An Empirical Examination of Green Star Certification Uptake and Its Relationship with BIM Adoption in New Zealand

Abstract

Purpose

Green BIM has been highlighted as an essential topic owing to its potential benefits. However, both Green Star and BIM are still in their earlier stages in New Zealand. This research aims to examine and evaluate the benefits, barriers/challenges, and solutions for the integration of Green Star and BIM in New Zealand.

Design/methodology/approach

Seventy-seven responses collected from construction professionals in New Zealand using questionnaires were analysed through descriptive and statistical tests

Findings

Building performance modellings used for Green Star assessment can be implemented using BIM; this was highlighted as the most significant benefit of the integration. Whereas, the most significant barrier preventing the integration of Green Star and BIM was the fact they are two completely separate processes. Regarding the solutions for the integration, showcasing BIM-Green Star benchmark projects was considered as the most effective solution amongst a range of eight provided.

Originality/value

The research provided insights into Green Star and BIM integration in New Zealand. By evaluating the significance of the benefits, barriers/challenges, and solutions for the integration, this research could be used as a guideline for Green Star and BIM development by New Zealand Green Building Council (NZGBC), the government, and construction practitioners in New Zealand. Specifically, the results here could be valuable inputs for Green Star manuals and the New Zealand BIM handbook.

Keywords: Green Star; green rating systems, BIM, green BIM, New Zealand Green Building Council (NZGBC); New Zealand

1 Introduction

The construction industry has been criticised due to its adverse impacts causing environmental degradation, carbon emissions, and global warming (Suzer, 2015). Green building has emerged as a key topic in the construction field to mitigate the current problem of the building sector (Doan *et al.*, 2017). Also, hundreds of green rating systems have been developed to reduce the negative impacts of construction projects on the environment (Vierra, 2016). Green Star New Zealand, established by the New Zealand Green Building Council (NZGBC), is one of the internationally-recognised rating systems to promote the sustainability of construction projects (NZGBC, 2020). However, only 254 construction projects were certified as Green Star projects during 2007 and 2019, a modest number of Green Star certified projects (NZGBC, 2021).

One of the reasons explaining the low uptake of Green Star in New Zealand could be a lack of understanding (Doan *et al.*, 2019). Also, Green Star has not been an attractive topic to the researchers in New Zealand, with very few publications. Amongst three journal articles focusing on Green Star conducted by other researchers, two of them examined the Indoor Environment Quality (IEQ) (Byrd and Rasheed, 2016, Rasheed *et al.*, 2017), a significant category amongst nine categories required for the assessment by NZGBC. Whereas, whether the cost of green buildings is higher than conventional buildings was investigated by Rehm and Ade (2013).

It is noticed that green BIM has caught researchers' attention recently. The integration of BIM and LEED (Leadership in Energy and Environmental Design) is expected to support the designers during the design stage to be more productive (Jalaei and Jrade, 2015). Also, BREEAM (Building Research Establishment Assessment Method)-BIM was researched to produce an automatic sustainability assessment (Ilhan and Yaman, 2016).

However, there is no research exploring the current practice of Green Star and Green Star and BIM integration in New Zealand except for Doan *et al.* (2019) research. Although benefits, barriers/challenges, and solutions for Green Star uptake and the integration with BIM were provided by Doan *et al.* (2019), a further validation stage is necessary to confirm the results. This is because the snowball sampling method used in that research could be susceptible to selection bias (Kalton and Graham, 1983, Wheeler *et al.*, 2014). Furthermore, the adopted triangulation method may not be entirely appropriate because literature from other green rating systems was used to validate the results from the research.

This research aims to validate the results of the Green Star uptake and its relationship with BIM adoption in New Zealand, revealed by Doan *et al.* (2019). By examining the perspectives of the construction practitioners in New Zealand, the research could provide insights into Green Star uptake. Findings of the research could be used as a guideline for NZGBC and construction companies in New Zealand to have effective strategies to achieve the potential benefits of Green Star uptake.

2 Green BIM

Green BIM has been focused by researchers recently due to its potential benefits in various areas (Jalaei and Jrade, 2015, Wong and Kuan, 2014, Azhar and Brown, 2009). The feasibility of integrating either LEED or BREEAM, the most popular green rating systems globally, with BIM has been investigated. After reviewing 400 studies related to this topic, Lu *et al.* (2017) stated that the management efficiency and success rate of applications could be increased while the cost of green building registration could be reduced with BIM implementation (Lu *et al.*, 2017). According to Jalaei and Jrade (2015), LEED-BIM assists the designer process, leading to an increase in design efficiency. Also, credits of green rating systems could be integrated with BIM for automatic assessment, which was mentioned in the current literature. A method that can partially automate the process of LEED and BIM was suggested by Jalaei and Jrade (2014). LEED was also focused by Nguyen et al. (2015) with the assistance of BIM to produce an automatic LEED score report. Similarly, automatic sustainability assessment can also be achieved when BIM is integrated with BREEAM (Ilhan and Yaman, 2016). Whereas, Chen and Hsieh (2013) developed a BIM-assisted rule-based approach to examine the green building design automatically.

Park *et al.* (2012) stated that BIM implementation could increase the speed and accuracy of the energy assessment. The use of BIM for energy analysis for passing the performance criteria of LEED or BREEAM was suggested by Motawa and Carter (2013). Half of the Energy and Atmosphere credits in LEED could be utilised with the BIM application (Wu and Issa, 2014). Azhar *et al.* (2009) mentioned the BIM application on LEED Daylight credit. Azhar and Brown (2009) revealed that LEED documentation was prepared as part of the BIM-based performance analyses by half of the construction professionals working in the US.

Amongst hundreds of green rating systems established globally, only LEED and BREEAM are the main focus on the integration. Other ratings, such as Green Star or CASBEE, should be researched as well because there are differences regarding the characteristics and context of each rating system. In other words, the results of LEED-BIM or BREEAM-BIM may be not applicable to the other green BIM. It is also noticed that the results of the integration shown in previous research are still limited. Only 5 LEED credits were examined with the use of BIM by Azhar *et al.* (2011) while only 26 BEAM plus credits amongst a total of 80 credits could be achieved with BIM implementation in Wong and Kuan

(2014) research. Therefore, further research into the challenges and solutions for green BIM implementation should be conducted to achieve the potential benefits of the integration.

In New Zealand, both Green Star and BIM are still in their early stages (Doan *et al.*, 2017, Doan *et al.*, 2020). Specifically, only three journal articles about Green Star and two journal articles about BIM in the New Zealand context could be found on the Scopus database (not including own authors' articles). These indicate the need for further research on these topics to explore Green Star uptake and BIM implementation along with the integration between them. Besides providing the guidelines for Green Star and BIM development in New Zealand, the results of this research could offer learning lessons for the other green rating systems, which has been neglected by academia. Also, it provides insights into green BIM, in which Green Star represents for the other ratings to be examined its relationship with BIM.

3 Research Methodology

Questionnaire was adopted as the primary data collection instrument. Its purpose is to generalise and to promote the confidence of the findings in Doan *et al.* (2019) research. In Doan *et al.* (2019) research, the qualitative approach, using 21 semi-structured interviews, was adopted to examine the perspectives of construction professionals towards Green Star uptake and its relationship with BIM in New Zealand. Although the qualitative method provides "deep, rich observational data," "the virtues of hard, generalisable survey data" could be generally offered by the quantitative one (Onwuegbuzie and Leech, 2005, Sieber, 1973). In other words, the quantitative method is considered appropriate in this research to add rigour to the qualitative approach used in Doan *et al.* (2019) research (Amaratunga *et al.*, 2002, Johnson and Onwuegbuzie, 2004). Construction professionals' perspectives towards Green Star uptake and its relationship with BIM in New Zealand were found out using sequential explanatory design. This mixed-method has "the potential to provide new insights into, and enhanced understanding of phenomena being investigated … providing rich data, lead to new lines of thinking, and by intentionally engaging multiple perspectives and presenting a greater diversity of views" (Krivokapic-Skoko and O'neill, 2011).

3.1 Questionnaire design

The questionnaire comprised three main sections, including demographics, Green Star uptake and BIM and Green Star integration. There are three themes investigated for Green Star uptake. These are the benefits of Green Star certification uptake, the barriers/challenges to Green Star certification uptake, and solutions for Green Star certification uptake. The themes chosen for BIM and Green Star integration were the benefits of Green Star and BIM integration, the barriers/challenges to Green Star and BIM integration, and the solutions for Green Star and BIM integration.

Demographic data collected included the respondents' positions in their companies, their companies' sizes, and their types of companies. It went on to establish their experience in the New Zealand construction industry. It examined the number of Green Star and BIM projects they have been involved in, and the highest BIM maturity levels and LODs (level of development) in their BIM projects.

Table 1 and Table 2 summarise the results in Doan *et al.* (2019) research regarding the benefits, barriers/challenges and solutions for Green Star uptake as well as the perspectives towards Green Star and BIM integration in New Zealand.

Table 1. Benefits, barriers/challenges, and solutions for Green Star uptake

Benefits of Green Star certification uptake	Code
The Green Star certified project reduces the environmental impact of the construction industry.	BE1
The Green Star certified project provides a healthy place for end-users.	BE2
The Green Star certified project saves operation costs for end-users.	BE3
The Green Star certified project is generally sold for a higher price compared to the non-certified project.	BE4
The Green Star certification is a marketing tool to attract end-users.	BE5
The Green Star certification raises the social conscience of sustainable construction.	BE6
The Green Star certification is a benchmarking system for the design for better building performance modellings (e.g., energy, lighting).	BE7
Barriers/challenges to Green Star certification uptake	**Code**
Perception of the cost of investing in the Green Star certification.	BA1
Lack of understanding of the Green Star benefits.	BA2
Lack of benchmark projects which can showcase the benefits of the Green Star certification.	BA3
Lack of client demand for the Green Star certification uptake.	BA4
The complex administration process of the Green Star certification uptake.	BA5
Solutions for Green Star certification uptake	**Code**
Clients should be educated about the benefits of Green Star certification.	SO1
Benchmark Green Star projects should be showcased widely.	SO2
Incentives (e.g., tax reduction) should be provided for Green Star certified projects.	SO3
The Green Star process should be optimised to simplify the administration of getting Green Star certification.	SO4
Green Star should be integrated with BIM.	SO5
Green Star registration fees should be reduced from the current level.	SO6

Table 2. Benefits, barriers/challenges, and solutions for Green Star and BIM integration

Benefits of Green Star and BIM integration	Code
Building performance modellings (e.g., energy, lighting) used for Green Star assessment can be implemented using BIM.	BEI1
Building models can incorporate all the information (e.g., Building Users' Guide, Commissioning report) for Green Star assessment of the project.	BEI2
Green Star credits can be integrated with BIM for automatic Green Star assessment.	BEI3
Using BIM for Green Star certification uptake can potentially reduce the assessment time.	BEI4
Green Star certification uptake requires the building performance modellings and related information, which are the aspects of the BIM process. Therefore, increasing the Green Star certification uptake can potentially increase the BIM adoption rate.	BEI5
Barriers/challenges to Green Star and BIM integration	**Code**
BIM implementation and Green Star certification have two completely separate processes.	BAI1
Lack of client demand for projects that required both BIM and Green Star.	BAI2
The New Zealand Green Building Council requires only 2D documents for the assessment process rather than a full BIM model.	BAI3
BIM maturity level in New Zealand is currently low.	BAI4
LOD in New Zealand is currently low.	BAI5
Lack of understanding on the positive potentials of integrating BIM with Green Star.	BAI6
Solutions for Green Star and BIM integration	**Code**
Clients and stakeholders should be educated on both BIM implementation and Green Star certification processes.	SOI1
The Green Star certification and BIM implementation processes should be integrated.	SOI2
The New Zealand Green Building Council should change their document requirements to reflect BIM adoption.	SOI3
BIM should be executed properly first (the BIM maturity level and LOD have to be high enough) before the integration with Green Star.	SOI4
Green Building Council should work with construction stakeholders to optimise the Green Star certification process.	SOI5
A Green Star material database should be created for BIM integration.	SOI6
Benchmark projects based on BIM-Green Star integration should be showcased widely.	SOI7
BIM implementation should be mandated in New Zealand for certain types of projects (e.g., public projects).	SOI8

Except the demographics part, a five-point Likert scale was used in the questionnaire, where 1 = Strongly Disagree; 2 = Slightly Disagree; 3 = Neutral; 4 = Slightly Agree; 5 = Strongly Agree. For Agree and Disagree scales, Revilla *et al.* (2014) recommended the five answer categories rather than others providing better quality for collected data.

3.2 Sampling

The criteria used to select the appropriate respondents was based on their experience. The questionnaire was distributed to construction professionals having at least three years' experience in the New Zealand construction industry. Also, participating in at least one Green Star or one BIM project was essential. Because Green Star and BIM are still in their early stages in New Zealand (Doan *et al.*, 2019), there may be a limited number of respondents satisfying the mentioned criteria. Therefore, a mixed sampling technique was adopted to increase the number of participants, which is a common technique in quantitative studies (Teddlie and Yu, 2007). Both random sampling and purposive sampling were adopted in this research. The random sampling ensures that "each individual in the population has an equal probability of being selected" (Creswell and Creswell, 2017), which "provides the ability to generalise to a population" (Creswell and Creswell, 2017). Whereas, the purposive sampling ensures the correctness of the data owing to the expertise of the participants (Teddlie and Yu, 2007).

The questionnaire was developed on Qualtrics which was then self-administered via Green Star and BIM groups on LinkedIn. Also, potential respondents were invited to participate in the research using contacts obtained from the NZGBC and the Architectural Designers New Zealand (ADNZ) database.

Before distributing the questionnaire, the pilot testing was conducted by inviting 21 construction professionals to check the research instrument. The purpose of this step is to avoid the misinterpretation of the questions and to check the time taken to complete the questionnaire, wording, layout, and ordering of the questions (Grimm, 2010). The final questionnaire was revised based on their suggestions.

After two months of distributing the questionnaire, 166 construction professionals accessed the questionnaire link amongst 403 invitations. However, only 85 participants completed the Green Star part in which the statements regarding the benefits, barriers/challenges, and solutions for Green Star uptake in New Zealand were answered. Whereas, 77 responses were received for the BIM and Green Star integration part. The response rate for Green Star uptake and Green Star and BIM integration is 21% and 19.1% respectively, considered as a usual rate for the questionnaire (Akintoye, 2000, Oke and Aghimien, 2018).

3.3 Analysis

The questionnaire data was analysed using both descriptive and statistical tests with the aid of the Statistical Package for the Social Sciences (SPSS) version 24. The one-sample *t*-test was adopted to determine the significance of the statements. In other words, all the statements in Tables 1 and 2 were analysed with the one-sample *t*-test to consider their appropriateness in the New Zealand context. The one-sample t-test was used in this research because it indicates the difference between the statement means and the test values (Dinh, 2020). Specifically, the test aims to reject the null hypothesis that the means of the benefits, barriers/challenges, and solutions for Green Star and BIM and Green Star integration are not significantly different from the test value with *p*-value < 0.05. With the five-point Likert scale, the test value of 3.0 is considered appropriate for the one-sample *t*-test (Kavishe *et al.*, 2018, Hwang *et al.*, 2014). Whereas, Owusu-Manu *et al.* (2018) and Manu *et al.* (2018) suggested testing the mean score with the test value of 3.5 in the five-point Likert scale. Consequently, the one-sample *t*-test was conducted in 2 rounds, with the test values of 3.5 and 3.0.

Although no minimum sample size is required for the one-sample *t*-test (Kavishe *et al.*, 2018), a comparison with other studies regarding the sample size was also carried out. The sample sizes in this research are appropriate compared to 45 of Robert *et al.* (2014), 34 of Cheung *et al.* (2012), and 28 of Kavishe *et al.* (2018) research.

To ensure the correctness of the results, the normal distribution of the data was checked before going through the one-sample *t*-test (Ross and Willson, 2018). According to Field (2013), the normality of the data could be spotted by calculating the values of skewness and kurtosis. All the statements have the values of skewness within the range ±2 and ±3 for the values of kurtosis proving the normality of the data (Griffin and Steinbrecher, 2013, Schneider and Wheeler-Kingshott, 2014).

4 Results

Before conducting further analysis, Cronbach's Alpha test was carried out to evaluate the reliability and internal consistency of the collected data. 0.7 was considered as the cut off point for the test by most of the studies (Kavishe *et al.*, 2018, Owusu-Manu *et al.*, 2018). The results for the test in this research are 0.771 for Green Star uptake and 0.84 for BIM and Green Star integration respectively, implying that the data is reliable for further analysis.

4.1 Demographic information

The criteria for selecting the respondents were checked to eliminate inappropriate cases. Firstly, the number of Green Star and the number of BIM projects were examined to remove the cases in which the construction professionals have not been involved in any BIM and Green Star projects. Eight cases were removed for the Green Star part, which is the same for BIM and Green Star integration part. Secondly, less than three year's experience in the New Zealand construction industry was checked to ensure that the respondents have perceived specific knowledge in the industry. One case was removed when the respondent only has one year's experience for both the Green Star part and BIM and Green Star integration part. It is noticed that four cases in Green Star part have two years' experience, but they were accepted for the analysis. This is because they proved their experience in this topic by the number of Green Star projects they have been involved in.

Table 3 shows the characteristics of the respondents participating in this research. Three is the average number of Green Star projects those respondents involved in while thirteen is the average number of BIM projects. Green Star Accredited Professionals (GSAP) account for the significant percentage of the respondents with around 26%, followed by architects and mechanical, electrical, and plumbing (MEP) engineers with 15% and 14%, respectively. It is noted that a respondent can hold multiple positions at the same time. For example, one respondent is an MEP engineer, a Green Star assessor, and a GSAP while another respondent is a BIM manager, an architect, and a GSAP. Furthermore,

Table 3 shows the number of respondents working in small and medium-sized enterprises (SMEs) and large companies. SMEs are those who have less than 20 employees, defined by the New Zealand Ministries (MBIE, 2017, MED, 2011).

Table 3. Respondents' demographics in Green Star uptake section

Respondent Role	Frequency (%)
GSAP	31 (26.05%)
Green Star Assessor	02 (01.68%)
Architect	18 (15.13%)
MEP Engineer	17 (14.29%)
Contractor	08 (06.72%)
BIM Manager	07 (05.88%)
Quantity Surveyor	07 (05.88%)
Project Manager	05 (04.20%)
Structural Engineer	04 (03.36%)
Client	03 (02.52%)
Others	17 (14.29%)
Company Size	Frequency (%)
SME	21 (27.63%)
Large company	55 (72.37%)
Experience	02-13-46*
No of Green Star projects	00-03-35*(50**)
No of BIM projects	00-13-100*(68**)

*Min-Average-Max
**Number of respondents involving in Green Star/BIM projects

The average experience of the respondents for BIM and Green Star integration section is fourteen years, see Table 4. Three and thirteen are the average numbers of Green Star and BIM projects they have been involved in respectively. Almost all of the respondents have been involved in BIM projects, and over three-quarters of the respondents have practical experience in Green Star. BIM level 2 and LOD 300 are considered as the average BIM maturity level and LOD in New Zealand, with almost a third of the respondents.

Table 4. Respondents' demographics in BIM and Green Star integration section

Respondent Role	Frequency (%)
GSAP	29 (26.85%)
Green Star Assessor	02 (01.85%)
Architect	17 (15.74%)
MEP Engineer	16 (14.81%)
BIM Manager	07 (06.48%)
Quantity Surveyor	06 (05.56%)
Contractor	05 (04.63%)
Project Manager	05 (04.63%)
Structural Engineer	04 (03.70%)
Client	03 (02.78%)
Others	14 (12.96%)
Company Size	Frequency (%)
SME	18 (26.47%)
Large company	50 (73.53%)
Experience	03-14-50*
No of Green Star projects	00-03-35*(52**)
No of BIM projects	00-13-100*(65**)
BIM maturity levels	Frequency (%)
Level 1	05 (07.69%)
Level 2	20 (30.77%)
Level 3	07 (10.77%)
Unsure	33 (50.77%)
LODs	Frequency (%)
200	03 (04.62%)
300	19 (29.23%)
350	15 (23.08%)
400	05 (07.69%)
500	04 (06.15%)
Unsure	19 (29.23%)

*Min-Average-Max
**Number of respondents involving in Green Star/BIM projects

Over a quarter of the respondents are GSAP, while two Green Star assessors also participated in the survey. Architects and MEP engineers have similar figures regarding the percentage of the respondents, around 15%. Whereas, the figures for BIM managers, quantity surveyors, contractors, project managers, structural engineers, and clients are not much different from each other ranging from 2.78% to 6.48%.

Almost three-quarters of the respondents are working in large companies, but there are still a higher number of respondents working in SMEs, with 18 cases. From the demographic information shown in

Table 3 and Table 4, it is reasonable to conclude that the respondents' knowledge is suitable for enhancing the reliability and validity of the research results.

4.2 Green Star uptake

4.2.1 Benefits of Green Star certification uptake

The data concerning the benefits of Green Star certification uptake were analysed using the one-sample *t*-test. Table 5 shows that BE2 was perceived as the most important benefit of Green Star, followed by BE1. They have the highest mean scores compared to the rest, which was then used to rank the benefits of Green Star. BE7 and BE5 have similar scores, which were ranked 3rd and 4th. While 5th and 6th places belong to BE3 and BE6, with almost identical scores. BE4 is the only benefit receiving the mean score close to 4.00, 3.96.

Table 5. One-sample *t*-test results of the benefits of Green Star certification uptake

					One-sample *t*-test (test value =3.5)					
									95% confidence interval of the difference	
Benefit	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BE1	4.26	0.839	0.096	2	7.934	75	0.000	0.763	0.57	0.95
BE2	4.38	0.711	0.082	1	10.806	75	0.000	0.882	0.72	1.04
BE3	4.09	0.897	0.103	5	5.754	75	0.000	0.592	0.39	0.8
BE4	3.96	0.871	0.100	7	4.610	75	0.000	0.461	0.26	0.66
BE5	4.13	0.806	0.092	4	6.834	75	0.000	0.632	0.45	0.82
BE6	4.08	0.744	0.744	6	6.783	75	0.000	0.579	0.41	0.75
BE7	4.16	0.880	0.101	3	6.516	75	0.000	0.658	0.46	0.86

All of the standard deviation (SD) values are less than 1, indicating a high consistency in agreement amongst respondents' perspectives. Furthermore, all values of the standard error (SE) mean close to 0, enhancing the reliability and validity of the results. In other words, the mean of the sample is sufficiently precise to the true mean of the population. Also, all the *t*-values are positive, and *p*-values are significant, indicating that the means are significantly higher than the test value of 3.5. In other words, the seven benefits of Green Star certification uptake are all important.

4.2.2 Barriers/challenges to Green Star certification uptake

Table 6 shows the one-sample *t*-test results of the barriers/challenges to Green Star certification uptake. BA1 and BA4 are the two most significant barriers/challenges to Green Star certification uptake, with the mean scores of 4.36 and 4.29, respectively. The results for BA2 and BA5 are similar with 3.97 and 3.91 mean scores. BA3 is the only barrier having the mean score of less than 3.50.

Table 6. One-sample *t*-test results of the barriers/challenges to Green Star certification uptake

First Round					One-sample *t*-test (test value =3.5)					
									95% confidence interval of the difference	
Barrier	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BA1	4.36	0.605	0.069	1	12.334	75	0.000	0.855	0.72	0.99
BA2	3.97	0.952	0.109	3	4.339	75	0.000	0.474	0.26	0.69
BA3	3.37	1.220	0.140	5	-0.940	75	0.350	-0.132	-0.41	0.15
BA4	4.29	0.861	0.099	2	7.991	75	0.000	0.789	0.59	0.99
BA5	3.91	1.022	0.117	4	3.479	75	0.001	0.408	0.17	0.64
Second Round					One-sample *t*-test (test value =3.0)					
									95% confidence interval of the difference	
Barrier	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BA3	3.37	1.220	0.140	1	2.632	75	0.010	0.368	0.09	0.65

Although the SD values of the barriers/challenges are higher than those of the benefits, the values are less than 2, indicating that the perspectives of the participants are consistent with each other (LabCE, 2019). Whereas, the SE mean values close to 0 promoting the reliability and validity of the data. Except for BA3, all the *t*-values of barriers/challenges to Green Star certification uptake are positive with significant *p*-values to the test value of 3.5. This proves that those barriers/challenges are significant towards Green Star certification uptake. BA3 was then checked with the test value of 3.0 in the second round as Hwang *et al.* (2014), and Kavishe *et al.* (2018) stated that 3.0 is still the appropriate test value to examine the significance of the barrier. The results in the second round show that BA3 is still a significant barrier/challenge to Green Star certification uptake with positive *t*-value and significant *p*-value to the test value of 3.0.

4.2.3 Solutions for Green Star certification uptake

Table 7 shows the results of the one-sample *t*-test for the solutions for Green Star certification uptake. Interestingly, SO2 was perceived as the most effective solution even though it has the lowest rank in the barriers/challenges to Green Star certification uptake in the previous section. SO1 and SO3 have the same mean score, 4.34. However, the SD value of SO1 less than the one of SO3; they were ranked 2nd and 3rd, respectively. The 4th place belongs to SO4. SO6 and SO5 are two solutions having the mean scores less than 4.00.

Table 7. One-sample *t*-test results of the solutions for Green Star certification uptake

First Round					One-sample *t*-test (test value =3.5)					
									95% confidence interval of the difference	
Solution	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
SO1	4.34	0.644	0.074	2	11.400	75	0.000	0.842	0.69	0.99
SO2	4.47	0.642	0.074	1	13.214	75	0.000	0.974	0.83	1.12
SO3	4.34	0.946	0.109	3	7.761	75	0.000	0.842	0.63	1.06
SO4	4.21	0.957	0.110	4	6.475	75	0.000	0.711	0.49	0.93
SO5	3.45	1.063	0.122	6	-0.432	75	0.667	-0.053	-0.30	0.19
SO6	3.53	1.013	0.116	5	0.226	75	0.821	0.026	-0.21	0.26
Second Round					One-sample *t*-test (test value =3.0)					
									95% confidence interval of the difference	
Solution	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
SO5	3.45	1.063	0.122	2	3.668	75	0.000	0.447	0.20	0.69
SO6	3.53	1.013	0.116	1	4.530	75	0.000	0.526	0.29	0.76

All the SD values close to 1 and the SE mean values close to 0, implying the reliability and validity of the data. SO5 is the only solution having a negative *t*-value, while the *p*-value of SO6 is not significant. They were then analysed in the second round with the test value of 3.0 to consider their significance as the solutions for Green Star development. In other words, the other four solutions are considered effective and should be followed to improve the number of Green Star certified projects. The results of

SO5 and SO6 in the second round shows that they have positives *t*-values with significant *p*-values suggesting the positive impacts of these two solutions on Green Star certification uptake.

4.3 BIM and Green Star integration uptake

4.3.1 Benefits of BIM and Green Star integration

The results of the one-sample *t*-test for the benefits of Green Star and BIM integration are shown in Table 8. BEI1 and BEI2 are two benefits having the highest mean scores, 3.93 and 3.79 respectively, which were ranked 1st and 2nd. BEI4 has a mean score of just over 3.50, holding the 3rd place, while both BEI3 and BEI5 have the mean scores below 3.50, ranked 4th and 5th. All the values of SD of five benefits are less than 1, while the values of SE mean close to 0, indicating the reliability and validity of the data collected.

Table 8. One-sample *t*-test results of the benefits of Green Star and BIM integration

First Round					One-sample *t*-test (test value =3.5)					
									95% confidence interval of the difference	
Benefit	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BEI1	3.93	0.982	0.119	1	3.581	67	0.001	0.426	0.19	0.66
BEI2	3.79	0.986	0.120	2	2.460	67	0.015	0.294	0.06	0.53
BEI3	3.46	0.921	0.112	4	-0.395	67	0.694	-0.044	-0.27	0.18
BEI4	3.54	0.984	0.119	3	0.370	67	0.713	0.044	-0.19	0.28
BEI5	3.34	0.956	0.116	5	-1.395	67	0.167	-0.162	-0.39	0.07
Second Round					One-sample *t*-test (test value =3.0)					
									95% confidence interval of the difference	
Benefit	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BEI3	3.46	0.921	0.112	2	4.080	67	0.000	0.456	0.23	0.68
BEI4	3.54	0.984	0.119	1	4.560	67	0.000	0.544	0.31	0.78
BEI5	3.34	0.956	0.116	3	2.918	67	0.005	0.338	0.11	0.57

It is clear from Table 8 that BEI1 and BEI2 are the two most perceived benefits from the respondents, with positive *t*-values and *p*-values < 0.05. Although BEI4 has the *t*-value > 0, its *p*-value = 0.713 > 0.05. Because the mean values of BEI3 and BEI5 are less than 3.50, they have negative *t*-values when the one-sample *t*-test was conducted with the test value equal to 3.5. As a result, BEI3-5 were analysed in the second round with the test value 3.0 to consider the importance of these three benefits.

The results in the second round indicate the importance of BEI3-5 to the test value of 3.0 with positive *t*-values and all *p*-values < 0.05. In conclusion, all the five mentioned benefits were well-perceived from the respondents.

4.3.2 Barriers/challenges to BIM and Green Star integration

The results of the one-sample *t*-test of the barriers/challenges to Green Star and BIM integration are shown in Table 9. Interestingly, BAI1 and BAI4 have the same mean score, 4.06. However, the SD value of BAI1 is less than the one of BAI4; BAI1 was then ranked 1st as the most significant barrier/challenge to Green Star and BIM integration. BAI6 holds the 3rd place with a similar mean score, 4.04. The 4th place belongs to BAI2 with a mean score of 3.87 while BAI3 and BAI5 share the lowest ranks with the mean scores of 3.72 and 3.63, respectively. All the SD values close to 1, along with the SE means close to 0 prove the reliability and validity of the collected data.

Table 9. One-sample *t*-test results of the barriers/challenges to Green Star and BIM integration

First Round								One-sample *t*-test (test value =3.5)		
									95% confidence interval of the difference	
Barrier	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BAI1	4.06	0.808	0.098	1	5.702	67	0.000	0.559	0.36	0.75
BAI2	3.87	1.006	0.122	4	3.014	67	0.004	0.368	0.12	0.61
BAI3	3.72	0.975	0.118	5	1.866	67	0.066	0.221	-0.02	0.46
BAI4	4.06	0.976	0.118	2	4.724	67	0.000	0.559	0.32	0.79
BAI5	3.63	1.091	0.132	6	1.000	67	0.321	0.132	-0.13	0.40
BAI6	4.04	0.836	0.101	3	5.365	67	0.000	0.544	0.34	0.75
Second Round								One-sample *t*-test (test value =3.0)		
									95% confidence interval of the difference	
Barrier	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
BAI3	3.72	0.975	0.118	1	6.095	67	0.000	0.721	0.48	0.96
BAI5	3.63	1.091	0.132	2	4.778	67	0.000	0.632	0.37	0.90

All the *t*-values for six barriers are positive, but the *p*-values for BAI3 and BAI5 are not statistically significant, *p*-values > 0.05. Therefore, BAI3 and BAI5 were analysed with the test value of 3.0 in the second round to check their significance. The results indicate the significance of the BAI3 and BAI5 with positive *t*-values and *p*-values < 0.05. In conclusion, Green Star and BIM have entirely separate processes, BAI1, is the most significant barrier. Whereas, low LOD in BIM adoption, BAI5, has the lowest rank regarding the barriers/challenges to Green Star and BIM integration compared to five other barriers/challenges.

4.3.3 Solutions for BIM and Green Star integration

Table 10 shows the results of the one-sample *t*-test for the solutions for Green Star and BIM integration in New Zealand. SOI5 is considered as the best solution with the highest mean score, 4.28, followed by SOI7 with a mean score of 4.26. SOI6 and SOI7 are the two solutions left with the mean scores higher than 4.00, 4.16 and 4.10 respectively. SOI4 and SOI8 share similar mean scores, 3.79 and 3.78. The 7^{th} place belongs to SOI3 with 3.40 mean score while SOI2 holds the lowest rank with 3.35 mean score. The values for SD and SE mean of all eight solutions close to 1 and 0 respectively implying the reliability and validity of the collected data.

Table 10. One-sample *t*-test results of the solutions for Green Star and BIM integration

First Round							One-sample *t*-test (test value =3.5)			
									95% confidence interval of the difference	
Solution	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
SOI1	4.10	0.794	0.096	4	6.259	67	0.000	0.603	0.41	0.80
SOI2	3.35	1.062	0.129	8	-1.142	67	0.257	-0.147	-0.40	0.11
SOI3	3.40	1.174	0.142	7	-0.712	67	0.472	-0.103	-0.69	0.18
SOI4	3.79	1.001	0.121	5	2.423	67	0.018	0.294	0.05	0.54
SOI5	4.28	0.688	0.083	1	9.345	67	0.000	0.779	0.61	0.95
SOI6	4.16	0.745	0.090	3	7.322	67	0.000	0.662	0.48	0.84
SOI7	4.26	0.785	0.095	2	8.038	67	0.000	0.765	0.57	0.95
SOI8	3.78	1.091	0.132	6	2.113	67	0.038	0.279	0.02	0.54
Second Round							One-sample *t*-test (test value =3.0)			
									95% confidence interval of the difference	
Solution	Mean	SD	SE Mean	Rank	*t*	*df*	Sig. (2-tailed)	Mean diff.	Lower	Upper
SOI2	3.35	1.062	0.129	2	2.741	67	0.008	0.353	0.10	0.61
SOI3	3.40	1.174	0.142	1	2.790	67	0.007	0.397	0.11	0.68

Except for SOI2 and SOI3, all the solutions have positive *t*-values and *p*-values < 0.05 indicating the effectiveness of the mentioned solutions. After analysing SOI2 and SOI3 with the test value of 3.0 in the second round of the one-sample *t*-test, the results indicate the significance of the solutions SOI2 and SOI3 with *t*-values > 2 and *p*-values < 0.05.

5 Discussion

Figure 1 summarises the results of this research. The findings align with existing literature. King (2017) stated that green-certified buildings could provide a sustainable and healthy place for building occupants. Furthermore, green rating systems have been used as benchmarking systems for the design. Pilechiha *et al.* (2020) indicated the positive relationship between sustainable certification systems and energy performance, a favourite topic recently with a wide range of research (Seyedzadeh *et al.*, 2020b, Seyedzadeh *et al.*, 2020a, Asadi *et al.*, 2012). Specifically, LEED has been used in the US to “provide a benchmarking system to assess levels of sustainability achieved by a building” (Krishnamurti *et al.*, 2010). Whereas, Green Star (Australia) has been adopted as a benchmarking system to measure the energy efficiency of a project (Ng *et al.*, 2013).

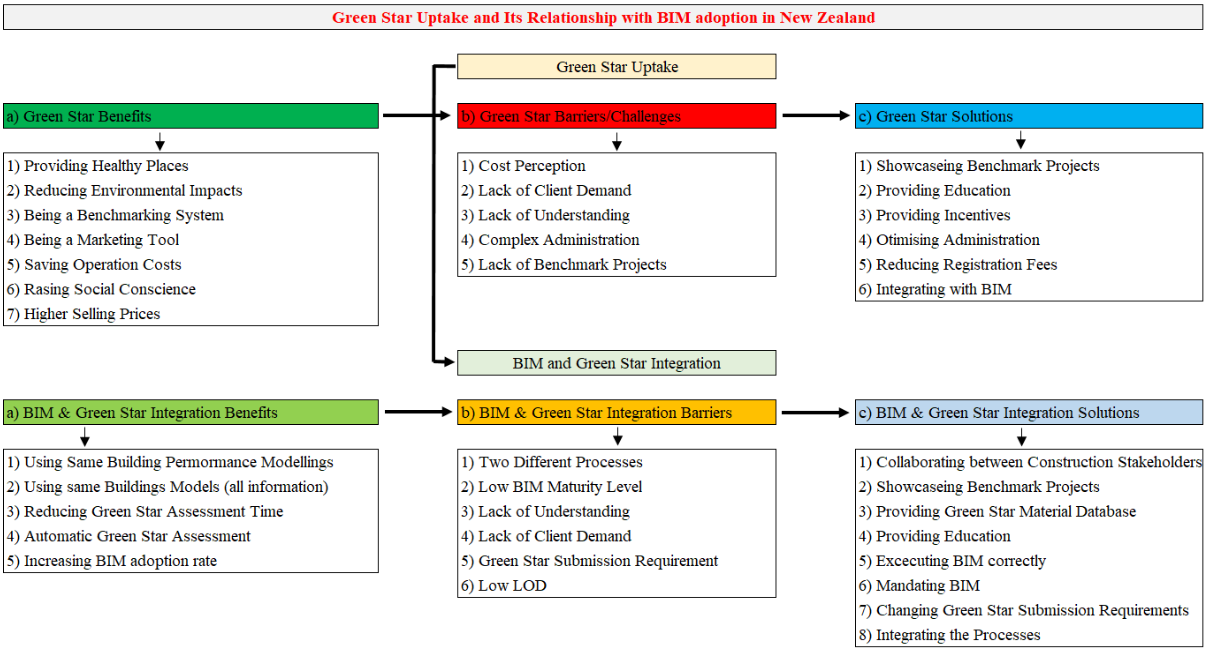

Figure 1. Green Star and BIM relationship

The benefit of green rating systems as a marketing tool to attract end-users was also mentioned in the literature. Fuerst and McAllister (2011) revealed that one of the benefits of LEED is a marketing benefit. Whereas, Byrd and Leardini (2011) highlighted the benefit of LEED is "for commercial marketing and promotion rather than for significant environmental concerns." This was also confirmed by Morris *et al.* (2018) that the potential of using Green Star (Australia) as a marketing tool was the most perceived benefit by construction professionals. Furthermore, saving operation costs were found out by Kansal and Kadambari (2010). Zuo and Zhao (2014) and Ying Liu *et al.* (2012) also implied the low operating cost of green buildings.

Regarding the 6th ranking benefit of Green Star, it was confirmed by Kato *et al.* (2009). Kato *et al.* (2009) revealed that Green Star (Australia) certified buildings encourage tenants to participate in sustainable events, inspire them to monitor energy and water use, and inspire the staff to be "green people." Higher selling price of Green Star certified projects compared to the non-certified projects is the only benefit having the mean score less than 4.00. Whether a green building has a higher selling price compared to a conventional building is an interesting topic which has been studied by many researchers. Zhang *et al.* (2018) summarised 18 studies towards the green price premium. Although the results of some studies indicated that the green price premium is positive, others concluded that it is not statistically significant. Consequently, the green price premium is still a controversial topic. This is consistent with the results of BE4 having the lowest rank compared to the rest.

Regarding the Green Star barriers/challenges, cost is the most significant barrier to Green Star in Australia (Morris *et al.*, 2018), green buildings in the US (Ahn *et al.*, 2013), and in China (Lam *et al.*, 2009). About the lack of client demand, it was determined as one of the most significant barriers to green buildings in Singapore (Hwang and Tan, 2012) and Malaysia (Samari *et al.*, 2013).

Lack of understanding was ranked first and a foremost barrier to green buildings in Kuwait (AlSanad, 2015) and second in the US (Darko *et al.*, 2017). It is also a common barrier to green buildings in various countries, such as in England (Williams and Dair, 2007), Malaysia (Samari *et al.*, 2013), and Singapore (Hwang and Tan, 2012). Besides, the complexity of the process was considered as one of the three most significant barriers to Green Star in Australia (Morris *et al.*, 2018). It was also determined as a barrier by Darko *et al.* (2017). Furthermore, the lack of benchmark projects was identified as a barrier to green buildings by Ayarkwa *et al.* (2017) and Samari *et al.* (2013). It, however, was ranked in a lower group of the barriers/challenges to green buildings, which is similar to the results of this research.

SO1, SO2, SO3 were not only considered as the most effective solutions for Green Star development in New Zealand, but also they were found out to have significant impacts on sustainable construction in the US (Darko *et al.*, 2017), Singapore (Hwang and Tan, 2012), and Ghana (Ayarkwa *et al.*, 2017). SO4 was also mentioned in Singapore (Hwang and Tan, 2012) and Ghana contexts (Ayarkwa *et al.*, 2017).

SO5 and SO6 were seen as the two less effective solutions compared to the rest in this research. This is reasonable because SO6 was only mentioned in Ayarkwa *et al.* (2017), one of three recent studies suggesting solutions for green rating systems, including Ayarkwa *et al.* (2017), Darko *et al.* (2017), and Hwang and Tan (2012), while SO6 was not mentioned at all in those three studies. However, Lu *et al.* (2017) summarised the results of 10 studies in green BIM proving the potential of using BIM to support green building assessments.

It is noted that the benefits of using BIM for Green Star certification uptake were more recognised compared to the opposite way in which uptaking Green Star can raise the BIM adoption rate. BEI5, the benefit of using Green Star for increasing BIM adoption rate, has the lowest rank compared to the benefits of using BIM for Green Star certification uptake, including BEI 1-4.

The implementation of BIM for green rating systems certification uptake has been mentioned in previous studies. According to Gandhi and Jupp (2014), 88% of Green Star (Australia) points could be achieved by implementing BIM. Whereas, GhaffarianHoseini *et al.* (2017) stated that BIM utilisation could help to obtain 75% of the Green Star criteria. This is consistent with the results of this research, where BEI1 and BEI2 were ranked as the highest benefits regarding the integration of Green Star and BIM.

As mentioned in the Green BIM section, automatic green assessment can be developed with the use of BIM (Jalaei and Jrade, 2014, Chen and Hsieh, 2013, Nguyen *et al.*, 2015). As a result, the assessment time for green building applications can be reduced (Park *et al.*, 2012). These are consistent with the results of BEI3 and BEI4.

Regarding BEI5, it is the new finding of the research focusing on the opposite way in which the Green Star certification uptake could affect the BIM adoption rate. Two-thirds of 21 interviewees in Doan *et al.* (2019) research pointed out the impact of Green Star on BIM, which was then proved as a significant benefit of the integration by the respondents participating in the questionnaire in this research.

It is understandable when BAI1 is considered as the most significant barrier. Several studies have been conducted to examine the feasibility of the integration of green rating systems and BIM. Siddiqui *et al.* (2009) provided insights into the integration of sustainable design solutions and BIM for better sustainable project delivery processes. Whereas, Wong and Kuan (2014) tried offering a solution to streamline the BEAM Plus process to have it integrated with BIM. However, Azhar *et al.* (2011) concluded that “no one-to-one relationship exists between LEED certification process and BIM-based sustainability analyses” currently even though the potential of the integration was demonstrated. Therefore, combining Green Star and BIM processes should be researched to mitigate the existing problem.

According to the BIM maturity levels adapted by Doan *et al.* (2020), BIM can only be linked to sustainability once it reaches level 3 or 6D BIM. In other words, high BIM maturity level and high LOD are the prerequisite requirements for the integration. BIM is still encouraged practices in NZ; therefore, it is understandable when low BIM maturity level and LOD were perceived by the respondents in New Zealand. It is also clear from Table 4 that the majority of the construction practitioners in New Zealand are still in BIM level 2 and LOD 300 as the highest BIM maturity level and LOD they achieved.

Lack of BIM understanding was pointed out as a significant barrier to BIM adoption in New Zealand (Doan *et al.*, 2020) while lack of Green Star understanding was determined as a considerable barrier to Green Star uptake in New Zealand (Doan *et al.*, 2019). Therefore, the barrier of lack of understanding of the positive potentials of integrating BIM with Green Star is understandable. In the same vein, lack of client demand for either BIM projects or Green Star projects were identified by Doan *et al.* (2020) and Doan *et al.* (2019). As a result, the lack of client demand for projects that required both BIM and Green Star is reasonable.

Regarding the BAI3, all the requirements for the Green Star assessment could be found out using Green Star Technical Manual v3.1 (NZGBC, 2016). According to the manual, most of the credits could be assessed using short reports and drawings instead of modellings (NZGBC, 2016). Therefore, the Green Star certification seekers are not encouraged to use BIM to bring benefits for both NZGBC and themselves.

Optimising the Green Star process with help from construction stakeholders in the industry, SOI5, was perceived as the most optimal solution for Green Star and BIM integration. This is appropriate due to the current complex administration process of Green Star pointed out in Doan *et al.* (2019) research, which may prevent Green Star and BIM integration. Besides, the requirements for Green Star assessment should be adjusted to have them linked to BIM adoption, SOI3, and integrating Green Star and BIM processes, SOI2, can provide positive impacts on the integration. Wong and Kuan (2014) indicated the need for a standardised process of the integration of green rating systems and BIM.

Creating a Green Star material database was found out as one of the best solutions for the integration, SOI6, which was also suggested by Seghier *et al.* (2018) when green BIM papers, focusing mainly on LEED and BREEAM, were reviewed. Providing education, SOI1, and showcasing benchmark projects, SOI7, were suggested as solutions for BIM adoption (Doan *et al.*, 2020) and Green Star certification uptake in New Zealand (Doan *et al.*, 2019). There is no exception for suggested solutions for Green Star and BIM integration; SOI7 is considered as the second most effective solution while the score for SOI1 is not far behind.

As found out in the barriers/challenges to Green Star and BIM integration section that the BIM maturity level and LOD of BIM adoption in New Zealand still need to be higher for better Green Star and BIM integration, suggested by Doan *et al.* (2020). Therefore, executing BIM properly first is one of the prerequisite factors that should be focused, SOI4. Mandating BIM, SOI8, was revealed as an effective solution for the integration, which was also mentioned by Wu and Issa (2014) and Dummenahally and Glema (2016).

6 Conclusion and Recommendations

This research evaluated the significance of the results revealed by Doan *et al.* (2019) regarding Green Star uptake and its relationship with BIM adoption in New Zealand. Specifically, seven benefits, five barriers/challenges, and six solutions for Green Star uptake along with five benefits, six barriers/challenges, and eight solutions for BIM and Green Star integration were examined. The results indicate that all the findings revealed by Doan *et al.* (2019) are correct in which all the statements are significant to the test value 3.0 through the one-sample *t*-test.

All the benefits, barriers/challenges, and solutions were ranked based on their significance. Regarding Green Star uptake, providing a healthy place for end-users, reducing the environmental impact of the construction industry, and being a benchmarking system are the three most benefits perceived by the respondents. Amongst highly ranked barriers/challenges to Green Star certification uptake, perception to cost, lack of client demand, and lack of understanding were the topmost barriers. While the top-ranked solutions belong to showcasing the benchmark Green Star projects, educating clients on Green Star benefits, and providing incentives for Green Star certified projects.

Towards BIM and Green Star integration, building performance modellings (e.g., energy, lighting) used for Green Star assessment can be implemented using BIM was revealed as the most significant benefit amongst the examined benefits. Followed by the benefit that building models can incorporate all the information (e.g., Building Users' Guide, Commissioning report) for Green Star assessment of the project and the benefit of reducing Green Star assessment time. Regarding the barriers/challenges, having two separate processes is the most considerable one to Green Star and BIM integration. Low BIM maturity level and the lack of understanding are the next two barriers/challenges. To mitigate the existing problems, collaborating between construction stakeholders to optimise the Green Star certification process was implied as the best solution. While showcasing BIM-Green Star benchmark projects and providing Green Star material databases were highlighted as the second and third most effective solutions.

Based on the results of the research, it is recommended that NZGBC should be more active in involving construction stakeholders in registering for Green Star projects. Amongst the five identified barriers for Green Star uptake, understanding is one of the essential factors to the development of Green Star. While the complex administrative process of Green Star and lack of benchmark Green Star projects prevents people from seeking their projects certified. The government/local authorities should also encourage the Green Star practice owing to the determined benefits by providing incentives for Green Star certified projects. For example, 50% remission of levies to 5 Star or higher Green Star certified projects has been offered by Wellington City Council promoting the development of both Green Star and society towards sustainable development of the country (Doan *et al.*, 2019).

Clients and current practitioners are the key factors affecting the development of Green Star. They should keep updating with green buildings practices to enhance their knowledge to perceive the benefits of Green Star, leading to the involvement in Green Star practices. Although integrating Green Star with BIM was not considered as the leading solution to Green Star development by respondents, many studies proved its effectiveness. Therefore, it is suggested that both NZGBC and construction practitioners examine the possibility of the integration owing to the explored benefits.

According to the research results of BIM and Green Star integration, it requires effort from not only NZGBC but also both the government and construction practitioners to achieve the potential benefits of Green Star and BIM integration. The NZGBC could work with construction practitioners to streamline the Green Star process, revising the requirements for Green Star assessment, providing Green Star material database, and showcasing the BIM-Green Star benchmark projects. Whereas, the government could mandate BIM to certain types of construction projects to support the integration leading to the benefits to the construction industry and the society.

This research contributes to the current knowledge in two key ways. Firstly, this research provided insights into Green Star uptake and its relationship with BIM adoption in New Zealand. Drivers and challenges to Green Star and its relationship with BIM were identified. To increase the number of Green Star certified projects and BIM adoption rate, solutions to the existing problems were also proposed in this research. Secondly, the characteristics of Green Star were determined and evaluated, which then can be used as guidelines for NZGBC, the government/local authorities, and construction practitioners to have effective strategies towards sustainable development. The results here could be considered for the development of Green Star manuals and the New Zealand BIM handbook.

Because executing BIM correctly was pointed out as an effective solution for the integration, further research will focus on evaluating BIM adoption in New Zealand to consider their readiness for the integration. Specifically, a framework for BIM adoption in New Zealand will be developed to determine the essential factors impacting the success of BIM projects. Based on the information in the framework, BIM practitioners have insights into BIM implementation to plan suitable strategies for projects in order to achieve a higher BIM maturity level and LOD.

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