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Building Information Modelling Feasibility Study for Building Surveying

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Abstract: Despite the advancements in digital technologies, the current building design examination practice is 2D and paper-based, and a large number of 2D plans and drawings need to be collated and interpreted to examine if the proposed designs comply with building regulations. Subsequently, it is prone to human errors that make sustainable and consistent design difficult. Although Building Information Modelling (BIM) is recognised as a means to transform the current practice into a more sustainable and productive practice, BIM has rarely been adopted in building design examination. This research aims to identify the reasons for the low uptake of BIM and to examine the feasibility of BIM for building design examination through a focus group interview and workshop. A lack of proper BIM training is identified as the most critical barrier to adopting BIM. Building design examiners indicate that BIM adoption requires consistent efforts with empirical errors, since the existing work processes are not flexible enough to embrace BIM instantly without proper BIM training. An average of three days can be saved by using BIM for a building regulations check. This research revealed that BIM is feasible for building regulation checking, and the low uptake is mainly caused by a lack of awareness of the BIM capabilities.

Keywords: BIM; building design check; building regulation; building code check; technology adoption

1. Introduction

Currently, building design examiners, also known as building surveyors, manually assess building designs based on 2D paper-based drawings to provide a building permit. Once a building permit is issued, it allows a building contractor to commence construction, and confirms that the design complies with the building regulations (i.e., building code). A building surveyor is responsible for assessing the building's design against building regulations, and inspects the construction project process during the project life cycle. The building design examiner also undertakes a final inspection to ensure that the property is safe for occupation, issuing an occupation certificate [1].

Notably, there are some issues with using traditional paper-based drawings, such as the ability to enhance visualization when drawings are presented in 2D [2], and the use of paper-based building designs can also be inefficient due to the possibility of human errors [3]. Furthermore, as a result of continuous updates of the regulations, the results of building examination can be open-ended depending on the surveyor's up-to-date knowledge, professional perspective, and experience, leading to schedule delays and budget overruns in a project [4].

In response to the current issues, researchers have recognised the potential of a digitalised automated building regulation checking tool, such as Building Information Modelling (BIM), for automated building regulation checking [5–9]. BIM is defined as an information management system to integrate and manage construction information throughout the entire construction project life cycle, and is based on a 3D parametric design to facilitate effective communication among project stakeholders, achieving the project goal(s) in a collaborative manner [10]. BIM is currently regarded as a major paradigm shift in the construction industry, as it is a catalyst for process changes as well as a cultural change that requires a greater integrated approach than ever [11]. Consequently, researchers increasingly study ways of utilizing BIM to improve productivity in the construction industry. The governments of the US, UK, Singapore, and South Korea have all mandated the use of BIM for public construction projects. For example, the US General Services Administration has established and encouraged the National 3D-4D-BIM Program policy since 2003, which mandated the use of BIM for all public building service projects. The UK government has also mandated the use of BIM for every construction project funded by the government since April 2016 based on the "government push and industry pull strategy" [12–16]. As of 2015, the BIM adoption status is indicated to be approximately 60% in North America, Europe, and Oceania [17].

Among the US, UK, Singapore, and South Korea, where mandating the use of BIM for construction projects is in practice, more than 70% of design and construction companies have adopted and are using BIM for their construction projects. A 3D building model that detects clashes, develops construction schedules, and plans construction site operations has proven to be beneficial to their daily operations [17–19]. It has been suggested that the power of BIM needs to be released not only in the design and construction phases, but also within the life cycle of facility management [20]. Moreover, building design examination—also known as building surveying—using as-built BIM models has gradually emerged as an important topic in the construction sector [21]. Despite some empirical evidence on its advantages, the adoption of BIM for the building surveying field has been limited, and building surveyors are not enthusiastic to adopt BIM in their practices [22–24]. Thus, this research aims to identify the main reasons for the low uptake of BIM and to examine the feasibility of BIM adoption for building surveying practices.

2. Implications of BIM in Building Design Examination Practice

Choi and Kim [6] forecasted that the continuous development of BIM software can realise a digitally automated building regulation check, and Ismail et al. [7] recently confirmed that a BIM system could be a possible solution for the current issues in building surveying practice, as well as an opportunity to improve the productivity of the building surveying field due to the characteristics of BIM: (a) 3D Parametric Design; (b) 3D BIM Object-Based System; (c) Single-Source Data Management Platform. Since BIM designs a building in a 3D manner with BIM objects containing the geometric and technical information of materials or building elements, building surveyors can appreciate the design of the building intuitively and identify design issues efficiently, regardless of years of individual experience, by envisaging a 3D building without the time-consuming integration processes of 2D drawings to visualise a building in 3D. In particular, the 3D BIM object-based building design can minimise the current discrepancy issues of building regulation assessment, as the assessment results can be different depending on building surveyors' experience [25]. The more experience a building surveyor has, the more relevant and valuable design advice can be given.

As BIM is a single-source data repository system, it can effectively and efficiently retain all of the essential design and construction data, such as drawings and material specifications, within a single electronic file. Hence, this characteristic of BIM can serve as a repository system to contain all of the essential data for building surveyors to utilise for building regulation assessment. More importantly, all of the data are contained within a single file; building surveyors do not need to waste time searching for necessary documents for the assessment or tagging and marking drawings manually to provide feedback to design professionals and clients, as shown in the Figure 1 [5].

A digitalised and automated building regulation check would be beneficial not only for building surveyors, but also for design and construction professionals [9]. Within a BIM system, all of the design changes and updates will remain and be retained within a single data file. This capability will improve the productivity of assessing re-submitted designs and documentation, as well as the effectiveness and efficiency of physical 2D paper-based drawings and report storage practices, i.e., a specific room or a dedicated storage facility is no longer necessary. This will reduce operational costs for the building surveying profession [26]. Researchers have identified that BIM has become an essential part of design and construction and that it will serve as an information platform to maintain digital assets for the operation and maintenance of physical built assets [9,27].

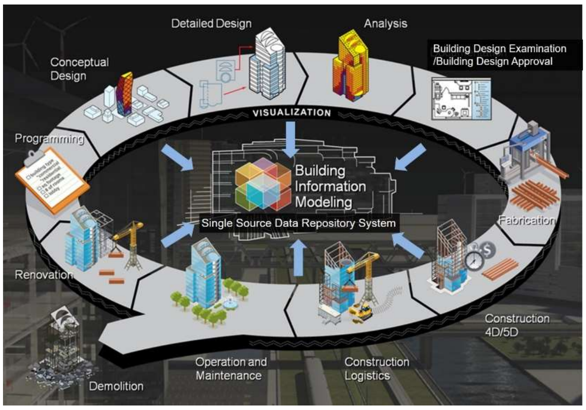

Figure 1. Building Information Modelling (BIM) life cycle workflow diagram (modified from Autodesk).

Additionally, the n-dimensional (nD) capabilities of BIM, such as 3D clash detection, 4D construction schedule visualisation, and 5D automated measurement of building components, all enable design, coordination, and construction project verification before the commencement of construction. This will allow building surveyors to utilise the 3D and 4D capabilities of BIM to provide design advice and recommendations. Building design professionals and other construction professionals can collaborate from the outset of a project based on one single source of data, empowering all of the key participants to improve the quality of the deliverables, including drawings, reports, and other documents, based on a collaborative workflow [25,26]. According to a case study of the Reid Steel company [28], the company saved 7000 GBP by adopting BIM and a digitalised building code checking system known as Eurocode, instead of hiring private certified building surveyors to identify design issues and amend the drawings and documentation before submitting them to an authority to obtain a building permit. Based on this case study, it is evident that using BIM can provide a means for the building surveying sector to improve their productivity, and can allow easier, effective, and efficient collaboration between building surveyors, design professionals, and construction professionals on design issues and design changes. BIM is not a simple 3D modelling tool, but a collaborative and intelligent methodology to deliver a building to a client based on the integration of diverse information over a project life cycle. BIM model and information updates are simultaneous with project information. However, the current BIM adoption and utilization has been limited in design and construction [19], and few attempts have been made to adopt BIM for the building surveying sector despite the recognised benefits and connections of BIM and the building surveying profession.

3. Global Status of BIM for Building Code Checking

There has been a global effort to integrate BIM with the building surveying sector by developing automated building code checking tools in Australia, Finland, Singapore, South Korea, the UK, and the US [28–32].

The Ministry of National Development in Singapore initiated and developed the building code checking system known as "COnstruction and Real Estate NETwork (CORENET) e-Plan check" to confirm if digital building models comply with the building codes, including building control, accessibility, and fire safety, under Singapore's E-Government strategy [12]. While the e-Plan check is well known as the world's first automated plan checking system, there has been an effort to develop specific software for building code checking known as Solibri Model Checker (SMC), and it is capable of checking accessibility, egress, fire safety, and building component detailing.

Currently, the SMC is regarded as the stand-alone advanced building code checking tool in the Architecture, Engineering, and Construction (AEC) industry, and is capable of dealing with hundreds of rules related to building codes to assess designs and identify design issues. The successful implementation of the e-Plan check by building and construction authorities in Singapore inspired other countries, including Malaysia, Brunei, and Norway [10]. Although the recent development shed light on the possibility of BIM utilization in the building surveying sector, the development of software has mainly been led by software developers or software coding specialists that rely on the building codes themselves, without proper integration of building surveyors' experience with the building codes. Nisbet et al. [33] criticized the adoption of building code checking software or the development process for building code checking software, since the most relevant professionals, who are building surveyors, have been excluded in the process. In order to overcome these shortcomings, the pre-fixed code checking software has been enhanced to facilitate open code customisation environment for professionals, and there have been various attempts to integrate a universal language for BIM datasets, such as the Industry Foundation Class (IFC), and national building code standards, such as with the current software [29,34].

Based on the IFC language and Australian Building Code for accessibility, the EXPRESS Data Manager for building code compliance was developed by adopting the use of intelligent data management for building codes [35]. The software can be considered as a major improvement in interoperability, but it is still a stand-alone software, and intended only for end-user or company-specific building code checking tools. Based on the current development, the Australian government funded a project to further develop a logic database platform for digital legislation, and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Data61 collaborated and constructed a digital legislation database platform in 2018 [36]. Digitalised construction laws and building regulations are available in a machine-readable format, enabling any third party to develop their own compliance application. This digitalised platform is expected to save time and costs for those who prepare an application for development and building permits, since they can prepare and submit an application form regardless of their knowledge and experience on building codes and regulations.

Similar projects have been conducted in Korea to assess the building regulation compliance of the Request for Proposal [31], and this effort has continued to establish a standardized digitalised language named KBimCode that assesses the building codes for building permits [30]. Although the efforts establish technical and experiential background information for the automated building code checking system, the research outcomes were not free from criticism of the programming language used for these tools. The language can only be understood and updated by a software developer or an expert in that field. As a result, a web-based Korean Building and Construction Regulation E-System was developed by the Korean Institute of Civil Engineering and Building Technology, and it has been operated as a pilot system from 2014 to the present, providing easier access to building regulations and accurate advice on planning and construction of buildings [37].

In 2014, the International Code Council (ICC), which is a US-based professional body established for building safety and fire prevention, developed SMART codes for residential and commercial building construction in the US. The SMART code has a unique two-stage process, where people can get expert knowledge on the building regulations written in English in conjunction with semantic mark-ups, as well as a digitalised text-based language that contains building regulations that semi-automatically assess the building [38,39]. Currently, the ICC has further developed the SMARTcode and established a cloud-based system named cpdACCESS for building code assessment [40].

Zhang and El-Gohary [41] proposed an automated regulatory compliance checking process based on Natural Language Processing, which is a subfield of artificial intelligence. This proposed method is capable of processing full sentences in regulatory documents and validating the regulatory compliance of construction documents. However, the method is limited in interpreting and validating uncommon expressions, and is prone to creating errors due to morphological analysis. In response to this limitation, Nawari [42] proposed a generalised adaptive framework (GAF) based on the IFC for building design review within a BIM system. A researcher applied the GAF to a two-story building to examine building regulations. Consequently, the GAF has been proven to reduce the time for building regulation examination and to support a neutral data standard, such as the IFC. Furthermore, the proposed framework is a design review process based on an object-based representation of building regulation, which is an essential characteristic of BIM and makes the framework expandable to other domains. Indeed, Messaoudi and Nawari [43] proposed a virtual permitting framework (VPF) for post-disaster recovery based on the GAF. Through the implementation of the VPF, researchers demonstrated that the framework can reduce time by about 18 h and save cost by about 10,032.75 USD per permit.

In 2002, the UK government initiated a website development project where people can submit a planning application through a website electronically, known as the Planning Portal. The website has been updated by adding building regulatory information content, interactive guides, and a web-based service for building regulation approval [44]. The Planning Portal serves as a bridge between people who submit planning applications, including architects, builders, and clients, and the local planning authority who will assess and approve the application. Based on the current development, the UK government further enhanced the Planning Portal and renamed it the PortalPlanQuest.

Housing and Planning Minister Brandon Lewis said: "With nearly 90% of planning applications being submitted through the Planning Portal, it was vital to secure investment to allow the Portal to reach its full potential and continue to play a vital role in the planning system for years to come. I know that PortalPlanQuest will be looking to take an innovative approach, building an up-to-date website, and developing new products alongside the core planning application service. I'm looking forward to seeing where they take the Portal in the future." It is evident that the UK is trying to digitalise the construction industry in conjunction with the Digital Britain strategy [45]. Aligning with the current movement in digitalised building code assessment, the EU also developed the Eurocodes Plus in collaboration with the British Standards Institution [46]. Eurocodes Plus is a user-friendly and efficient software system that makes it easier to design and navigate through Eurocodes, as well as British standards. This software focuses on integrated datasets that can provide all of the referenced documents for a user, enabling professionals to seamlessly manage the design and any problems that arise from the outset of a project. The key findings and issues of the current research and studies in the building code checking system are summarised in Table 1.

Table 1. Key findings and issues of global efforts for BIM integration into building code checks.

Country/Researcher	Study/Research/Tool	Remarks for Findings and Issues
Australia	EXPRESS Data Manager	Description: Stand-alone software capable of reading various standard data formats, such as Industry Foundation Class (IFC) and Programming Language for Microcomputers (PLM).
		Strength: Improved interoperability with other data formats.
		Issue: Not flexible enough to be adopted for general use.
	Digitalised Construction Laws and Building Regulations	Description: Data platform based on a machine-readable format setting.
		Strength: Capability to enable any third party to develop their own compliance application.
		Issue: Under development, and not tested on an actual project.
European Union	EUROCODE Plus	Description: Web-based software and data platform for building code references.
		Strength: User-friendly system enabling end-users to identify various references for building codes.
		Issue: Text-based and not capable of supporting visual design examination.

Table 1. *Cont.*

Country/Researcher	Study/Research/Tool	Remarks for Findings and Issues
Finland	Solibri Model Checker	Description: BIM-based building design examination software enabling end-users to set up customised code checking rules.
		Strength: Building designs can be digitally stored in the IFC data format, enhancing interoperability.
		Issue: Limited flexibility to set up customised building code checking rules, since building design examination rules can only be tailored within the given datasets.
Singapore	COnstruction and Real Estate NETwork (CORENET) e-Plan check	Description: World's First Automated Plan Checking System
		Strength: Building plans can be digitally examined.
		Issue: The process and results of code checking are not transparent.
South Korea	KBimCode	Description: BIM-based building code checking system.
		Strength: Building code datasets can be maintained and updated regularly with consistency.
		Issue: Programming language used for the system can only be modified by a software developer. Flexibility to customise building codes is absent.
	Web-based Korean Building and Construction Regulation E-System	Description: Web-based building and construction regulation reference checking data platform.
		Strength: All regulations can be provided via web-based platform.
		Issue: Not BIM-based system, and only references can be identified. Actual building code checking is not possible.
United States	cpdACCESS (further developed from SMART code)	Description: Cloud-based system providing expert knowledge on the building regulations for residential and commercial buildings.
		Strength: Effective information accessibility regarding building regulations.
		Issue: Not a BIM-based system, and text-based references can be identified.
United Kingdom	PortalPlanQuest (further developed from Planning Portal)	Description: Web-based system for submitting a planning application.
		Strength: User-friendly interface providing advice and knowledge regarding building regulations.
		Issue: Not a BIM-based system, and building regulations cannot be assessed automatically.
Zhang and El-Gohary [41]	Automated Regulatory Compliance Checking Process	Strength: Capability to process full sentences in regulatory documents and validate the regulatory compliance of construction documents.
		Limitation: Limited in interpreting and validating uncommon expressions.
Nawari [42]	Generalized Adaptive Framework (GAF)	Strength: IFC-based building design review framework within a BIM system. The GAF is expandable to other domains.
		Issue: Technical knowledge and skills for managing the IFC data format are pre-requited to fully utilise the GAF.
Messaoudi and Nawari [43]	Virtual Permitting Framework (VPF) for Post-Disaster Recovery	Strength: Specialised in a post-disaster recovery project based on VPF that is further developed from the GAF.
		Issue: Technical knowledge and skills for managing the IFC data format are pre-requited.

There have been major developments in the automated building code checking system around the world, and yet, there has been limited uptake of the automated tools for building code checking. The main reasons for this low uptake have not been clearly identified and understood, except for a lack of integration of expert knowledge and insight rendered from professional experience and lessons learned. Hence, this research aims to identify the main reasons for the low uptake of BIM in building surveying sector and to examine the feasibility of BIM adoption for building surveying practices.

4. Research Method

The aim of this study is to identify the main reasons for the low uptake of BIM in the building surveying sector and to examine the feasibility of BIM adoption in Australia. As the qualitative approach is suitable for exploring participants' experience in real-world settings [47], this research was conducted in a qualitative manner, including two sequential steps. Step 1 involved focus group interviews, and Step 2 was a BIM-enabled workshop using a real-life commercial construction project as a demonstration project. The latter aimed at validating the findings in the first step. Such a sequential research design, according to Morse [48], creates studies at different levels of analysis, and it has been used increasingly in BIM-related works [43,49].

The population of this study are practitioners in the Australian construction industry, including 60 professionals. They were identified via internationally recognised professional organisations, such as the Chartered Institute of Building (CIOB), Royal Institution of Chartered Surveyors (RICS), Australian Institute of Building Surveyors (AIBS), and Australian Institute of Building (AIB). Local government authorities and council officers, as well as national construction companies of Tiers 1 and 2, were also included. Thus, it is evident that the interviewees had adequate global and national perspectives and experience for this study. There were 20 interviewees in Step 1, and six other participants in Step 2; they were selected according to purpose sampling, as this technique helps researchers to gain insights in the field via participants' perception and experience [50]. The focus group and workshop were organised in Adelaide, South Australia. Both meetings were video-recorded and transcribed for further analyses. The transcripts in Step 1 were analysed by using the thematic coding technique of Braun and Clarke [51]. In particular, the authors read all transcripts thoroughly, getting familiar with the data. After that, codes were developed from phrases, sentences, or paragraphs; the codes sharing some similarities were then grouped into a theme. Given the purpose of validating findings, the provisional coding approach was used in Step 2 [52,53], in which the data were analysed by using the themes identified in the previous step.

The interviews were conducted as a form of group discussion by providing and explaining questions and facilitating group discussion among the professionals to identify the answers. The interviewees were recruited based on groups of strangers, as this type of group composition ensures greater anonymity and detail about participants' opinions and experiences in the discussion [54]. The focus group methodology assists researchers in exploring and investigating people's perceptions, in exploring how, why, and what they perceive about the issues of significance to them, and in uncovering aspects of understanding that are normally ignored in traditional interviews [55]. The interview protocol was developed based on the guidelines of Krueger [56], consisting of four main sections: Opening, introduction, key questioning, and ending. The research questions were mainly developed based on the findings in the current literature summarised in Table 1. For the purpose of data collection, such questions were divided into several sub-questions. In Step 1, the following key questions were asked to design and construction professionals to understand the current perceptions and challenges of BIM adoption, as well as the feasibility of BIM utilization in the building surveying sector:

1. What is the current status of BIM adoption in the building surveying sector?
2. What are the barriers to adopting BIM in the building surveying sector?
3. Is BIM feasible to be utilised for the building surveying sector?

In Step 2, a workshop using a real-life commercial construction project, which is a two-story office building with 809.2 m^2 (width: 23.8 m × length: 34 m × height: 8.2 m), was conducted to demonstrate the potential capability of a BIM tool for building surveying practice by addressing possible solutions to the identified current challenges and barriers from Step 1 via a BIM system. A validation workshop provides an adequate safeguard against interpretation bias, ensuring that the findings are valid and recognisable by members of the targeted population [57]. Subsequently, researchers can identify how design and construction professionals would embrace the possibilities of BIM for their practices after experiencing BIM's capability, and can recognise any insights about further improvement of BIM usage for building surveying practice based on actual practitioners' perspectives. The procedure for organising questions and answers of this workshop was the same as the format of the previous step. It should be noted that the first researcher was the moderator for both group discussions. For the BIM demonstration, Autodesk Navisworks was used, as this BIM tool is currently dominant in the construction industry, and its user interface is intuitive and easy to understand [19].

5. Research Findings and Discussions

5.1. Step 1: Focus Group Interview Results and Discussions

A total of 60 professionals were invited for the focus group interviews, and the response rate was 35% (21 out of 60). This is due to a lack of experience in using BIM for building regulation checking and a lack of interest and demand from clients. From the beginning of the research, researchers were able to grasp the reason for the current low uptake of BIM in the building surveying sector. The average amount of experience of participants in their fields was 12 years, and 60% (12 participants) had more than 10 years of experience. The respondents' profile is shown in Table 2. The balance between the private sector and the public sector was 12 participants and 9 participants (57% vs. 43%), and it can be considered that the focus group interview outcomes reflect both perspectives regarding BIM adoption in the building surveying sector.

Table 2. Participants' profile.

Number of Interviewee	Profession	Sector	Years of Experience
Interviewee 1	Building Surveyor	Private Practice	16
Interviewee 2	Building Surveyor	Private Practice	14
Interviewee 3	Building Surveyor	Private Practice	14
Interviewee 4	Building Surveyor	Private Practice	12
Interviewee 5	Building Surveyor	Private Practice	11
Interviewee 6	Architect	Private Practice	17
Interviewee 7	Architect	Private Practice	14
Interviewee 8	Architect	Architectural Company	9
Interviewee 9	Architect	Architectural Company	9
Interviewee 10	Contractor	Tier 1 Master Builder	12
Interviewee 11	Contractor	Tier 2 Master Builder	9
Interviewee 12	Contractor	Tier 2 Master Builder	9
Interviewee 13	Building Surveyor	City Council	15
Interviewee 14	Building Surveyor	City Council	13
Interviewee 15	Building Surveyor	City Council	13
Interviewee 16	Building Surveyor	State Government	11
Interviewee 17	Architect/Planning	State Government	9
Interviewee 18	Architect/Planning	State Government	9
Interviewee 19	Architect/Planning	City Council	8
Interviewee 20	Architect/Planning	City Council	8
Interviewee 21	Asset Manager	State Government	9

Note: Private sector—Interviewees 1 to 12; Public sector—Interviewees 13 to 21.

5.1.1. Current Status of BIM Adoption

All participants were aware of BIM, but only seven of the participants, including four architects, two building surveyors, and one contractor in the private sector, were currently using BIM. A total of 13 participants (65%) were not currently using BIM, and among the 13 participants, the government employees (eight participants, 35%) were not using BIM at all, as shown in Figure 2.

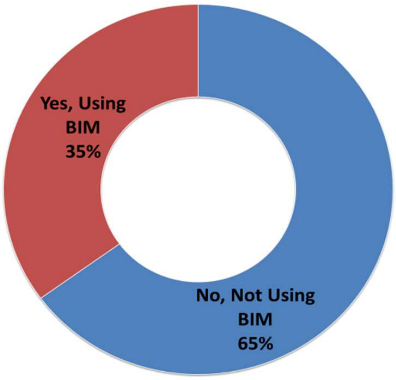

Figure 2. Current status of BIM adoption.

The government employees commented that they were aware of the transformation in the construction industry due to technological advancements. However, as the Australian government does not mandate the use of BIM, there is no official guideline for them to use BIM. One government employee also added a comment that the adoption of BIM is one hurdle to overcome, but there will be more due to the learning curve of BIM. This participant presented a concern about the levels of competency in BIM use between the private and the public sectors.

Australia is slow in the BIM mandate compared to other countries, such as the US, UK, Singapore, and South Korea. Recently, the Queensland government announced that BIM use for infrastructure projects will be mandated from 2023 [58]. All participants agreed that the BIM mandate will expedite the use of BIM in the public sector, and the current unbalanced BIM adoption status between the two sectors will be abated.

5.1.2. Current Status of BIM Training

A total of 13 participants indicated that they had received BIM training including a fundamental and advanced training, as shown in Figure 3. Interestingly, 12 out of 13 respondents were in the private sector, which means that all professionals from the private sector had received BIM training, while only one out of the eight public sector professionals had received training.

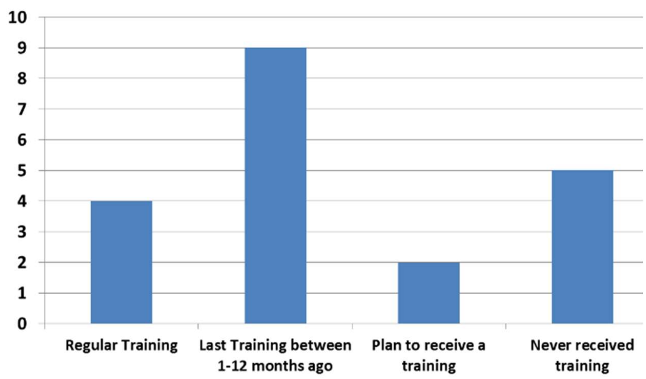

Figure 3. Current status of BIM training (y-axis: Number of respondents).

This status echoes with the concern addressed by one government employee about the difference of the BIM competency level between the two sectors. Only two respondents indicated that they would participate in BIM training organised by their organisations.

The government employees addressed that people who plan to organise BIM training are not clear how BIM will be beneficial to their jobs, and this makes the person reluctant to organise BIM training. These comments are matched with the responses of "never received training", and all five respondents emphasised that this is not because they are not interested in BIM, but because of a lack of demand and a lack of interest in the senior management for BIM training and adoption. Five respondents indicated that they have expressed their interests in BIM training, but there was no training organised or provided to date.

One participant commented that BIM training is one part of the current low uptake of BIM in the building surveying sector, and asserted that the maturity level in an organisation is also critical to adopting BIM, since BIM is a platform where collaborative efforts are required from all key project participants. If the maturity and interest are not high enough to connect all key participants through a BIM system, the fragmented nature of the construction industry will undermine the efforts to adopt BIM. Thus, proper BIM training on a regular basis is instrumental in increasing the uptake of BIM in the building surveying sector.

5.1.3. Feasibility of BIM Adoption in Building Surveying Practice

All participants were asked to indicate the feasibility of BIM adoption in the building surveying sector in terms of timing, such as "Too Early" or "Too Late".

As a result, 52% (11 respondents) indicated that it is the right time to adopt BIM, as shown in Figure 4. Eleven of the respondents have received BIM training previously, and seven out of 11 respondents are in the private sector. Respondents added their observation that the more they learn, the more they see the benefits of BIM, and this is the main reason for why they believe it is the right time to adopt BIM. This is also echoed with the previous interview result that training is crucial to educating people and increasing their awareness and maturity related to BIM adoption and utilization. One respondent with 14 years of experience in design strongly emphasized that a movement to drive BIM adoption should take place, rather than individuals trying to advocate for BIM. A respondent indicated that the government mandate in Queensland will serve as a movement to increase the uptake of BIM.

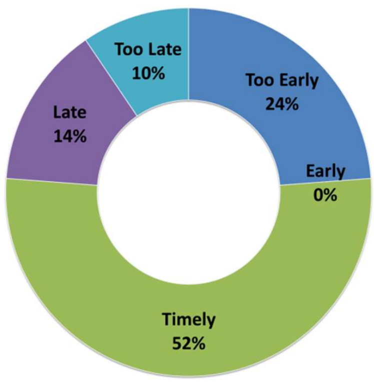

Figure 4. Feasibility of BIM adoption in building surveying practice.

The rest of the respondents (10 respondents) were divided into two groups. One group is "Too Early", and the other group is either "Too Late" or "Late". The interesting point is that no one indicated that BIM adoption is "Early", and five respondents rather indicated "Too Early". The five respondents are all in the public sector, and have never received BIM training. They commonly mentioned a lack of sense of urgency for BIM adoption in the building surveying sector. In particular, they commonly addressed the mindset related to new technology adoption in the building surveying sector. Since they have the authority to approve the submitted design and provide a building permit to a design professional or a client, they are not in the position to worry about project schedule delays, cost overruns, and change orders during the construction stage. As they have relatively less stress on these project management attributes, they did not see the benefits of BIM in terms of effective design changes and updates, as well as the efficient communication and collaboration on design issues relevant to them. Furthermore, the respondents are still sceptical about the actual benefits of BIM related to the building surveying practice. One respondent, who had received regular BIM training, addressed that BIM's potentials would only be realised when all key participants across the value chain of a construction project actively utilised BIM in a coordinated manner. In relation to this comment, another respondent pointed out unbalanced BIM use between large companies and small–medium enterprises (SMEs). He commented that a large number of architects, BIM consultants, and contractors are using BIM, but these are mainly limited to large design and engineering companies or large contractors. The major challenge of BIM adoption will be raised by the SMEs. Thus, it is instrumental for the government to lead the construction industry as well as clients, like in the UK's 'Push and Pull' strategy in the PAS 1192-2 [59].

The five respondents who indicated "Too Late" or "Late" addressed the differences in BIM competency between the two sectors. They mainly argued that the current AEC industry is quickly moving toward digital-technology-oriented practice, while the public sector is slow and just commenced e-planning for building surveying purposes, where design professionals can submit the required documents for a building permit in the PDF format, not a BIM model or equivalent digital representation. They were mainly concerned about the possibility that they might be left behind in an era of digital transformation. One of the five respondents was currently involved in the Adelaide Smart City project, and he has seen many benefits and capabilities of smart technologies, including BIM. So, he has a more pessimistic viewpoint compared to the others, but he also made a valuable comment that society is comprised of individual components, but it exists as a whole. Thus, the current digital technology cannot be avoided, and the building surveying sector should have adopted or explored BIM capability a long time ago. He finalised his comments, saying that BIM education and training are the only way to bring the building surveying sector up to speed.

5.1.4. Current Barriers of BIM Adoption in Building Surveying Practice

All participants were asked to indicate the current barriers to adopting BIM in the building surveying sector. The most significant identified barrier was a lack of client demand, as shown in Figure 5, and this cannot provide any motivations or reasons to adopt BIM actively and invest time and costs in BIM training. This finding is similar with the comment identified in the previous section explaining that the public sector is not in a hurry to adopt BIM, and they do not feel the sense of urgency, since they are in the position with the authority to approve the designs or recommend design amendments to design professionals and their clients.

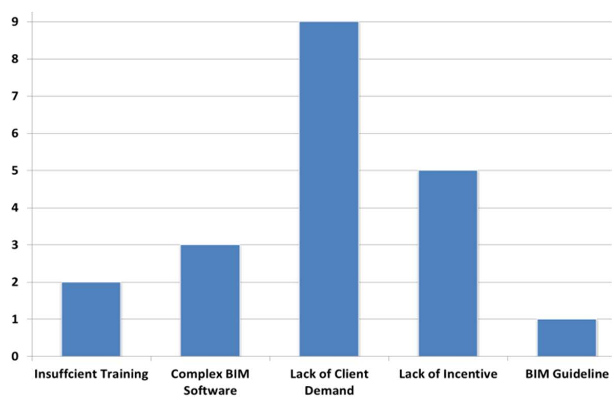

Figure 5. Barriers to BIM adoption in the building surveying sector (y-axis: Number of respondents).

Furthermore, five respondents from the private and public sectors commonly addressed that there is a lack of government drive behind BIM adoption. Apart from the individual responses, all 20 participants agreed that the government needs to facilitate digital transformation by providing an incentive to building surveyors who actively adopt and utilise BIM for their practices. Otherwise, BIM adoption will require a large amount of effort to learn how to embed BIM into building surveying processes, and there will be a learning curve, as building surveyors in both sectors will learn from their empirical errors. Thus, proper reinforcement or financial incentive schemes should foster the BIM adoption in the building surveying sector. Interestingly, five respondents indicated that the current BIM software is complicated to learn, and the software itself is not intuitive. Three respondents addressed that they had a series of BIM training sessions to teach them how to use the software, but it confused them, as the training did not teach workflow in a BIM environment. Consequently, respondents indicated that BIM software is not user-friendly, and is specially developed for design professionals. In addition, they emphasised the importance of proper BIM training, which should not be simple software training, but a BIM-workflow-based software training. Two building surveyors with 14 years of experience emphasised that there is no one-size-fits-all solution for every building, since building codes are detailed and complex, and will be applied differently from one another. All architects agreed with the comments, and they addressed that each building, particularly large commercial and high-rise buildings, is required to be assessed on its own merits, and although the classification of the building may be the same, there will be other variables requiring consideration for each building. Consequently, they pointed out that BIM can be utilised for building code checking, but BIM use could end up as an extremely time-consuming exercise if BIM datasets are not fully equipped with all of the relevant clauses of the building codes for each and every situation.

Indeed, the current construction industry is leaning towards digitalised Architecture, Engineering, and Construction (AEC) practice due to BIM's capabilities—named 'nBIM capability'—as project facilitators motivate the construction industry to adopt BIM in various construction projects over life cycles effectively and efficiently. nBIM capability can be explained as 3D BIM for visualization of design intent, 4D BIM for project scheduling based on 3D visualization, 5D BIM for project cost management, and 6D BIM for facility management during the maintenance and operation phase of a building. Thus, it is evident that the construction industry needs to adopt BIM for improving productivity and gaining a competitive advantage over others in the market, and it is essential to retain skilled and experienced BIM personnel to manage a BIM-enabled construction project. Consequently, BIM-ready graduates have become highly desirable, as the construction industry wants to minimise the expenses for basic BIM training. BIM competence is currently expected for those who want to work in the construction industry [60], for various researchers and projects, and to enhance the construction industry [61].

5.1.5. Impact of BIM on the Role of Building Surveyor

All participants were asked to indicate how they think about the impact of BIM adoption in the building surveying sector. Thirteen respondents indicated that many changes will be made due to changes in work processes and improved productivity of building surveying practices, as shown in Figure 6.

Ten out of 13 respondents have a sense that the use of BIM might provide effectiveness and efficiency to building surveyors, but it can also make the current building surveying job market worse, as BIM will replace many job opportunities for junior or early-career building surveyors. Three respondents mentioned that artificial intelligence will replace building surveyors eventually. In relation to this comment, seven respondents strongly addressed that there will be no changes, since software or machines cannot fathom the insights of experienced building surveyors. Furthermore, one respondent pointed out that the quality of datasets in BIM must be checked and confirmed by building surveyors, and, therefore, BIM and building surveyors will collaborate with a complementary relationship. At the end of a group discussion, all participants shared the common opinions that a qualified building surveyor will be essentially required, since BIM cannot enter the data and make sure it is entered correctly by itself. Another commonly shared thought was that BIM may be a useful tool to assist building surveyors when undertaking a building inspection, particularly with the use of 3D modelling and being able to walk though buildings virtually. For example, while on site, building surveyors can check that emergency exit lights are installed where required by looking at a 3D building model of where it should be using a tablet while they are standing in that location in the building, and save having to look though a large set of drawings on a small screen or carry rolls of plans with them.

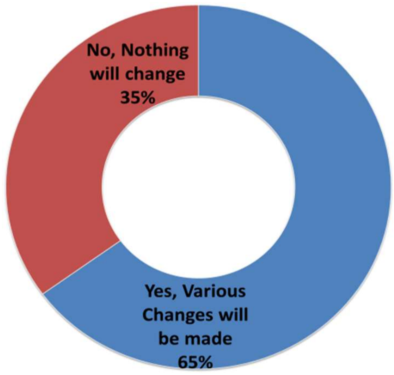

Figure 6. Impact of BIM on the role of building surveyor.

More importantly, seven respondents that indicated that "nothing will be changed" addressed that BIM cannot change building surveying practice dramatically, since the current building designs are developed based on performance solutions rather than deemed-to-satisfy (DTS) solutions. As a DTS solution is descriptive and specifies all of the details of building design and materials, which highly constrains design flexibility, many cases adopt the use of performance-based building codes. After this comment, all respondents agreed that the current BIM system, including cloud-based collaboration tools, might not be able to cope with the dynamic interactions and coordination among diverse experts, such as structure engineers, fire engineers, and energy and disability access consultants. Consequently, it was concluded that BIM can support building surveying practice, but the building surveyor is still essential for a construction project where performance-based solution building codes are adopted.

5.2. Step 2: BIM-Enabled Workshop Results and Discussions

Three major concerns about BIM were identified from the focus group interview: (1) Ineffective training; (2) unclear benefits of using BIM; (3) concerns about BIM system replacing building surveyors in the future. A workshop using a real-life construction project, as shown in Figure 7, was adopted to demonstrate BIM capability and address potential BIM benefits in response to the three major concerns. Five building surveyors with more than 10 years of experience participated in the workshop.

(1) Ineffective training: At the beginning of the workshop, a brief demonstration of the BIM tool (Autodesk Navisworks Manage 2020) was conducted to improve workshop participants' understanding of BIM's capability, with researchers and participants applying the BIM tool for co-investigation of building code and design issues of the real-life building model. During the demonstration, all participants constantly commented that learning a BIM tool can be highly effective when there is a well-established connection between software skill and domain knowledge. One participating building surveyor with 14 years of experience indicated that demonstrations with case-, task-, or situation-based BIM applications tremendously supported him to synchronise his current BIM skills with his daily tasks. Based on participants' comments and feedback, proper BIM training is indeed instrumental in increasing the awareness of BIM benefits in professionals' practices.

(2) Unclear benefits of using BIM: After the brief demonstration, building code and design issues were examined in detail. During the co-investigation workshop activity, all participants actively were engaged to address their needs, such as "How can I find the material specification?", "How can I walk

through this building or this zone?", "Can I measure this component and distance?", and "Can I insert my comments using some kind of markup function?". In response to the questions, the following outcomes, as shown in Figure 8, resulted from BIM tool application after the co-investigation workshop.

Figure 7. BIM model for demonstration (top: Isometric view; bottom left: Front elevation; bottom right: Floor plan view).

All participants agreed that BIM capabilities—the 3D model walk-through and material specification check (refer to Figure 8, top) and the safety check, including signage and egress of building (refer to Figure 8, middle and bottom)—can save a large amount of time for collating documents for material specifications and 2D drawings, for assessing design issues, and for providing adequate design recommendations. Participants commented that the current practice makes participants occasionally miss critical design issues or building code violations, as building design and structure have become complex. This causes rework and potential delays in obtaining a building approval before the commencement of construction. These positive experiences and feedback are perfectly matched up with design and construction professionals' expectations, as revealed from the focus group interview (refer to Section 5.1.5). Participants were asked to indicate how many days of work can be saved or reduced if BIM is used for building code checks. Interestingly, experienced building surveyors with more than 10 years of experience indicated that it might take them longer if they start to use BIM due to the learning curve and empirical errors. Furthermore, they commented that there will be no big difference, since they already knew from experience which part of building design will most likely cause design issues, as well as where the easiest part that can be overlooked is. This is echoed with literature that states that the full BIM capabilities can be realised when experienced building surveyors use BIM [25], as well as the comments obtained from a focus group interview stating that BIM itself cannot fully deploy the insights and experience of an experienced building surveyor. Nevertheless, all participants indicated a minimum of one day to a maximum of three days to assess one to two floor plans if building designs are complex and not typical, and this has resulted in average savings of three days to assess compliance with the building codes.

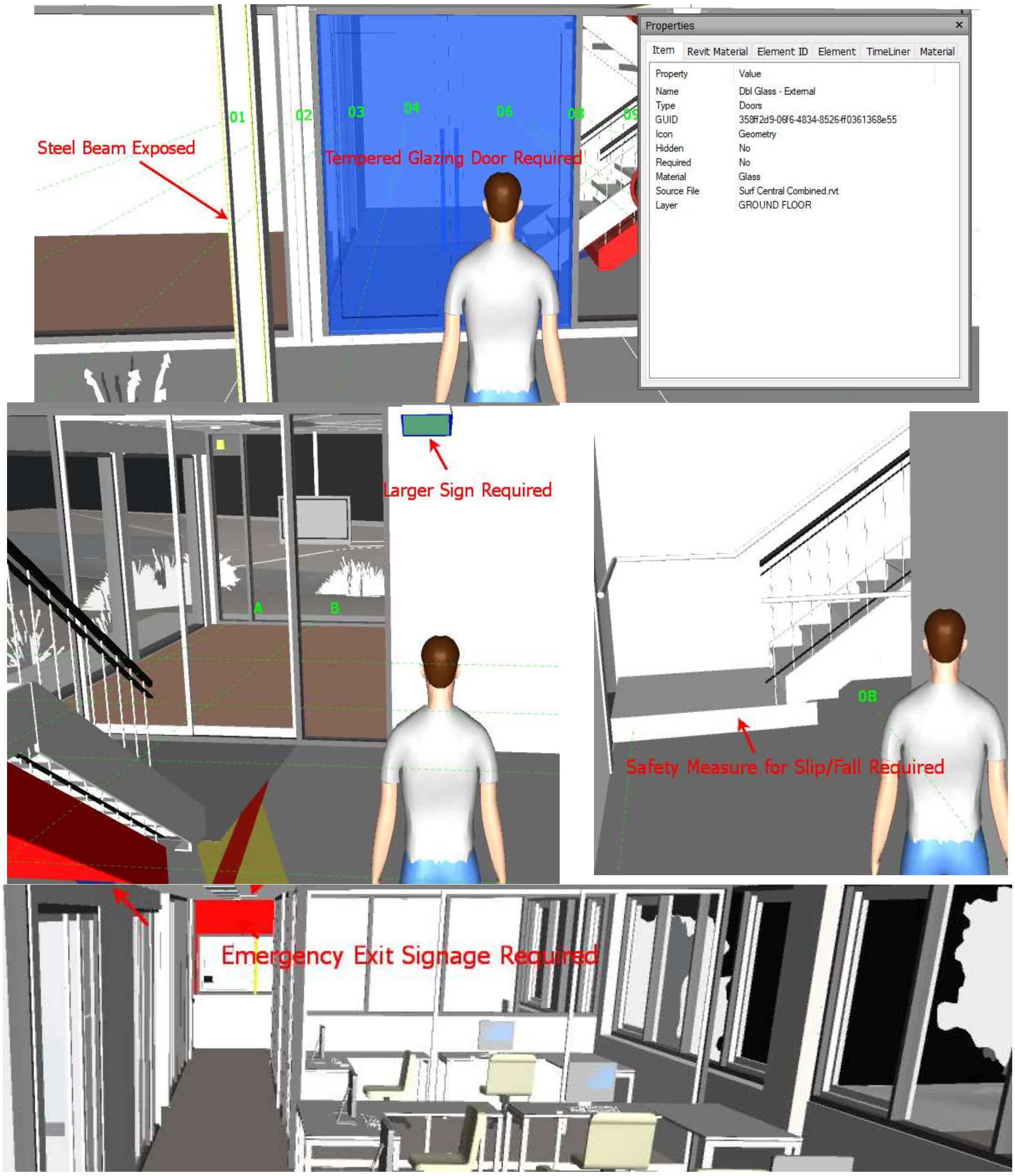

Figure 8. BIM-enabled co-investigation results (top: Entrance of building; middle left: Emergency exit sign; middle right: Stair and step; bottom: Emergency exit signage on the second floor).

(3) Replacement of building surveyors by BIM in the future: Before the workshop, interviewees in the focus group discussions addressed their concerns about job security. Indeed, BIM is mandated in various countries and changes the method of design and construction. It is productive, with fewer design errors and construction reworks. Despite the current technologies and their potential, participants addressed their confidence in their roles after the workshop. This is because they gained a practical and clearer knowledge about what BIM can or cannot replace, such as a simple walk-through function in 3D, as well as their knowledge obtained and accumulated from experience. Workshop participants discussed that there is a high probability that artificial intelligence systems can further improve BIM systems by feeding more accurate data and information, and eventually building code checks can be overtaken by artificial-intelligence-based building code checking systems in conjunction with BIM. All participants agreed that their roles and responsibilities in this era of digital transformation are to

prepare for knowledge transfer to successors, and to archive their empirical knowledge and experience in a digitally transferrable format, such as big datasets.

This research has proven that BIM adoption is inevitable, and BIM can provide various benefits to building surveyors and their practices. Furthermore, it is confirmed that BIM will be continuously and increasingly adopted and utilised in the design and construction sectors in the near future. There is the potential that BIM can further improve the current productivity in the design and construction industry by embracing other advanced digital technologies, such as artificial intelligence and big data. Therefore, this research sheds light on the future directions of BIM and its application, and the research findings will be recognised as a future-proof direction for BIM application in the building surveying sector.

6. Conclusions

There has been a global effort to integrate BIM with the building surveying sector by developing automated building code checking tools in Singapore, Australia, South Korea, and the US. Although BIM has various capabilities of improving the productivity in the building surveying sector, the current BIM adoption in the building surveying sector is limited, and the main reasons have not been clearly identified. Hence, the aim of this study is to identify those main reasons for the low uptake of BIM in the building surveying sector and to examine the feasibility of BIM adoption for the building surveying profession. Through a focus group interview, the three major research questions have been answered: (a) Current status of BIM adoption in the building surveying sector; (b) barriers to adoption of BIM in the building surveying sector; (c) feasibility of BIM adoption in the building surveying sector. For the first research question, all participants are aware of BIM, but there is a difference in BIM adoption status between the public and private sectors. The public sector is relatively low in BIM adoption within the building surveying practice. The most critical barrier, among other barriers, has been identified as a lack of incentives when building surveyors adopt BIM. It has been revealed that BIM adoption requires the time and effort of building surveyors, as it is not easy for BIM to be embedded into the existing work processes without proper planning. Thus, a learning curve is presented, and the efforts should be compensated by financial benefits. Consequently, building surveying professionals commonly emphasise a government incentive scheme to encourage the BIM adoption in the building surveying sector. Furthermore, this research revealed that building surveyors are aware of the importance of BIM adoption in the building surveying profession, and more than half of the professionals that responded agreed that BIM adoption is timely and should be carried forward to transform the current AEC industry, including the building surveying sector. During the focus group interview, the importance of proper education or training in BIM has been identified as instrumental in preparing present and future generations. Finally, this research revealed that current design and construction professionals agreed that digital transformation is essential, and thus, it is feasible for BIM to improve the current building surveying practices, and BIM should also capture the essential insights and lessons learned from experienced building surveyors to make better decisions on design assessment. This research contributes to demystifying the barriers to and feasibility of BIM adoption in the building surveying sector. More importantly, this research significantly contributes to providing the actual benefits of BIM applications perceived by building surveyors for design review and examinations. Furthermore, this research confirms that BIM can serve as an information integration platform by embracing other advanced digital technologies, such as artificial intelligence and big data. Therefore, this research contributes to identifying the future direction of BIM and its application in the building surveying sector. Due to the limited number of professionals who are currently involved in the BIM adoption process or using BIM, this research conducted an exploratory feasibility study on BIM adoption for the building surveying profession. Thus, the research findings in this research should be understood in the confined context of the building surveying sector. Adequately tailored BIM training or education is necessary for further BIM adoption and use, and future research can focus on how to develop and deliver BIM education or training for building design examination professions.

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