5D BIM IN A CONSULTING QUANTITY SURVEYING ENVIRONMENT

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ABSTRACT

BIM is triggering a revolution in the construction industry, and the concept known as 5D BIM, which ultimately is concerned with a cost dimension being added to objects contained within the BIM model, has the potential to be used by consultant quantity surveyors (QSs) to streamline their workflows and increase the quality of the services they provide.
Questionnaires were emailed to participants, and followed up by semi-structured interviews with consultant QSs from one large global practice, experienced with the use of 5D BIM, on their perceptions of the benefits of, and barriers to, 5D BIM implementation. The sample was limited to New Zealand and Australian offices of the practice.
The findings suggest that 5D BIM provides numerous benefits to QSs over traditional methods, mainly through increased efficiency and visualization. Furthermore, other benefits could be achieved such as improved value management services to the client and rapid identification of design changes. However, as currently practised, these perceived benefits were only being achieved to a modest extent, due to a number of barriers limiting 5D BIM implementation. These barriers were mainly associated with incomplete design in the BIM model, lack of standards to facilitate electronic measurement, legal issues, lack of data within BIM model objects required for 5D BIM, and a lack of government support. As a consequence, the use of 5D BIM appears to be limited, and professional quantity surveyors are still heavily reliant on using traditional methods. Despite this, there was a strong indication that 5D BIM implementation will achieve these benefits to a greater extent in the future.
Further research should be carried out to identify the BIM skills which QSs will need in the future to reach the full potential of 5D BIM as described in the literature, and in this research.

KEYWORDS:

Building Information Modelling; 5D BIM; quantity surveying.

INTRODUCTION

Building Information Modelling [or Management] (BIM) provides an innovative, collaborative environment, offering many opportunities to various disciplines within the construction industry, through the utilisation of BIM models throughout the design, construction, and facility management of a building. BIM 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 (NBIMS, 2010). 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 et al., 2011). 5D BIM then, specifically concerns the extraction and modification of such cost-related data, becoming the primary source of information for quantity surveying (QS) services.

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 and barriers of 5D BIM implementation within a single, large multi-national consulting quantity surveying practice in New Zealand. The results are hoped to inform and facilitate the next step in the process, which is to develop solutions for overcoming the barriers, in order to obtain the benefits of 5D BIM within that practice.

5D BIM IN NEW ZEALAND

Use of a single BIM model that contains all design documentation is not apparent within the New Zealand market; instead, projects often utilise up to three different (and separate) models, which can encompass architectural, structural and services design documentation (Boon & Prigg, 2012). A very few large projects have recently used a single integrated BIM model which can be shared with other project participants.
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, 2012). Boon & Prigg (2012) suggested that 5D BIM is rarely being implemented in New Zealand; however, Stanley and Thurnell (2013) suggest that New Zealand's use of 5D BIM technologies is limited but developing. 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 a shift in current workflows is required (Masterspec, 2012).

RESEARCH METHODS

A qualitative survey approach was adopted, with data collected using an emailed closed ended questionnaire with follow up semi-structured interviews used to discuss the main themes that surfaced from the questionnaire responses. Purposive, non-probabilistic sampling ensured that only those people that had some 5D BIM experience were selected, and as 5D BIM is leading edge QS practice, there is a dearth of experts in 5D BIM, and so a sample of five professional quantity surveyors from New Zealand and Australian franchises of the large global consulting quantity surveying practice was obtained. The format allowed participants to elaborate when needed, though also answer questions that were more targeted and closed, by using a semantic rating scale to assess their attitudes towards the benefits of, and barriers to, implementation of 5D BIM in their organization. The interviews were recorded which enabled post-hoc analysis of qualitative responses, in order to reduce bias. Due to the limited sample size, no generalisations can be made across the entire population of consulting quantity surveyors.

FINDINGS

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 experience ranging between 5 and 20 years. One of the participants was a director, 3 were senior quantity surveyors, and one was an intermediate quantity surveyor.

All 5 participants had used 5-D BIM in the past 3 years to generate cost plans and/or schedules (bills) of quantities, on between 1 and 9 projects, in New Zealand, Australia and the USA.

Benefits of 5D BIM

The questionnaire asked participants to indicate their level of agreement with statements derived from the literature that related to the benefits of using 5D BIM in a professional quantity surveying environment. The participants' overall ratings are identified in Table 1 below.

Table 1: Benefits of 5D BIM (n=5)

[NB: 1=Strongly Disagree, 5=Strongly Agree]	**1**	**2**	**3**	**4**	**5**
3-D function improves decision making, reduces inaccurate drawing interpretation and reduces the assumptions the QS needs to make.			2	3	
Enables more efficient early stage preliminary estimates ($/GFA) (by auto-generation of quantities from BIM model objects).	1	1	2		1
Enables more efficient detailed elemental cost plans (by auto-generation of quantities from BIM model objects).			2	2	1
Enables more efficient production of schedules of quantities (by auto-generation of quantities from BIM model objects.)			1	3	1
Automatic quantities generation allows more time to be spent on other QS services for the client (e.g. cost advice on more design alternatives)		1	2	2	
Design changes can be more easily and rapidly identified by overlaying previous BIM models with revised BIM models.			1	2	2
Automatic quantities generation provides less room for human error.		2	1	2	
Improves the accuracy of estimates when there is insufficient time for detailed measures.		1		4	
Improves communication and access to information in the project team.			1	4	
Provides early construction schedule details which more accurately reflect the scope of work involved.			4	1	
Provides a commercial advantage over competitors.				4	1
Increases coordination through integration of specifications and clash detection				4	1

Enhanced visualization

No participants disagreed with the notion 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 felt neutral, believing 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 & Martins (2013) suggest quantity extraction is "a tricky feature and tends to be only used by an expert" (p. 239); similarly, Boon & Prigg (2012) emphasise "the importance of the QS being able to identify items that were not in the model at the time of quantity extraction" (p. 94).

Efficient data extraction for early stage (preliminary) estimating

Somewhat surprisingly, only 1 participant agreed that 5D BIM enables efficient data extraction for early stage preliminary estimates, which is contrary to the findings from the literature (e.g. Matipa et al., 2008; Sabol, 2008, and Thuraiarajah & 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"*.

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

Participants tended to agree 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 (2013) New Zealand study indicated that 5D BIM is currently used to support cost planning at a detailed design stage. Some participants suggested that in order to facilitate the measurement of more building items, it is imperative that the QS works 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.

Efficient data extraction for producing Schedules (Bills) of Quantities

No participants disagreed that the ability of 5D BIM to automatically generate quantities speeds up the process of producing schedules of quantities, 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 contradicts much of the international literature; Quek (2012) reports that 5D BIM did not facilitate this type of measurement due to the many problems associated to the way the design is embedded into the model, suggesting quantities did not conform to standard methods of measurement. Participants, however, suggested that the more industry uses the tool, and resolve the challenges associated with design embedment, producing schedules of quantities will become increasingly efficient.

Rapid identification of design changes

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).

Improved accuracy, communication and access to information in the project team

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"*. No participants disagreed 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 with the company's standard rules of measurement, something that couldn't have been achieved if they worked in isolation. The use of a single model increases communication and improves information accessibility (Thurairajah & Goucher, 2013).

Commercial advantage

Most participants agreed that 5D BIM gives a commercial advantage over competitors, which is supported by Thurairajah & 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 the them*".

Improved coordination and clash detection

All participants agreed 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.

Barriers to Achieving 5D BIM

The questionnaire asked participants to indicate their level of agreement with statements derived from the literature that related to the barriers to using 5D BIM in a professional quantity surveying environment. The participants' overall ratings are identified in Table 2 below.

Table 2 - Barriers to achieving 5D BIM (n=5)

[NB: 1=Strongly Disagree, 5=Strongly Agree]	**1**	**2**	**3**	**4**	**5**
BIM model is not compatible with take off/estimating software tools.		5			
A high level of design detail at the early stages of a project can confuse decision-making.		2	1	2	
Data embedded into the BIM model objects by design consultants is not compatible with elemental estimating formats.			1	4	
Data embedded into the BIM model objects by design consultants is not compatible with schedules of quantities formats.			1	4	
Lack of industry standards/protocols that would facilitate the embedment of design data in BIM model objects that relate to estimating formats.				4	1
Use of BIM for quantity surveying services is too risky as there is no contractual framework governing its use.		2	1	2	
Time taken reviewing/checking extracted quantities means that 5D BIM is not significantly faster than doing manual take offs.		1	1	3	
Lack of direct government intervention to set up BIM standards/protocols reduces the likelihood of a common, agreed upon framework that is required to facilitate the process of 5D BIM (e.g. standardisation of use of IFCs, etc.).				5	
Allowances for wastes, jointing and lapping (for example) are not made as BIM superficially presents auto quantities, reducing the accuracy of estimates.				5	
The high cost and time associated with training staff in 5D BIM is too great for owners/directors.	1	3	1		
There is a cultural resistance to change from traditional QS approaches.		1		4	
Software and hardware upgrades associated with 5D BIM are too expensive for owners/directors.	1	4			

Software interoperability issues

All participants disagreed that BIM models are not compatible with estimating software tools, on the basis that their company's in-house software tool was compatible with various BIM model formats. This differs from 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 et al (2010) 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 beginning to now not use 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"*. This view is echoed by Quek (2012) who 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).

Excessive design detail at early stages can confuse decision making

Participants were equivocal on whether a high level of design detail can confuse decision making, one commenting "*the structure can often be far ahead of the rest*" of the models; when a detailed model is provided at an early stage, it won't be coordinated with the other models (e.g. architectural and services), and also its detailed nature can complicate the thinking of the QS when deciding which design alternative is more economical. For example, instead of having the footprint of the building, the gross floor area, some elevations and maybe a construction methodology that is commonly available at early design stages, the QS would have a detailed structure that identifies steel columns, rafters, and purlins, including their size, their connections, and their finish. This level of detail can cause confusion, as such information is neither required nor necessary at this early project stage. It is important to identify what level of detail is required at each design stage, such as at the concept stage, in order to eliminate unnecessary detail, reduce complexity and confusion, which should in turn facilitate the smooth encapsulation of required data at each design stage (Sabol, 2008).

Incompatibility with QS formats

Participants agreed that the design embedded into the BIM model is not compatible with QS formats for estimating (i.e. elemental format), nor 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"*.

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 agreed that there is a lack of industry standards and protocols to support 5D BIM implementation, which Boon & Prigg (2012) also allude to. A New Zealand BIM Schedule (BRANZ,

2014) and New Zealand BIM Handbook (Building & Construction Productivity Partnership, 2014) have been developed, and are currently out for industry consultation, 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.

Legal and liability issues

Opinion was divided on the use of BIM for quantity surveying being too risky due to a lack of a contractual framework governing its use. Foster (2008) believes that the lack of contractual framework to support this collaborative procurement method significantly hinders BIMs use, due to the current legal system supporting stakeholders in isolation, and that reform needs to occur in order to recognise shared responsibility for the BIM model. However, one participant felt that the QS's role and responsibilities are no different to the traditional approach: "*as per manual take off, the quantity surveyor has the role and duty to clarify what the correct information is if there are coordination or clash issues, however if the designer has got it wrong in the BIM model, it's still up to them to make sure that information is correct"*. Some participants also mentioned the confusion as to whether or not the BIM model is a contract document, and believed that current contract documentation needs to be revised to help resolve this complication, particularly as sub-contractors are now beginning to price directly from BIM models.

Necessity of manually reviewing/checking extracted quantities

Participants tended to agree 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 (2013) 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 agreed that there was a lack of government intervention to set up the required protocols to facilitate 5-D BIM (e.g. standardization 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. However, since this survey was carried out (in mid-2013), as already mentioned, the drafts of the New Zealand BIM Schedule and the New Zealand BIM Handbook are currently out with industry for comment, 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 agreed 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

No participants agreed that cost and time implications associated with training staff in 5D BIM are 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 localized QS consultancies may find that training costs for 5D BIM are a significant challenge to overcome.

Cultural Resistance

Most participants agreed that there is a cultural resistance to change to 5D BIM from traditional quantity surveying techniques. This is also mentioned by Stanley and Thurnell (2014), who contend that the industry's adversarial culture poses another barrier to successful BIM adoption and use for 5D BIM by QSs, and that cultural transformation is a much greater challenge than any technological challenge arising from BIM.

Prohibitive software/hardware upgrade costs

All participants disagreed that software and hardware upgrades associated with 5D BIM were too expensive for directors; it was felt that a large global practice should have the resources available to upgrade software/hardware necessitated by the switch to 5D BIM; however, smaller QS practices may not. Appleby (2012) contends that companies must have the capacity to run varied formats and large volumes of intelligent BIM data, and smaller companies may have difficulty achieving this. All participants indicated the company's hardware systems had no problem running BIM files however for larger projects, due to the large files, its use was slow.

Interview open ended responses

Participants were asked elaborate on the reasons behind the semantic scale ratings they gave to the benefits of, and barriers to, 5D implementation in their large, global consulting QS practice. The main themes identified were:

-BIM models are insufficiently detailed to use for preliminary estimating, but can be used as a bulk-checking tool.
-BIM models are best used for estimating from a developed (approximately 80%) design stage, due to incompleteness at early design stages.
-Bulk checking of extracted quantities is imperative at all stages of design.
-2D drawings are needed for details, contractors and subcontractors, and may always be required.
-The absence of standards/protocols is a major hindrance to implementation of 5D BIM.
-Significant confusion exists around the term 5D BIM, and the difference between 3D and BIM.
-BIM models contain numerous errors and are often incomplete.

-Early QS involvement is extremely important, particularly without the use of BIM standards or protocols.
-An increase in accuracy for estimates and schedules of quantities by using 5D BIM is anticipated in the future.
-The lack of government intervention to drive BIM is a major limitation
-5D BIM increases costs to clients, which is unattractive, and thus is a significant barrier to its use.

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.

CONCLUSION

This research has identified the perceived benefits of, and barriers to, 5D BIM implementation within a large, multi-national consulting QS practice. In addition, it has established that usage of 5D BIM is increasing, and its adoption has the potential to impact the QS profession in every area, and that 5D BIM is anticipated to be where the future direction of quantity surveying lies.

The main perceived benefits of 5D BIM were found to be: increased visualization of the building; a bulk checking device for manual measurement; efficient data extraction for estimating at developed design stages, as well as for producing schedules of quantities; 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: 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 correctness of extracted quantities; a lack of government intervention to support BIM, and additional costs to the client.

The benefits of 5D BIM implementation for quantity surveyors and their clients have been established; however, its use in New Zealand remains modest, due to the numerous barriers to its successful adoption. 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 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 had doubts for the feasibility of Level 3 full collaborative BIM, that contains integrated cost data within a single integrated BIM model, 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 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 drafts of the NZ BIM Handbook (Building & Construction Productivity Partnership, 2014) and NZ BIM Schedule (BRANZ, 2014) out for industry consultation.

Due to the small sample surveyed, the findings of this research are not generalizable to the wider population of consulting quantity surveyors in New Zealand, and aimed 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 could identify the BIM skills which QSs will need in the future to reach the full potential of 5D BIM, and also 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.

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