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Amplifying the practicality of contemporary building information modelling (BIM) implementations for New Zealand green building certification (Green Star)

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Abstract

Purpose – Green Star is becoming a broadly accepted mark of design quality and environmental sustainability. Compared to other green tools, Green Star is considered as one of main streams green assessment tools, which cover almost sustainable criteria. Simultaneously, building information modelling (BIM) has also been introduced into the industry. BIM is expected to aid designers to shift the construction industry towards more environmentally and economically sustainable construction practice. Whilst the aspirations of Green Star rating and BIM implementation are broadly aligned, in the context of New Zealand this has led to some disconnects in design strategy and process. The purpose of this paper is to improve the practicality of BIM implementations for delivering Green Star certification in New Zealand.
Design/methodology/approach – The extensive literature review is conducted through a series of incremental steps. A conceptual framework focussing on the relationship between benefits and challenges of BIM and Green Star is then developed.
Findings – BIM supports practitioners to achieve the majority of Green Star criteria (75 per cent). Energy efficiency criterion is the key factor affecting the assessment process of Green Star and National Australian Built Environment Rating System in New Zealand. Research questions about lessening the challenges which can be encountered during the BIM and Green Star implementation are developed.
Research limitations/implications – This paper is limited to a conceptual research. Further empirical research should be conducted to validate and modify the conceptual framework and the propositions presented in this paper to provide an initial insight into BIM and Green Star connectivity within the context of New Zealand.
Originality/value – This paper provided a clear picture for investors, developers, practitioners about benefits and challenges of BIM and Green Star implementation. The outcomes are anticipated to deliver visions for shifting the country further towards development of sustainable future cities.

Keywords Building information modelling (BIM), BIM tools, Green building certification

Paper type Literature review

Introduction

The construction industry plays an important role in the national economy. In New Zealand, it is the third largest industry with over 500,000 enterprises (Statistics New Zealand, 2009). Its activities contributed around 4.3 per cent to GDP and employed one in every 12 New Zealanders in the workforce, roughly 178,000 people, over the year 2010 (Building a Better New Zealand (BaBNZ), 2013). However, it is also considered as one the primary sources consuming significant natural resources, energy, along with producing carbon emissions.

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According to Forsyth *et al.* (2014), the industry is responsible for around 40 per cent natural resources, 30 per cent energy consumption and 30 per cent greenhouse gases.

The increase costs in natural resources, and energy, together with environmental concerns have pushed the demand for green buildings (Autodesk Inc., 2005). Pursuing green building principles can achieve three main motives for New Zealand, lowering lifecycle costs, raising building value marketability and contributing to the protection of the environment (BCI Economics, 2014; New Zealand Green Building Council (NZGBC), 2010). To be more specific, green building can save around 5 per cent in capital cost, 10 per cent return of investment (ROI), 9 per cent operating costs, and 60 per cent water and energy (NZGBC, 2010). In addition, it also can lead to the increase in sales price and lease value, 16 and 10 per cent, respectively (NZGBC, 2010).

Simultaneous to Green Star becoming a broadly accepted mark of design quality and environmental sustainability, building information modelling (BIM) has also been introduced into the industry (Green Building Council of Australia, 2013; Ryan *et al.*, 2013; Holness, 2008). BIM design methodology is similarly flagged as providing the construction industry with improvements in design sustainability as well as increasing process productivity. BIM is expected to aid designers shift the construction industry towards more environmentally and economically sustainable construction practice. Whilst the aspirations of Green Star rating and BIM implementation are broadly aligned, in the context of New Zealand this has led to some disconnects in design strategy and process.

This paper aims to amplify the practicality of BIM implementations for the New Zealand green building certification. Practicality can defined in a number of ways including realism and usefulness (Buchmann, 1989) to the quality of being effective, useful or suitable for a purpose or situation (Lorenz, 1998). For this paper, the practicality is examined through reviewing the relationship between BIM and Green Star certification to understand their synergy and similarities. The paper aims to build a BIM framework from the understanding benefits and challenges, focussing on the relationships between BIM and Green Star, to deliver the Green Star certification, along with the propositions to improve the understanding of BIM benefits in New Zealand. The results from this study are expected to contribute to the increase the number of BIM users. This can lead to a growth in the quantity of green buildings receiving the Green Star certifications, because the Green Star rating system and BIM implementation are broadly aligned. Consequently, National Australian Built Environment Rating System in New Zealand (NABERSNZ) can be also achieved.

The review methodology

A literature review is a crucial part to develop the conceptual framework (Boons *et al.*, 2011; Seuring and Müller, 2008). It is "a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents" (Fink, 1998). Therefore, this research approach was carried out in two main stages, the extensive literature review and the formulation of a conceptual framework for complimentary BIM and Green Star implementation (see Figure 1). In the former stage, the extensive literature review was conducted to gain understanding of the existing problems in construction industry, the potential benefits and challenges of BIM application and the Green Star tool in the context of New Zealand. The subsequent stage of the conceptual framework focussing on the benefits of BIM and Green Star implementation is then developed.

In this research, the extensive literature review process consists of four steps, which are the combination of four factors including the scope of the study, identification of the keywords, study selection and evaluation (Colicchia and Strozzi, 2012). The review approach was undertaken incrementally from the initial literature review and progressing to an exploratory literature review, then a focussed literature review and ultimately refined literature review. The initial stage was to survey the available body of knowledge within the field to outline the importance of the construction industry, its high energy usage and the need for green building. Next, found papers were reviewed to explore the adoption of BIM and green assessment tools both in New Zealand and globally. After that, the benefits, challenges and uptake of BIM and of green tools, with a focus on the context of New Zealand were critically reviewed. The ultimately refined literature review was then completed with the aim of providing an overview and synthesis of the papers with the most relevant content (see Figure 2). This was used to inform the development of a conceptual framework for the successful complimentary implementation of BIM and the Green Star tool to achieve common benefits.

This approach provides incremental steps to critically overview the significance of green assessment tools and specifically the Green Star tool of New Zealand, BIM along with its benefits and challenges, and the relationship Green Star and BIM within the context of New Zealand.

The search for related publications was conducted as a structured keyword search. Related keywords are “Building Information Modelling”, “BIM Tools”, “Green Building Certification”, “Sustainable Future Cities”, “Green Star” and “New Zealand”. Major databases were used to search for related articles, such as those provided by major publishers, Elsevier (www.journals.elsevier.com), Emerald (www.emeraldinsight.c-om), Wiley (www.wiley.com), American Society of Civil Engineers (http://ascelibrary.org-/journals), Taylor & Francis (www.tandfonline.com).

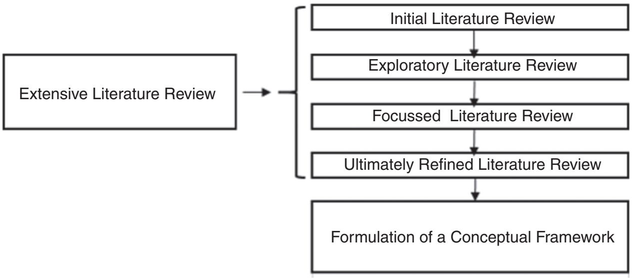

Figure 1.
Research stages

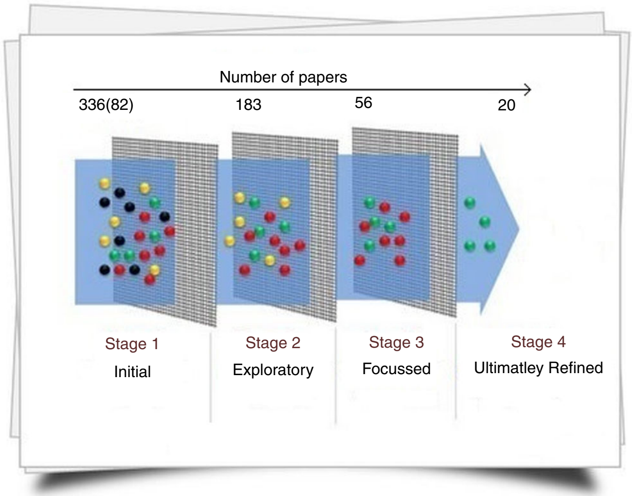

Figure 2.
Extensive literature review

"For a literature review it is particular important to define clear boundaries to delimitate the research" (Seuring and Müller, 2008). In this context, three important issues are noted: first, the analysis aimed only at peer reviewed papers written in English because information in these papers were examined independently to ensure its reliability. This excludes papers in other languages and those with a technical or political science focus. Second, publications in developing countries, based on The International Monetary Fund standard, were not considered. New Zealand is a developed country, so referring information from those countries with the same patterns could bring expected results. Third, publications before 2005 were not considered. As BIM is an advanced technology, information and technologies over a decade ago were not considered as suitable materials.

At the first stage, 418 papers were identified, but only 336 papers were considered after delimitations. Figure 2 drops to 183 papers, which focusses on BIM and Green Star, at the next stage. Once the New Zealand context is focussed, the figure is just 56 before falling to solely 20 papers in the end (see Figure 2).

Figures 3 and 4 show the number of annual publications per year across the period studied at the focussed and ultimately refined review. It is clear from the Figure 3 that the number of publications had increased significantly from only two in 2007 to eight in 2015. High numbers of publications are found for the time period between 2013 and 2015. While the final review step, which focusses on BIM and Green Star in New Zealand, had seen the considerable increase in the number of papers from solely two to seven during the period 2010-2015.

Literature review

The literature review provides a critical overview of the green assessment tools, their benefits and uptake in New Zealand, focussing on the New Zealand Green Star tool and its benefits and challenges. It goes on to review the benefits and challenges associated with the implementation of BIM in New Zealand. It concludes by examining the relationship between Green Star and BIM for effective simultaneous implementation.

Green assessment tools

Many assessment tools have been developed globally to promote sustainability in how buildings are designed, built and operated. Leadership in Energy and Environmental Design (2015), developed by US Green Building Council, is one of the most popular green

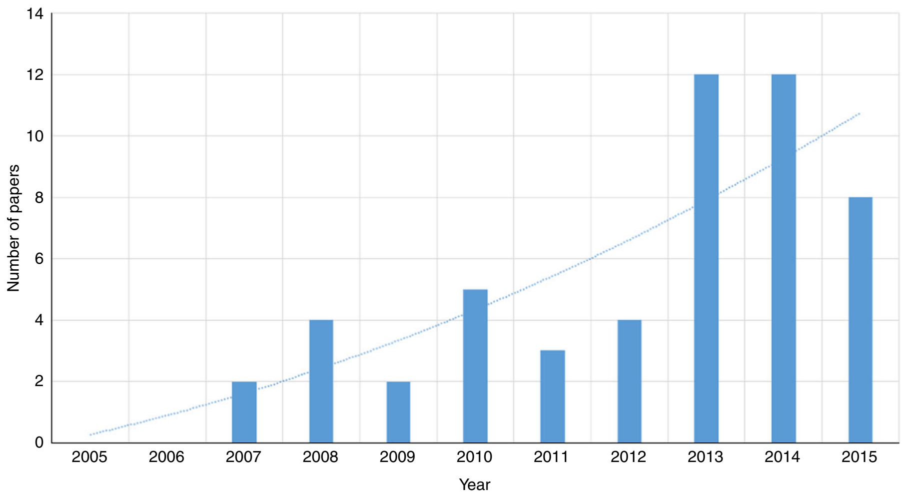

Figure 3. Distribution of publications per year across the period studied at the third review step

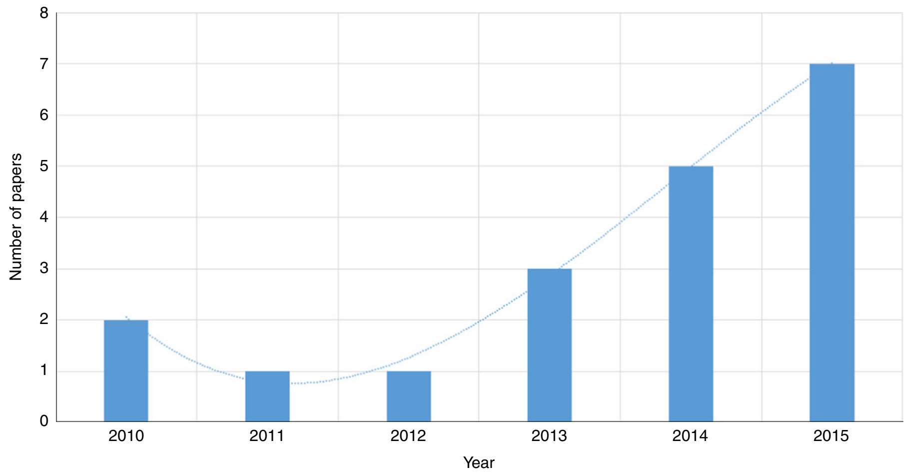

Figure 4.
Distribution of publications per year across the period studied at the final review step

building certification programmes, which is recognized across the globe. Other successful certificate systems include: Excellence in Design for Greater Efficiencies (EDGE) (2015), which is popular in Africa and Building Research Establishment Environmental Assessment Methodology (2015) being used in excess of 70 countries.

The green assessment tools have been appraised on their flexibility, usage domain and lifecycle coverage (see Table I). Xiaoping *et al.* (2009) demonstrated the detailed similarities and differences among six sustainable/green assessment tools based on different regions. Xiaoping *et al.* (2009) stated that Building Research Establishment Environmental Assessment Methodology (BREEAM), seen as the first real green building rating tool in the world, is the foundation of the development of the others. As Green Star (New Zealand) was focussed in this paper, it was added in table to provide an overview comparison of several mainstream sustainable assessment tools. These mainstream sustainable/green building rating tools are dominated by non-profit third party organizations and national governments. The majority of the tools offer increased flexibility for the customers and the current regulatory requirements of the built environment of the country. The tools reviewed offer a wide range of usage domains ranging from residential and non-residential building to all building types. The tools also offer the opportunity for use during all elements of the lifecycle of the project from programming through to operation.

Sturge (2009) compared different criteria of green building assessment in different geographic areas. Criteria of Green Star, based on New Zealand Green Building Council (NZGBC) (2015), were added to make the comparison of popular green tool in the world. Energy efficiency is the key criterion and is compulsory for all green assessment tools, while the economy is the least expected criterion. European regions including Germany, France and Italy, evaluate the green building rating applications more strictly in comparison to other countries with a total of 15 criteria being utilized. The UK has a variety of rating tools with four different ratings available for green building, including BREEAM, Code for Sustainable Homes, Energy Performance Certificates and Display Energy Certificates. Australia and New Zealand adopt the same tool, Green Star, and its criteria are identical to BREEAM's which cover almost criteria except economy. Green Globes and Leadership in Energy and Environmental Design certifications are the main certifications to assess the green ratings in buildings in America (Table II).

Although a number of green building certifications have been promoted, the recognition of the importance of green building in New Zealand is still in its early stages and the

Table I. A comparison between global green building assessments tools

Comparison items	Mainstream sustainable/green building rating tools						
	LEED	BREEAM	SBTool	CASBEE	BCA-GM	ESGB	Green Star (NZ)
Organizations providing rating tools	USGBC (non-profit third party)	BRE (non-profit third party)	iiSBE (international non-profit collaboration)	JaGBC (joint of government, industry, academy)	BCA (dominated by national government)	MHURD (dominated by national government)	NZGBC (non-profit organization)
Flexibility	Increasing flexibility in USA, and relative moderate flexibility in the overseas	Increasing flexibility in UK, and relative moderate flexibility in the overseas	High flexibility around the world	Increasing flexibility in Japan, and relative low flexibility in the overseas	Increasing flexibility in Singapore, and only focus on native field	Low flexibility and more improve required	Increasing flexibility in New Zealand, and only focusses on native field
Usage domains (building types)	Residence, office, retail, industrial, education, healthcare, other buildings type, data centres, mixed use	Residence, office, retail, industrial, education, healthcare, other buildings type, data centres, mixed use	Almost any type of the building	Residence, temporary construction, heat island, multifunction building, etc.	Residential and non-residential building	Residence, office, hotel, commercial building	Office, industrial, education, interior fit-out projects, other buildings type
Lifecycle coverage (building phases)	Programming, design, construction, operation	Programming, design, construction, operation	Programming, design, construction, operation	Programming (tool – 0, underdevelopment), design, operation, renovation	Programming, design, construction, operation	Programming, design, construction, operation	Programming, design, construction, operation

Source: Adapted from Xiaoping *et al.* (2009)

Table II.
A comparison between the criteria of global green building assessment tools

Assessment criteria	UK BREEAM	UK CFSH	UK/EU EPCs	UK/EU DECs	Hong Kong BEAM	Japan CASBEE	Germany DGNB-Seal	Australia/ New Zealand Green Star	France HQE	Canada/U.S. Green globes	USA LEED	Italy Protocol ITACA
Energy	X	X	X	X	X	X	X	X	X	X	X	X
CO_2	X	X	X	X			X	X	X	X	X	X
Ecology	X	X			X	X	X	X	X	X	X	X
Economy							X		A	X		A
Health and well-being	X	X			X	X	X	X	X	X		A
Indoor environment quality	X	X			X	X	X	X	X	X	X	A
Innovation	X				X		A	X	A		X	A
Land use	X	X			X		A	X	X	X	X	A
Management	X	X		X	X	X	A	X	A	X		A
Materials	X	X			X	X	X	X	A	X	X	X
Pollution	X	X			X	X	X	X	X	X	X	A
Renewable technologies	X	X	X				A	X	A	X	X	X
Transport	X	X			X		X	X	A	X	X	A
Waste	X	X			X		A	X	X	X	X	X
Water	X	X			X	X	X	X	X	X	X	X

Note: A, data for DGNB-Seal, HQE, and protocol ITACA are not exhaustive and additional criteria may be included in the assessment
Source: Adapted from Sturge (2009)

obstacles still outweigh the perceived benefits (BCI Economics, 2014). Only around a quarter of New Zealand survey participants, from 110 professionals from the domestic building and construction industry, were involved in green building projects (BCI Economics, 2014).

In comparison with other major markets of Australia, the UK, Canada and the USA regarding the number of Green Star rated buildings, New Zealand is still lagging behind (Bond and Perrett, 2012). According to Myers *et al.* (2008), sustainable buildings will play an important role in New Zealand property portfolios in the future. To encourage the popularity of green buildings in New Zealand, Green Star has been established to become a tool to rate and communicate the sustainability of commercial buildings (NZGBC, 2015).

The Green Star New Zealand rating tool was first launched in 2007 by New Zealand Green Building Council, which based on the Australian Green Star tool (Byrd and Leardini, 2011; Baird, 2009). It evaluates a number of environment impacts according to nine categories: management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions, and innovation (Baird, 2009).

Green Star certification is a voluntary practice in New Zealand currently, but it is anticipated to become mandatory for all new buildings in the near future (Gregory, 2008), however, to date this has not happened. Based upon the success of other mandatory green tool certification schemes globally, it is likely that once it is obligated, the construction industry will see a dramatic increase in the number of green buildings. It should be noted that the idea of an adoption of mandatory Green Star was mooted in 2008 (Gregory, 2008); however, it remains to be voluntary at the start of 2016. Whilst mandatory Green Star could be seen as a benefit, the lack of regulation to date is a challenge to widespread uptake of the system.

In comparison with noncertified building, certified green building is expected to achieve lower operating costs, higher employee productivity, tax credits and image benefits (Fuerst and McAllister, 2011). All of investors, developers and owners can earn benefits by obtaining the certified green building ratings (NZGBC, 2010). According to NZGBC (2010), the benefits of Green Star are numerous, investors can achieve risk mitigation, increased return in investment, enhanced marketability, along with reduced carbon risk. Further benefits identified for developers include: capital cost savings, increased sale price, improved marketability, access to the capital, asset protection and compressed schedules. Owner benefits are suggested as obtaining lower operating costs, tenant attraction and retention, reduced liability and risk, higher lease rates together with increased property values (NZGBC, 2010). Based on Gandhi and Jupp (2014), benefits of Green Star over conventional designs have been defined offering a 45 per cent reduction in greenhouse gas emission, a 79 per cent reduction in electricity consumption, a 66 per cent reduction in operation energy consumption, a 51 per cent reduction in water savings and a 54 per cent reduction waste management and recycling.

A number of barriers exist to the widespread uptake of Green Star. It is undeniable that the absence of government incentives is one of the substantial barriers to Green Star development (Bond and Perrett, 2012). In addition, the cost of obtaining Green Star certification also constricts the practitioner's uptake of its system (Bond and Perrett, 2012). Not only that, some evidence concerning additional costs to achieve the Green Star rating was collected by tenants (Levy and Peterson, 2013). Therefore, Bond and Perrett (2012) stated that the project should be managed correctly to limit the accrued expenses.

BIM

Recently, BIM has drawn attention of the construction sector due to its widely recognized benefits during the lifecycle of construction projects (Bryde *et al.*, 2013; Gray *et al.*, 2013; Leite *et al.*, 2011; Eastman *et al.*, 2008). BIM is defined by international standards as "shared digital representation of physical and functional characteristics of any built object […] which forms a reliable basis for decisions" (Volk *et al.*, 2014; ISO Standard, 2010). BIM has the potential power to transform the construction industry, bringing "fundamental change in the way building are designed, constructed and operated" (Ryan *et al.*, 2013; Holness, 2008). The energy efficient and environmentally conscious design could be enabled at the beginning of a project, and the requirements for heating, cooling, ventilation and electrical loads can be reduced substantially by BIM implementation (McGraw-Hill Construction, 2014).

Energy efficiency, the most important criterion, is one of the major benefits of BIM adoption (The Building and Construction Productivity Partnership (BCPP), 2014; McGraw-Hill Construction, 2014; BECA, 2013; Malkin, 2010). According to Malkin (2010), the energy can be analysed in sustainable designs by using BIM, thereby potentially leading to the energy saving. Regarding to the second key criterion, indoor air quality, BIM allows designers to demonstrate accurately the airflow, sunlight and surrounding environment to ensure the quality of the atmosphere inside (BECA, 2013; Malkin, 2010). The benefit of BIM application in water systems is also confirmed by BECA (2013). In addition, materials can be modelled and analysed with the precise quantification to reduce material wastage during the construction stage (BCPP, 2014; BECA, 2013; Malkin, 2010). According to McGraw-Hill Construction (2014) and Drop Malkin (2010), improvement in environmental and waste management could be achieved with the use of BIM. Besides, overall project duration, contractors' capability, asset operation and safety are also improved by BIM adoption (BRANZ, 2015; McGraw-Hill Construction, 2014). All these benefits have been incorporated into the BIM conceptual framework. The framework provides a possible insight into how BIM can deliver Green Star certification. Additionally, the NABERSNZ certified rating can also be awarded, because BIM enables the improvement in energy performance during the building lifecycle (BCPP, 2014).

Numerous studies have been carried out examining the range of applications of BIM in a New Zealand context from 2007 through to 2015 (see Table III). Boon and Prigg (2012), for example, examined the BIM application by using quantity surveying practice. Ryan *et al.* (2013) provided an overview of the suitability of the existing standard forms of contract in conjunction with BIM usage. Stanley and Thurnell (2013) investigated the current and future impacts of BIM on cost modelling in Auckland. Davies (2014) explored the influences of BIM adoption on the roles and relationships of industry participants. GhaffarianHoseini *et al.* (2014) proposed specific utilization of BIM in the maintenance stage for the post-construction energy efficiency.

It is clear that BIM application has attracted increasing attention from researchers in New Zealand from one paper in 2007 to six papers in 2015 (see Figure 5). The majority of papers focussed on benefits and barriers of BIM adoption. BIM handbooks and standards have been developed as they are seen as key barriers to BIM uptake in New Zealand, and they need to be solved to encourage BIM users (The Building and Construction Productivity Partnership (BCPP), 2015; BRANZ, 2015; McGraw-Hill Construction, 2014).

Lacking awareness concerning BIM benefits and expertise is considered as the most popular barriers to BIM uptake in New Zealand (BRANZ, 2015; EBOSS, 2014; McGraw-Hill Construction, 2014). However, less efficiency when applying BIM to small projects is the most common challenge to architectural/engineer firms, contractors and government clients (BRANZ, 2015; McGraw-Hill Construction, 2014). This may explain why lacking demand is proffered as the leading reason for not adopting BIM (McGraw-Hill Construction, 2014).

The relationship between Green Star and BIM

A variety of discipline specific authoring and analysis tools are covered by BIM. According to Gandhi and Jupp (2014), various BIM tools can be used to achieve Green Star criteria. For example, IES Virtual Environment/Transys, Ecotect/AnTherm can be adopted to obtain the indoor air quality criterion. Ener – Win/Trace 600 could help users to acquire higher energy efficiency while Revit/ArchiCAD/Stats/Navisworks enable the

Topic	Author
BIM in 2007 – are we there yet?	Amor *et al.* (2007)
BIM for efficient sustainable design	Malkin (2010)
Factors affecting the uptake of building information modelling (BIM) in the Auckland architecture, engineering and construction (AEC) industry	McCartney (2010)
Evolution of quantity surveying practice in the use of BIM – the New Zealand experience	Boon and Prigg (2012)
New Zealand National BIM Survey 2012	Masterspec (2012)
Shaving BIM: establishing a framework for future BIM research in New Zealand	Tran *et al.* (2012)
Current and anticipated future impacts of BIM on cost modelling in Auckland	Stanley and Thurnell (2013)
NBS international BIM report 2013	NBS (2013)
New Zealand National BIM Survey 2013	Masterspec (2013)
Research strategy for the building and construction industry	BaBNZ (2013)
Successfully implementing building information modelling in New Zealand: Maintaining the relevance of contract forms and procurement models	Miller *et al.* (2013)
University of Auckland Undergraduate Laboratories-BIM assisting detailed building services coordination	BECA (2013)
Application of nD BIM integrated knowledge-based building management system (BIM-IKBMS) for inspecting the post-construction energy efficiency	GhaffarianHoseini *et al.* (2014)
BIM in New Zealand – an industry-wide view 2014	EBOSS (2014)
Building information modelling from a practical and legal perspective	Stewart and Saxton (2014)
NBS international BIM report 2014	NBS (2014)
Productivity benefits of BIM	BCPP (2014)
The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand	Stanley and Thurnell (2014)
The business value of BIM in Australia and New Zealand: how building information modelling is transforming the design and construction industry	McGraw-Hill Construction (2014)
The impact of building information modelling (BIM) on professional roles, relationships and skills in the architecture/engineering/construction industry	Davies (2014)
5D BIM in a consulting quantity surveying environment	Harrison and Thurnell (2014, 2015)
Achieving construction productivity gains by adopting building information modelling (BIM)	New Zealand Government Procurement (2015)
BIM implementation in a New Zealand consulting quantity surveying practice	Harrison and Thurnell (2014, 2015)
Government as client: using building information modelling on NZ construction projects	BRANZ (2015)
New Zealand BIM handbook	BCPP (2015)
Sharing to gain, Maximizing 5D BIM technology	Nichols (2015)

Table III. Key literature themes outlining BIM application in New Zealand

improvement of material resources. Accelerating the use of BIM in the construction process will therefore become a priority to gain a high score in Green Star conditions.

Although BIM plays an important role in Green Star achievement, not all Green Star criteria can be guaranteed by utilizing BIM application. Based on Gandhi and Jupp (2014), BIM possibly assists practitioners to obtain 88 per cent of credits, but only 66 per cent of them were achieved in the practice. This is because raising awareness about the benefits of both Green Star and BIM have still received insufficiency attention (BRANZ, 2015). Besides, the lack of substantial guidelines and case studies which can be used to identify and realize benefits is also considered to be a key challenge (BRANZ, 2015; EBOSS, 2014; McGraw-Hill Construction, 2014).

In contrast to the aforementioned benefits, awareness about the benefits of both green buildings and BIM is limited. Half of the survey respondents still do not recognize the benefits of green buildings (BCI Economics, 2014). Whilst the increased costs

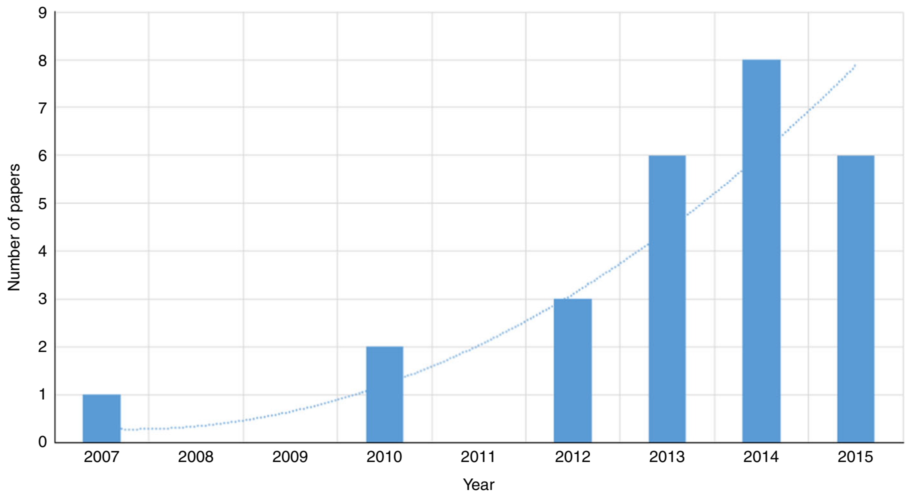

Figure 5.
Number of BIM publications in New Zealand

associated with BIM application and Green Star achievement in construction projects is one of the most common challenges to architectural/engineer firms and contractors (McGraw-Hill Construction, 2014; Hankinson and Breytenbach, 2013; Levy and Peterson, 2013). Besides, the practitioners' entrenched behaviours could delay the Green Star and BIM application (BRANZ, 2015; EBOSS, 2014; Levy and Peterson, 2013). Lacking of government incentives is also considered as a significant barrier (EBOSS, 2014; Bond and Perrett, 2012).

The main barriers of seeking a formal Green Star recognition is the time taken used to evaluate the Green Star rating applications and the difficulty of certification process (BCI Economics, 2014). Whereas, lacking of standards, expertise and less efficiency for small projects are the key factors delaying the decision to use BIM (BRANZ, 2015; McGraw-Hill Construction, 2014).

One of the significant outcomes of aligning BIM with the Green Star tool is that of contributing to National Australian Built Environment Rating System was introduced in New Zealand in 2013, as a method to rate energy efficiency of office buildings (NABERSNZ, 2015). NABERSNZ solely considers energy performance of one-year building upward. It means that "NABERSNZ is a valuable tool to ensure Green Star buildings are commissioned and tuned well, so are performing as they are designed to" (NABERSNZ, 2015). The introduction of NABERSNZ offered three key opportunities for the construction industry: benchmarking of individual buildings and portfolios; increased ability to improve the environmental performance of a building on a measured basis; and better level of information available for existing and/or prospective tenants of a building, were hoped to be provided by Bond and Perrett (2012). This rating tool is also expected to become mandatory as it has been in mandatory in Australia (Bond and Perrett, 2012).

NABERSNZ is highly flexible, the system provides three types of rating: it can be carried out for base buildings, tenancies, or whole buildings (NABERSNZ, 2015). According to NABERSNZ (2015), 21 per cent of New Zealand's electricity, costing $800 million each year, is consumed by commercial buildings, and building energy performance could be improved by 20-25 per cent on average (NABERSNZ, 2015). It is suggested that NABERSNZ energy rated buildings can improve energy use by an average 9 per cent and could deliver a relative premium in property values (NABERSNZ, 2015).

Conceptual framework development

The literature review examined the range of Green tools available and the lack of widespread uptake of Green Star in New Zealand, it also introduced the Green Star system and lack of specific research on the tool. It has examined the key benefits and challenges associated with BIM and the current uptake of BIM. The relationship between BIM and Green Star has been examined, reviewing similarities of both systems in terms of benefits and challenges. The conceptual framework of potential benefits and challenges of BIM and Green Star implementation was developed and is illustrated in Figure 5.

The framework has five main parts, see Figure 6. The bottom of the pyramid is the shared benefits and challenges of BIM and Green Star in the New Zealand context based on the literature review. While the second and third layers of the framework from the bottom demonstrate the benefits and challenges of BIM and Green Star separately. As both BIM and Green Star have not yet matured in New Zealand, it is unavoidable to face with challenges along with the unintegration. However, once fully understanding all the benefits and challenges, the integration and the achievement of BIM and Green Star are undoubtable and BIM is seen as a background for Green Star gaining. The UK and Australia, which have the same patterns in construction industry with New Zealand, in which the majority of the industry comprises small scale construction firms (McClements and McKane, 2015; Dumrak *et al.*, 2013), have had a route to reach the fully BIM adoption (McCullough Robertson, 2015; UK Cabinet Office, 2011). As a result, transport, land use and ecology, waste/emission benefits, which are criteria at the layer 3 of Green Star, are being achieved by BIM adoption in Australia and the UK (Love *et al.*, 2015; Oti and Tizani, 2015; Abanda *et al.*, 2010). Therefore, BIM and Green Star of New Zealand could be developed in the same way. Once these are reached, the energy efficiency, which is also the criterion of NABERSNZ after one-year performance, could be fully attained.

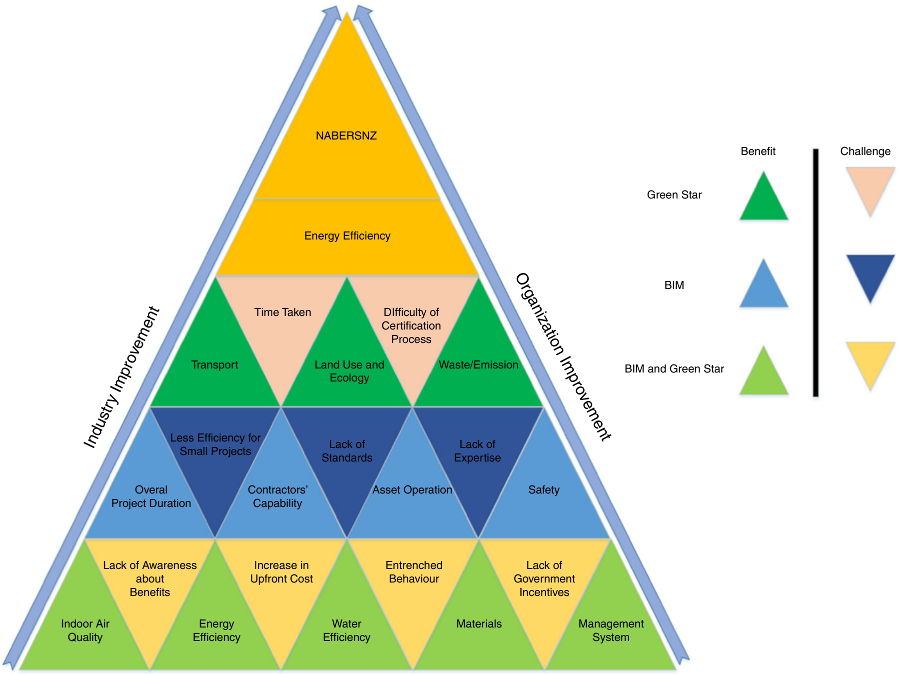

Figure 6. The conceptual framework of potential benefits and challenges of BIM and Green Star implementation

If the layers of the pyramid are achieved, the construction organizations and industry will be surely improved. This is because both BIM and Green Star are seen as marketing tools to attract customer besides bringing savings in project duration, capital cost, ROI and operating costs (Mulquin, 2015; Nair and Paulose, 2014; NZGBC, 2010).

From a theoretical viewpoint, the framework in Figure 6 aims to provide a complete overview of benefits and challenges literature to understand thoroughly all of published works in the New Zealand context which overlap and are complementing each other. It is believed that the framework could be used during the BIM and Green Star implementation. It could help adopters to identify and classify all possible challenges and benefits to support the investment decision. The relationship between the benefits and the possible costs may be discovered. For example, identifying the upfront cost in the early project stages may help users realize risks for budget overruns. In addition, the connections between BIM and Green Star are explored to prove that BIM is the priority technology delivering Green Star certification. During post implementation, the project success can be assessed by using the framework, which is used as a checklist to examine whether all BIM benefits are fully exploited to achieve Green Star rating.

It is clear from Figure 6 that BIM could be utilized to its nearly full potential for Green Star certification, 75 per cent of criteria including energy efficiency, indoor air quality, water efficiency, materials and management system. Once Green Star certification is obtained, the other three benefits could be achieved, consisting of transport, land use and ecology, and waste/emission (25 per cent of the criteria). Although many potential benefits can be attained, encountering obstacles is unavoidable during the BIM application. All of the potential challenges are displayed in the Figure. Both BIM and Green Star have some identical challenges in application, lacking of awareness about benefits, increasing in upfront cost, entrenched behaviours and lacking of government incentives. While lacking of standards, expertise and less efficiency for small projects should be resolved to enable the greater number of BIM users, time taken and difficulty of certification process are the important factors preventing Green Star certification. A higher level benefit that can be achieved from Green Star is that with the improvement in energy efficiency gained through the implementation of the tool, after one year of the buildings operation, the energy efficiency of the building can be evaluated to attain NABERSNZ. The conceptual framework suggests that a positive outcome associated with overcoming the challenges of BIM and Green Star certification provide a range of benefits to the organizations and that this can lead to organizational improvement and permeate into overall industry improvement.

The development of the conceptual framework raises a number of questions for further exploration. In the framework, there is a relationship between benefits and challenges in BIM and Green Star application. This relationship could be explored in more detail through a number of research questions which have been developed based upon a combination of the literature review and the formulation of the conceptual framework.

Based on McGraw-Hill Construction (2014), all form of BIM benefits should be clearly proved to give the confidence for BIM users:

R1. Awareness of the benefits, BIM benefits will enhance the confidence and use of BIM.

There is a current lack of expertise. For example, how the benefits of BIM can be fully achieved when the practitioners cannot use BIM appropriately. In this case, training would play an important role to give the support for the benefits achievement (EBOSS, 2014):

R2. BIM training enhances the usability of BIM and the benefits associated with BIM.

Providing appropriate standards is seen as one of the major factors encouraging BIM adoption, as this will help to ensure all project teams are working collaboratively to obtain BIM benefits (EBOSS, 2014; McGraw-Hill Construction, 2014):

R3. Appropriate BIM standards enhance the benefits associated with BIM.

According to McGraw-Hill Construction (2014), tangible cost savings could motivate the number of BIM users, thereby exploiting the BIM benefits:

R4. Optimization of upfront cost in BIM implementation enhances the benefits associated with BIM.

It is anticipated that the expected reduction in charges of Green Star will promote a higher number of property developers and investors to obtain Green Star certification for their buildings (Bond and Perrett, 2012):

R5. Reduction in charges of Green Star enhances the benefits associated with Green Star.

Based on Bond and Perrett (2012), government intervention could be seen as a key factor in the uptake of green building in New Zealand by reinstating the green leasing policy and through regulation, tax breaks and other incentives:

R6. Increasing government incentives enhances the benefits associated with Green Star.

To make BIM become popular in New Zealand, all the challenges should be addressed. Opening workshops to improve the knowledge about BIM usage may enable a greater number of users. Using proof and case studies in variety of projects, from small to major projects, which show the potential benefits of BIM adoption is also necessary to encourage clients and contractors to consider adopting BIM. In addition, providing the apparent standards for BIM implementation could be a useful way to convince the BIM non-users.

Conclusion

The construction industry plays and important part in the national economy and it is considered as one the primary consumers of natural resources, and energy. New Zealand as a developed country is expected to significantly improve its environmental performance. Given the simultaneous introduction of Green Star and BIM in New Zealand, this research attempts to improve the practicality of BIM implementations for delivering Green Star certification in New Zealand.

The research approach provided a literature review which was undertaken through a series of incremental steps. It began with an initial review, before developing through an exploratory and development phases. The paper has presented the refined literature review. It suggests that BIM can support practitioners to obtain the majority of Green Star criteria; however, in practice, the number of practitioners who have achieved this to date is relatively small. This is due to a number of challenges associated with identifying and realizing benefits of Green Star and BIM application.

The findings are important as they examine BIM and the Green Star tool simultaneously, which to date has had little discussion. The study goes on to develop a conceptual framework for implementation. This framework is the first one in the New Zealand context, which can be used to assist the practitioners to successfully manage the benefits of BIM implementation in their projects, as it builds a bridge between the benefits and challenges and BIM and Green Star simultaneously. Green Star is becoming mandatory for all new buildings in the near future and the developed conceptual framework found that BIM potentially delivers almost credits to achieve Green Star certification, 75 per cent of criteria including energy efficiency, indoor air quality, water efficiency, materials and management system. Hence, increasing in the number of BIM practitioners in the short term is unavoidable.

Many BIM-related issues stem from concerns about BIM benefits. Developed conceptual framework in this paper provides the collaborative use of the team and parties, especially the clients. Education of clients as to BIM benefits is considered as one of the appropriate way to popularize BIM adoption. The framework can also eliminate the entrenched behaviours of stakeholders by giving steps, potential benefits and challenges that they could confront with; thereby preparing to cope with obstacles will be surely made compulsory. The challenges are therefore minimized.

This paper is limited to a conceptual research, which is defined as devoting purely to thought-based conceptions that is devoid of data (MacInnis, 2011). Further empirical research should be conducted to validate and modify the conceptual framework and the propositions presented in this paper to provide an initial insight into BIM and Green Star connectivity within the context of New Zealand. Future work could also be conducted to improve the framework by examining BIM uses and Green Star's criteria in more detail as this would allow for specific features to be identified more comprehensively.

To implement BIM and Green Star certification, proper guidelines and the conceptual framework are needed that successfully guide BIM adopters through their projects. This paper made a first attempt to provide a conceptual framework that can be used for benefits and challenges management. The results from this study are hope to increase the number of BIM users. This can lead to a growth in the quantity of green buildings receiving the Green Star certification. In the following, some possible solutions are suggested to lessen the challenges which can be encountered during the BIM implementation.

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