-capable project participants were not prepared to share BIM information between firms (Brewer, Gajendran & Runeson, 2013). This type of culture or dynamic on projects may pose another barrier to successful BIM adoption and use for 5D BIM by QSs, and cultural transformation is a much greater challenge than any technological challenge arising from BIM (Stanley & Thurnell, 2014).

Increased client costs

One participant indicated that consultants are currently driving BIM, not clients, as there is an increase in project costs, should the client wish to use BIM: "*we had a client that was interested in BIM so that they could use it through construction in order to get an as-built model at the completion of the project, however when looking at costs, it appeared to cost 2-3% more than what traditional procurement methods would cost*". These additional costs were said to be attributed to an increase in consultant fees, the requirement for contractors to employ a BIM manager, and subcontractors often needing to upgrade their hardware systems to operate in the BIM environment. Additional client costs were not found to be a significant issue in the literature, and no other participants commented on this as a barrier to BIM implementation.

Participants' experiences with 5D BIM

This section asked participants open-ended questions regarding their experience with 5D BIM, their views on the use of one single model that contained integrated cost data and to elaborate on the main themes identified in the questionnaire.

One participant said his experience with 5D BIM was attending regular Australasian and American BIM inter-office conference calls and looking after a major university project that used elements of 5D BIM. Another participant suggested he was given the role by his employer to write a case study on using 5D BIM on a three hundred million dollar hospital project in Perth. The other participants provided information such as the number of projects they had been involved with that used aspects of 5D BIM, or the type of project they were most familiar with, and what their role was.

When asked what the difficulties were in achieving one single BIM model that has integrated cost data, participants all responded, with a variety of different points of view; one participant suggested that pricing could be integrated into components, i.e. chairs, tables etc., however he didn't believe pricing could ever be integrated into all construction items. Other participants provided comments such as it being unachievable or unbeneficial.

When asked to comment on their own experiences with 5D BIM implementation in their own firm, participants identified the following issues:

1. Models are insufficiently detailed to use for preliminary estimating but can be used as a bulk-checking tool.

2. Models can be used for estimating from a developed design stage (approx. 80% developed).

3. Bulk checking of extracted quantities is imperative at all stages of design.

4. 2D drawings are needed for details, contractors and subcontractors and may always be required.

5. The absence of standards/protocols is a major hindrance to the use and implementation of 5D BIM.

6. Significant confusion exists around the term BIM and how it differs to 3D CAD models.

7. BIM models contain numerous errors and are often incomplete.

8. Early quantity surveyor involvement is essential on BIM-enabled projects, in order to provide cost advice on alternative designs ("optioneering").

Overall, the findings suggested that the benefits of 5D BIM were currently only being achieved to a limited extent, due to a number of barriers inhibiting its full potential; as a consequence, QSs still relied heavily on using traditional methods. Despite this, the perceived future outlook for 5D BIM was exceptionally positive.

CONCLUSIONS

The perceived benefits of, and barriers to, 5D BIM implementation within a single large, multi-national consulting QS practice in New Zealand have been identified, using a survey approach. The research has established that in New Zealand, usage of 5D BIM is increasing, and its adoption has the potential to impact the QS profession in every area, and that the future direction of quantity surveying lies with 5D BIM.

The main perceived benefits of 5D BIM were found to be that it: enables increased visualization of the building; provides a bulk checking device for manual measurement; enables efficient data extraction for estimating at developed design stages, as well as for producing schedules of quantities; allows for rapid identification and costing of design changes, and provision of a commercial advantage over competitors. However, numerous barriers hindering 5D BIM's implementation were found, the main ones being: frequent (and often numerous) design errors, and incompleteness, in the BIM model; incompatibility with QS standard methods of measurement (e.g. NZS 4202:1995); a lack of industry standards and protocols to facilitate design embedment within BIM models; a lack of context for construction methodologies; the need for extensive manual bulk checking to ensure the accuracy of extracted quantities; a lack of government intervention to support BIM, and to a far lesser extent, additional costs to the Client. Participants felt that some of these barriers will be resolved in the near future, mainly through gaining experience with 5D BIM taking place outside the core BIM model, by live linking it to third party estimating software.

Participants asserted that the greatest benefits to date have been achieved when undertaking BIM in a collaborative environment, in particular, when the QS is involved early on in the design process. Participants had doubts for the feasibility of Level 3 full collaborative BIM, that contains integrated cost data within a single integrated BIM model (Australian Institute of Architects, 2009), and suggested that the ultimate goal of BIM may never eventuate. However, there was a strong indication that 2D drawings would eventually succumb to BIM in the future.

Government support in driving the development of BIM was thought to be essential, but has been sadly lacking in the past. Hopefully, recent developments on this front will provide forward momentum for the development of BIM in New Zealand, with the recent publication of the NZ BIM Handbook, and NZ BIM Schedule. However, it remains to be seen how, and if, the NZ construction industry responds to these Government initiatives.

The implications of this research are that as the use of BIM increases, a cultural change will take place, and 5D BIM is seen as the way of the future, and will be more widely used by quantity surveyors in the Auckland construction industry for cost modelling. However, it is clear that increasing cross-disciplinary collaboration on BIM-enabled projects, in conjunction with more widespread use of integrated project delivery, will be necessary in order to achieve the full potential of 5D BIM.

Given the small survey sample size, the findings of this research are not generalisable to the wider population of consulting quantity surveyors in New Zealand; to some extent, the researchers sought to counter this by selecting only those participants with some 5D BIM experience. The aim was only to provide a 'snap shot' of the current opinion on the benefits and barriers of 5D BIM implementation within a single, large global consulting QS practice.

Further research is required to investigate specific areas where the development of BIM (including 4D and 5D BIM) can be supported, for instance by developing methods to improve inter-operability and collaborative working in the BIM environment. Other possible future research is needed to identify the BIM skills which QSs will need in the future to reach the full potential of 5D BIM in such an integrated project delivery environment.

REFERENCES

Aranda-Mena, G., Crawford, J., Chevez, C. & Froese, T. (2008). Building information modelling demystified: Does it make business to adopt BIM? In Proceedings, CIB W78 2008 International Conference on Information Technology in Construction, Santiago, Chile, 15-17 July 2008.

Australian Institute of Architects (2009). *Towards Integration. National Building Information Modelling (BIM) Guidelines and Case Studies, 2009*. Retrieved June 23, 2014, from http://www.construction-innovation.info/images—/pdfs/Brochures/Towards_Integration_Brochure_170409b.pdf

Boon, J. (2009). Preparing for the BIM revolution. In Proceedings, 13th Pacific Association of Quantity Surveyors Congress (PAQS) 2009. Retrieved June 12, 2014, from http: //rismwiki. vms. my/images/7/72/PREPARING_FOR_THE_BIM_REVOLUTION.pdf

Boon, J. & Prigg, C. (2012). Evolution of quantity surveying practice in the use of BIM – the New Zealand experience. In Management of Construction: Research to Practice Proceedings, Joint CIB International Symposium of W055, W065, W089, W118, TG76, TG78, TG81 & TG84, Montreal, Canada, 26-29 June 2012; pp.84-98.

Brewer, G., Gajendran, T. & Runeson, G. (2013). ICT & innovation: A case of integration in a regional construction firm. *Australasian Journal of Construction Economics and Building, 13*(3), 24-36.

buildingSMART Australasia. (2012). *National Building Information Modelling Initiative, Vol.1*. Retrieved May 30, 2014, from http://buildingsmart.org.au/nbi-folder/NationalBIMIniativeReport_6June2012.pdf

Building Research Association of New Zealand. (2014). *New Zealand BIM Schedule, 2014*. Building Research Association NZ. Retrieved July 7, 2014, from http:// buildingvalue. co.nz/sites/default/files/NZ-BIM-Schedule.pdf

Building & Construction Productivity Partnership. (2014). *New Zealand BIM Handbook, 2014*. Retrieved August 8, 2014, from http: // www. buildingvalue. co. nz/sites/default/files/New-Zealand-BIM-Handbook.pdf

Bylund, C. & Magnusson, A. (2011). *Model based cost esimations–an international comparison*. Retrieved May 20, 2014, from http: //www. bekon. lth. se/fileadmin/byggnadsekonomi/CarlBylund _AMagnusson_Model_Based_Cost_Estimations_-_An_International_Comparison__2_.pdf

Demian, P. & Walters, D. (2014). The advantages of information management through building information modelling. *Construction Management and Economics*, 32(12*)*, 1153-1165. http://dx.doi.org/10.1080/01446193.2013.777754

Eastman, C., Teicholz, P., Sacks, R. & Liston, K.(2011). *BIM handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors.* USA: John Wiley.

Firat, C.E., Arditi, D., Hamalainen, J.P., Stenstrand, J. & Kiiras, J. (2010). Quantity take-off in model based systems. In Proceedings, CIB W78 2010: 27th International Conference, Cairo, Egypt,16-18 November 2010.

Forgues, D., Iordanova, I., Valdivesio, F. & Staub-French, S. (2012). Rethinking the cost estimating process through 5D BIM: A case study. Proceedings of the Construction Research Congress 2012, American Society of Civil Engineers (ASCE), p.778-786.

Hartmann, T., Fischer, M. & Haymaker, J. (2009). Implementing information systems with project teams using ethnographic-action research. *Advanced Engineering Informatics*, **23**(1), 57-67.

Karamaena, D. & Domingo, N. (2014). 5D building information modelling in the New Zealand quantity surveying profession. In Proceedings of the 2014 CIB W55/65/89/92/96/102/117 & TG72/81/83 International Conference on Construction in a Changing World International Conference, Colombo, Sri Lanka, 4-7 May 2014.

Kraatz, J.A., Sanchez, A.X. & Hampson, K.D. (2014). Digital modeling, integrated project delivery and industry transformation: An Australian case study. *Buildings*, *4*, 453-466.

Masterspec (2012). *New Zealand National BIM Survey 2012*. Retrieved Jan 31, 2014, from http://www.masterspec.co.nz/news/reports-1243.htm

Masterspec (2013). *New Zealand National BIM Survey 2013*. Retrieved June 12, 2014, from http://www.masterspec.co.nz/news/reports-1243.htm

Matipa, W. M., Kelliher, D. & Keane, M. (2008). How a quantity surveyor can ease cost management at the design stage using a building product model. *Construction Innovation: Information, Process, Management. 8*(3), 164-181.

Matipa, W.M., Cunningham, P. & Naik, B. (2010). Assessing the impact of new rules of cost planning on building information model (BIM) schema pertinent to quantity surveying practice. In Proceedings, 26th Annual Association of Researchers in Construction Management (ARCOM) Conference, 2010. Retrieved June 13, 2014, from http://web.itu.edu.tr/~yamanhak/yayin/p2010b. pdf

Mitchell, D. (2012). 5D BIM: Creating cost certainty and better buildings. In Proceedings of Construction and Building Research Association Conference (COBRA) 2012, Royal Institution of Chartered Surveyors (RICS), Las Vegas, Nevada, USA, 11-13 September 2012.

Monteiro, A. & Martins, J.P. (2013). A survey on modeling guidelines for quantity takeoff-oriented BIM-based design. *Automation in Construction*. *35*, 238-253.

National Building Information Modeling Standard (NBIMS) (2010). *National Building Information Modeling Standard*, USA: National Institute of Building Sciences.

Olatunji, O.A. & Sher, W. (2014). Perspectives on modelling BIM-enabled estimating practices. *Australasian Journal of Construction Economics and Building*, *14* (4), 32-53. http://dx.doi.org/10.5130/ajceb.v14i4.32

Pauwels, P. (2014). Supporting decision-making in the building life-cycle using linked building data. *Buildings*, *3*, 549-579.

Popov, V., Migilinskas, D., Juocevicius, V. & Mikalauskas, S. (2008). Application of building information modelling and construction process simulation ensuring virtual project development concept in 5D environment. In Proceedings, 25th International Symposium on Automation and Robotics in Construction Conference, 2008. Retrieved June 21, 2014, from http://www.iaarc.org/publications/fulltext/7_sec_090_Popov_et_al_Application.pdf

Quek, J. K. (2012). Strategies and frameworks for adopting Building Information Modelling (BIM) for quantity surveyors. *Applied Mechanics and Materials*, *174*, 3404-3419.

Roberts, B. (2012).Team BIM. *RICS Construction Journal*. Feb-Mar 2012, 12-13.

Sabol, L. (2008). *Challenges in cost estimating with building information modeling*. Retrieved May 17, 2014, from http://dcstrategies.net/files/2_sabol_cost_estimating.pdf

Samphaongoen, P. (2010). A visual approach to construction cost estimating, 2010. Retrieved May 30, 2014, from http: //epublications.marquette.edu/theses_open/28

Sattineni, A. & Bradford II, R. H. (2011). Estimating with BIM: A survey of US construction companies. In Proceedings, 28th ISARC, 2011. Retrieved May 30, 2014, from http: //www.iaarc.org/publications /proceedings_of_the_28th_isarc/estimating_with_bim_a_survey_of_us_construction_companies.html

Shen, Z. & Issa, R.R.A. (2010). Quantitative evaluation of the BIM-assisted construction detailed cost estimates. *ITcon*,*15*, 234-257.

Stanley, R. & Thurnell, D. (2013). Current and anticipated future impacts of BIM on cost modelling in Auckland. In Proceedings, 38th Australasian Universities of the Built Environment (AUBEA) International Conference, Auckland, New Zealand, 20-22 November 2013.

Stanley, R. & Thurnell, D. (2014). The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. *Australasian Journal of Construction Economics and Building, 14*(1), 105-117.

Thurairajah, N. & Goucher, D. (2013). Advantages and challenges of using BIM; A cost consultant's perspective. In Proceedings, 49th ASC Annual International Conference, 2013. Retrieved July 16, 2014, from http://ascpro.ascweb.org/chair/paper/CPRT114002013.pdf

Tran, V., Tookey, J. E. & Roberti, J. (2009). Shaving BIM: Establishing a framework for future BIM research in New Zealand. *International Journal of Construction Supply Chain Management. 2*(2), 66-79.

Won, J., Lee, G. & Lee, C. (2009). Comparative analysis of BIM adoption in Korean construction industry and other countries. In Proceedings, ICCEM/ICCPM Conference 2009, Jeju, Korea, pp. 587-592.