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Barriers and Strategies for Building Information Modelling Implementation: A comparative study between New Zealand and China

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Abstract
Building Information Modelling (BIM) is a sharing platform that can present a parametric 3D model with various project information in the form of a digital display. In recent years, BIM adoption has become increasing globally as the Architectural, Engineering, Construction (AEC) industry has recognised its benefits. Meanwhile, many challenges of BIM adoption in different countries have been well documented. To address the gap in literature, this study examines the differences and similarities of BIM adoption between New Zealand and China. A questionnaire was conducted across the two countries to investigate the barriers and strategies for the implementation of BIM. Data from 146 respondents was collected in New Zealand and China. The result shows that there is a difference in the perception of Knowledge Barrier, Technology Barrier, Internal Strategy and External Strategy (Legal/Technology viewpoint) between New Zealand professionals and Chinese professionals. The differences identified offer important implications for government agencies to promote BIM implementation and for BIM service providers to better target the end-users.

Keywords: Building Information Modelling, Challenges, Strategies, New Zealand, China

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1 Introduction

Building Information Modelling (BIM) as a high-tech tool has arisen in the Architecture, Engineering, and Construction (AEC) industry since its origin in the 1980s (Eastman, Teicholz, Sacks, & Liston, 2008). Together with emerging information technologies, such as cloud computing, the Internet of Things, Artificial Intelligence, it has penetrated into different life cycle stages of the building and take an essential role in construction management (Chen et al., 2020; Mohamed et al., 2017). It can be explained as a three-dimension representation whose function is sharing, exchanging, and storing the digital information of the project by some related software (Miettinen & Paavola, 2014). In recent years, BIM has become very popular in AEC industry all around the world (NBS, 2020). Juan, Shih, and Lai (2017) introduced the status of BIM implementation in the US, the UK, Germany, and France, and the results showed that the percentage of high-level users in these countries increased from 20% - 52% in 2015 - 2017. Furthermore, some countries and regions published the BIM mandatory policies from 2007 to 2017, such as Norway, Denmark, Finland, the US, South Korea, Singapore, the UK, Dubai, Italy, and France, successively (Sacks, Eastman, Lee, & Teicholz, 2018). Therefore, it is possible to argue that BIM will play a critical role in AEC industry in the coming year.

Many scientific works have highlighted the benefits and potential values of using BIM (Ahankoob et al. 2019; Mohammed 2019, Sherif et al. 2020). An annual survey on BIM use in New Zealand (BIM Acceleration Committee 2017), involving participants from engineering and construction businesses, revealed 57% of industry groups used BIM in all their projects, 38% of the client group had an awareness of BIM, who had used BIM-based applications in their 7% of construction sites. On the other hand, *The Business Value of BIM in China* 2015 (Dodge Data & Analytics, 2015) reported that 46% samples of the architects and 31% samples of the contractors were in the low-level of BIM, while less than 15% of their projects utilised BIM. As far as national development is concerned, obviously, these two countries are different: the developed country of New Zealand develops steadily, while the developing country such as China develops rapidly (The World Back, 20201). Moreover, the different aspects of population, economy, and culture may lead to various differences in the AEC industries.

The existing statistics (Dodge Data & Analytics, 2015, BIM Acceleration Committee 2017) show that BIM is not utilised so extensively in New Zealand nor China. However, there are attractive features that motivate this research. These two countries are located in the Asian-Pacific region, where frequent business relationships have taken place in several industries, including the AEC industry (NZ Government, 2006; Zhu, 2009; Gibson, 2016). This relationship was strengthened in 2007, as New Zealand was the first Western country to sign a free-trade agreement with China (Fiedler et al., 2021). However, the business culture in these two countries is significantly different, such as the forms of companies' structures, management and communication (Zhu, 2009; Zhu, 2021). Further, major differences between the opinions of AEC professionals in New

Zealand and China on BIM could influence the decision on the BIM adoption (Hong et al., 2020). Considering the similarities in BIM usage status and the differences in assessing the barriers of BIM implementation, this study selects the compare the barriers of BIM adoption between New Zealand and China.

To date, many efforts have been made to explore the barriers to implement BIM in China. For example, Li et al. (2017) conducted a survey to owners, designers, and contractors to analyse the BIM adoption in China and found the conflicting perceptions of BIM adoption barriers exist among the three groups. Wu et al. (2021) analysed the barriers to BIM adoption for industrialised building construction in China and identified the capital-related factors and the lack of support from owners are the main barriers. Tan et al. (2019) employed an interpretive structural modelling approach to explore the interrelationships among the barriers of BIM implementation in China's prefabricated construction and identified the lack of standards and domestic-oriented tools and shortage of research work in BIM are the main hindrances. Only one study was found to explore the barriers of BIM implementation in New Zealand, and few attempts have been made to this issue. Doan et al. (2020) carried out semi-structured interviews to investigate the critical perspectives of BIM adoption in NZ and identified BIM understanding was the most significant barrier. Furthermore, the interests in comparing the barriers of BIM adoption between countries is increasing. Hong et al. (2020) compared the BIM adoption decision-making process in Australia and China. Bui (2020) compared BIM implementation in infrastructure projects between Vietnam and Norway.

This study will fill the gap to identify the barriers and possible strategies for BIM implementation and compare the perception of these barriers and strategies between NZ and China. To achieve this goal, barriers and strategies were identified using a literature review to create a questionnaire. Using this questionnaire, data were collected in NZ and China and analysed, combining Exploratory Factor Analysis and Multiple Regression Analysis to assess the perceptions of these barriers and strategies between NZ and China.

2 Literature Review

BIM can be seen as a visual process including all components, disciplines, and systems by a parametric 3D model, and it can help all the project stakeholders (such as clients, contractors, consultants, and suppliers, etc.) to cooperate more accurately and efficiently than the traditional process of project management (Azhar, 2011). Further, BIM includes multiple dimensions that helps enhancing the construction process. For instance, the 4^{th} and 5^{th} dimensions account for scheduling and cost respectively (Sacks et al, 2018).

Many pieces of academic literature and case studies have stated the advantages of BIM implementation for several reasons. Several works have shows how BIM can be a valuable tool to reduce design clashes and to reduce project cost (Abanda, Tah, &

Cheung, 2017; Azhar, 2011; Bryde, Broquetas, & Volm, 2013; Lee, Kwangho Park, & Won, 2012). Other studies have shown how BIM can improve the quantity surveyor's work efficiency (Olsen & Taylor, 2017; Sacks et al., 2018) and run accurate simulations of the construction duration (Bryde et al., 2013). Finally, further studies have highlighted how BIM can enhance project quality (Lou, Xu, & Wang, 2017; Wang et al., 2013) and improve project safety (Benjaoran & Bhokha, 2010; Martínez-Aires, López-Alonso, & Martínez-Rojas, 2018). Through the previous literature, this article categorised the BIM barriers into five groups, which are insufficient knowledge and understanding, high capital cost, technology incompatible, cultural resistance, and legal requirements.

2.1 Insufficient Knowledge

A great number of academic research into knowledge issues has emphasised the insufficiency of BIM knowledge and the relevant IT knowledge (Ahmad, Thaheem, & Maqsoom, 2018; Curtis & Derek, 2015; Elmualim & Gilder, 2014; Jin, Hancock, Tang, & Wanatowski, 2017; Ku & Taiebat, 2011; Liao & Ai Lin Teo, 2018). Due to the inadequacy of BIM knowledge, this may result in the lack of experienced and skilled personnel as highlighted by Arunkumar, Suveetha, and Ramesh (2018) and Ku and Taiebat (2011). Another reason which was related to the knowledge issue can be extracted as the lack of BIM training (Liao & Ai Lin Teo, 2018; Rogers, Preece, & Chong, 2015). Moreover, some of the industrial stakeholders reflected the inadequate experience of using BIM in real projects (Ahmad et al., 2018; Chien, Wu, & Huang, 2014; Hamid, Taib, Razak, & Embi, 2018).

2.2 High Capital Cost

As mentioned above, BIM is a high-tech tool based upon the 3D display; for the furtherance of well-operating BIM, high configuration computer hardware and the relevant software are needed. However, the price of these pieces of software is usually high compared to the mainstream solutions in the market. Therefore, it may lead to the reason why some companies had not put the necessary investment in software licenses and hardware (Ahmad et al., 2018; Ahuja, Sawhney, Jain, Arif, & Rakshit, 2018; Arunkumar et al., 2018; Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth, 2017; Hamid et al., 2018; Stanley & Thurnell, 2014).

Besides, the high training cost could be one of the BIM implementation obstacles as well (Ahmad et al., 2018; Ahuja et al., 2018; Bosch-Sijtsema et al., 2017; Stanley & Thurnell, 2014). From the viewpoint of enterprise management, some of the company top management would not like to pour much of their money into the hardware, software, or training; that may be because they did not think they could gain the benefit in the short term (Arunkumar et al., 2018; Jin et al., 2017). Furthermore, due to the long construction duration, it is not easy to find enough historical data of Return on Investment (ROI) or BIM explicit value (Ahmad et al., 2018; Elmualim & Gilder, 2014;

Gerbov, Singh, & Herva, 2018; Ku & Taiebat, 2011).

2.3 Cultural Resistance

It is common that many complex technologies cannot be easily accepted by the majority of people in the initial phase. It can be seen in some companies that they insisted on their current software, which has already met their needs; thus, they did not think that the current one needed replacement immediately (Arunkumar et al., 2018; Stanley & Thurnell, 2014). Some staff may not accept the new workstyle, such as new BIM technology (Elmualim & Gilder, 2014; Jin et al., 2017). Furthermore, there can be found that some enterprises persisted in their previous daily routines and refused to alter their organisational structure and culture because of the conservative notion and uncertain fear (Arunkumar et al., 2018; Jin et al., 2017; Liao & Ai Lin Teo, 2018).

Due to the BIM feature of open digital collaboration, a lack of sharing information may lead to the BIM function not being maximised (Ahmad et al., 2018; Gerbov et al., 2018). Bosch-Sijtsema et al. (2017) claimed that some industrial stakeholders did not always provide the accessible 3D model for others' use; thus, resulting in inaccurate data input, low data quality, and extra design checking (Zhao, Feng, Pienaar, & O'Brien, 2017).

From the viewpoint of communication management, Gerbov et al. (2018) found that the majority of the samples recognised their lack of communication with the other designers and engineers, whose thesis was similar to Zhao et al. (2017). Furthermore, Liao and Ai Lin Teo (2018) confirmed the analogous concept that lack of trust, communication, and cooperation skills among the industrial stakeholders can hinder BIM, and another hindrance can be described as the staff's inadaptability to coordinate with other participants in front of the computer screen.

2.4 Technology and Legal Limitations

Another BIM barrier is due to the fact that some BIM pieces of software cannot meet the users' requirements because of lack of compatibility with other software (Ahmad et al., 2018; Arunkumar et al., 2018; Chien et al., 2014; Ku & Taiebat, 2011). Correspondingly, Stanley, and Thurnell (2014) mentioned the reason for the lower rates of reliability and efficiency might be because the BIM models lacked integration. In other words, the problems of data format, transformation, and non-interoperation could hinder the application intention of more possible users (Gerbov et al., 2018; Zhao et al., 2017).

What is more, Ahmad et al. (2018) claimed that the BIM feature of online operation could possibly lead to the leak or loss of digital data. Therefore, from the standpoint of company model management, it was hard to protect their intellectual property of the

3D visual model (Chien et al., 2014). In addition, Zhao et al. (2017) stated that the different versions of the BIM model creating from different kinds of BIM tools from different stakeholders in the same project could not adopt each other. Besides the unfriendly interface, the high configuration of the computers and network bandwidth was the essential requirement for a better-operation BIM platform (Bosch-Sijtsema et al., 2017).

2.5 Support Requirements

Most of the industrial professionals supposed that the government should offer more financial support and subsidy for promoting BIM; however, it appears to be inadequately reported in Malaysia (Rogers et al., 2015). Similar to India, BIM users argued that their government did not provide obtainable incentives for BIM development (Ahuja et al., 2018). As to Taiwan, Juan et al. (2017) revealed that the financial incentive would influence their attitude toward BIM utilisation. Moreover, professional associations or committees could play a vital role in new technology development (Rogers et al., 2015). Many studies clarified that one of the BIM hampers could be a lack of mandatory policies from the Government (Arunkumar et al., 2018; Rogers et al., 2015).

Although governmental promotion could accelerate BIM development, the market should raise awareness through those policies; however, the industrial market did not have the high BIM requirement (Agirachman, Putra, & Angkawijaya, 2018; Ahuja et al., 2018; Arunkumar et al., 2018; Bosch-Sijtsema et al., 2017; Rogers et al., 2015).

3 Research Methodology

This section illustrates the methodology used in this work to investigate and compare the barriers and strategies for BIM implementation in NZ and China. Section 3.1 provide a description of the questionnaire adopted in this study while the participants of this study and the procedure used to share the questionnaire is illustrated in Section 3.2. Finally, the statistic tools used to analyse the data are described in Section 3.3

3.1 Questionnaire design

Studies on human perceptions can be carried out using different research methods classified as qualitative or quantitative (Sutrisna, 2009). While qualitative studies often rely on interviews or focus groups, quantitative studies often use close-ended questionnaires (Davies and Hughes, 2014). Quantitative methods allow researchers to reach a greater number of participants in research studies as they rely on questionnaires that require a relatively short time to be completed by individuals. Further, the participants can participate simultaneously in the questionnaire, and a bigger sample can be reached by using online dissemination of questionnaires (Fellows and Liu 2015).

By far, barrier of BIM implementation research has been predominantly carried out with the questionnaire survey since the questionnaire is an effective instrument to gauge people's perceptions and the resulting information can be used to reveal the inter-correlations of their perceptions (Spector, 1994; Lee et al. 2015; Babatunde et al. 2018; Jin et al, 2019; Zou et al, 2019). Hence, in line with the existing literature, a BIM implementation questionnaire was designed to collect data for this study. This study adopted the quantitative methodology to build a new close-ended questionnaire assessing the perception of these barriers and strategies using the items already identified in the literature. The questionnaire developed in this study was used to investigate the barriers for BIM implementation between New Zealand and China. The advantage of using questionnaires is to have a large volume of quantitative data, allowing generalization of the findings. This is a fundamental aspect in this research to perform inference on the results on the entire population as specified in Section 3.2.

The questionnaire consists of 33 items which are based on the literature review. Table 1 shows 23 of these items which focuses on the barriers identified in the literature review. As such, these are divided into 5 groups following the structure of the proposed review in Section 2. Other 10 items were added in the questionnaire to investigate the perception of different strategies for implementing BIM, which aims at overcoming the 5 types of barriers. These strategies are listed in Table 2 and are divided into two types of strategies: Internal and External. The former ones are strategies that can be achieved within a company, while the latter ones are the ones requiring structural changes in the construction field, such as through construction organisations and policies.

Likert scale is a psychometric scale commonly used in research that employs questionnaires, which is the most widely used approach to scaling responses in survey research (Russell and Cohn 2012). 7-point Likert scale was adopted in this study as Seven-point Likert items have been shown to be more accurate, easier to use, and a better reflection of a respondent's true evaluation (Finstad 2010). The questionnaire requires the respondents to choose the different extent of agreement on each factor, in the presentation of the seven-point Likert items, whose possible responses include -3= strongly disagree, -2= disagree, -1= somewhat disagree, 0= Neutral, 1=somewhat agree, 2= agree, 3= strongly agree. Moreover, the questionnaire required the respondents to provide information regarding their demographics, education, and role in the construction industry.

A pilot study was run before starting the data collection to identify possible issues regarding the readability and understandability of the proposed questions. The pilot study was sent to one quantity surveyor and one designer in New Zealand, and three quantity surveyors in China, who provide comments on elements requiring improvements. The pilot study identified a couple of two new barriers (see C3 and W3 in Table 1), which were not originally included.

The final version of the questionnaire was implemented in SurveyMonkey in two languages: English and Chinese. Considering the respondents covering a wide geographic areas, an online questionnaire survey was adopted in this study. In fact, the literature shows that online questionnaires can be optimal when

the goal is reaching large numbers of potential respondents in a relatively quick timeframe and with low costs (Jamsen et al., 2007; Wright, 2005). The survey was disseminated by email and using social media, such as Twitter, LinkedIn, and WeChat, from August 2018 to October 2019.

3.2 Participants and Procedures

This work aims at assessing the perceptions of the barriers and strategies for BIM implementation and compare the perception between NZ and China. Industry professionals such as designers, contractors, consultants, and other related roles as well as academics with hands-on BIM experience were targeted for questionnaire survey. To achieve this goal we adopted statistical inference, which relies on the use of random sample from a population and then to use the information from the sample to make inferences on the entire population (Arsham, 2005).. To identify the sample required to investigate the proposed research question, two criteria were defined to identify participants for this study:

1) The sample needs to include participants having different roles (i.e., consultants, contractors, other roles) in the AEC industry.
2) The sample from the Chinese and NZ groups need to have similar characteristics in terms of demographics and participant roles, and working experiences.

Criterion 1 is fundamental as it allows to generalise the finding of this research to the full AEC industry. To achieves this goal, the questionnaire was made available online and disseminated through social networks (e.g., LinkedIn, WeChat and Twitter) and emailed to a random sample of construction and engineering companies operating in NZ and China (note: companies names cannot be disclosed for ethical requirements). The goal of this strategy was to achieve a relevant number of respondents belonging to different areas of expertise.

Criterion 2 is instead fundamental to ensure that the perceptions for BIM implementation can be compared between NZ and China. As such, the dissemination of the survey in the two countries follows the same adverting approach illustrated in the previous paragraph.

3.3 Data Analysis

This work combines the results of an Exploratory Factor Analysis and Multiple Regression Analysis. The first analysis was used to identify the latent factors explaining the variance of the answers provided for the 33 items described in Section 3.1. Further, a Multiple Regression Analysis was carried out to compare the NZ sample and Chinese samples for each latent factor identified in the Exploratory Factor Analysis. A brief description of these statistical tools is provided in Sections 3.3.1 and 3.3.2. respectively.

3.3.1 Exploratory Factor Analysis

The Exploratory Factor Analysis is a statistical tool that is used to identify and measure underlying factors (i.e. latent factors) using a (much larger) number of observed variables. These latent factors (such as perceptions and attitudes) are generally difficult to measure directly, but they can be inferred by observing their impact on measurable variables (Kline, 2014; Watkins 2018). In this study, the latent factors are the participants' perception of barriers and strategies for BIM implementation, while the observed variables are the 33 items specified in Tables 1 and 2.

Equation 1 provides the mathematical formulation for a Factor Analysis, which is carried out using a p x 1 vector **X** of observed measurements and a m × 1 vector **F** of latent factors.

$$\boldsymbol{X} = \boldsymbol{\mu} + \boldsymbol{LF} + \boldsymbol{e} \qquad \text{Equation 1}$$

where **μ** is a p x 1 vector a vector of means; **L** is a p × m matrix of loadings; and **e** is a p × 1 vector of residuals. In Factorial Analysis, the mean of **F** and **e** is equal to zero while the covariance metric of **F** and **e** are diagonal matric in the assumption of unrotated analysis. Under these assumptions, the covariance matrix of **X**, Cov(**X**), can be specified as in Equation 2

$$Cov(\boldsymbol{X}) = \boldsymbol{LL^T} + \mathrm{Cov}(\mathbf{e}) \qquad \text{Equation 2}$$

The Exploratory Factor Analysis is a powerful tool to identify the number of factors explaining the great majority of the variance of the observed variables. However, it can be used to associate each survey respondent a score for each latent factor identified in the analysis (i.e. factorial score). In other words, it is possible to estimate a matrix r p matrix of factorial scores **S** where p is the number of latent factors, and r is the number of survey respondents. These values can be thus used to compare respondents' groups (i.e. NZ and Chinese groups in this paper) and run Multiple Regression Analysis as explained in Section 3.3.2.

3.3.2 Multiple Regression Analysis

Multiple Regression Analysis is used in this paper to compare the factorial scores of the NZ sample and Chinese samples. This technique was used instead of simple statistical tests as the two groups had some differences in terms of their education, working experience and BIM experience (see Section 4.1 and Table e). As such, these variables were also included in the regression too to eliminate their impact while comparing the NZ and Chinese samples. In this paper, a regression analysis is carried out for each factor identified through the Exploratory Factor Analysis using the relative factorial scores. Assuming $\mathbf{S}_i$ the r × 1 vector which represents the i-th column of **S** matrix (note: this vector represents the scores of the i-th factor for all the respondents), it is possible to specify the equation of the multiple regression analysis as illustrated in Equation 3.

$$\boldsymbol{S_i} = \boldsymbol{X\beta} + \boldsymbol{\varepsilon} \qquad \text{Equation 3}$$

where **X** the matrix of the independent variables; $\boldsymbol{\beta}$ is the vector of parameter weighting the impact of each independent variable on the i-th factor; and $\boldsymbol{\varepsilon}$ is the vector representing the residuals. In this work, the independent variables include a Boolean variable describing whether the respondents are from the NZ or Chinese group, the education of the respondents, their working experience and BIM experience as illustrated in Section 4.3.

Table 1: BIM Barriers

Barriers	No.	Barrier Item	References
Knowledge Barriers	K1	Lack of BIM and IT knowledge	Ahmad et al. (2018); Curtis and Derek (2015); Elmualim and Gilder (2014); Jin et al. (2017); Ku and Taiebat (2011); Liao and Ai Lin Teo (2018)
	K2	Lack of experienced and skilled personnel	Arunkumar et al. (2018); Ku and Taiebat (2011)
	K3	Lack of training	Liao and Ai Lin Teo (2018); Rogers et al. (2015)
	K4	Lack of enough time for learning	Pilot Study
	K5	Inadequate project experience	Ahmad et al. (2018); Chien et al. (2014); Hamid et al. (2018);
Cost Barriers	C1	Lack of investment in software	Ahmad et al. (2018); Ahuja et al. (2018); Arunkumar et al. (2018); Bosch-Sijtsema et al. (2017); Hamid et al. (2018); Stanley and Thurnell (2014)
	C2	Lack of investment in hardware	Ahmad et al. (2018); Ahuja et al. (2018); Arunkumar et al. (2018); Bosch-Sijtsema et al. (2017); Hamid et al. (2018); Stanley and Thurnell (2014)
	C3	Lack of investment in BIM maintenances	Insight from the Pilot Study
	C4	Lack of investment in training	Ahmad et al. (2018); Ahuja et al. (2018); Bosch-Sijtsema et al. (2017); Stanley and Thurnell (2014)
	C5	Uncertainty of possible return on investment	Ahmad et al. (2018); Arunkumar et al. (2018); Elmualim and Gilder (2014); Gerbov et al. (2018); Jin et al. (2017); Ku and Taiebat (2011)
Willing Barriers	W1	Reluctance of companies to accept new BIM technologies	Arunkumar et al. (2018); Elmualim and Gilder (2014); Jin et al. (2017); Liao and Ai Lin Teo (2018); Stanley and Thurnell (2014)
	W2	Reluctance of companies to share their own information	Ahmad et al. (2018); Bosch-Sijtsema et al. (2017); Gerbov et al. (2018); Zhao et al. (2017)
	W3	Reluctance of companies to be honest in the open platform	Insight from the Pilot Study
	W4	Reluctance of companies to cooperate with other stakeholders	Ahmad et al. (2018); Bosch-Sijtsema et al. (2017); Gerbov et al. (2018); Zhao et al. (2017)
	W5	Lack of communication/ trust between the stakeholders	Gerbov et al. (2018); Liao and Ai Lin Teo (2018); Zhao et al. (2017)
Technology Barriers	T1	Data transfer, integration, format and interoperability problems	Ahmad et al. (2018); Arunkumar et al. (2018); Chien et al. (2014); Gerbov et al. (2018); Ku and Taiebat (2011); Stanley and Thurnell (2014); Zhao et al. (2017)

Barriers	No.	Barrier Item	References
	T2	Risk of data leak or loss	Ahmad et al. (2018); Chien et al. (2014)
	T3	Unfriendly user interface of BIM tools	Bosch-Sijtsema et al. (2017); Zhao et al. (2017)
	T4	High demands for technical competence (e.g. Hardware, Bandwidth, etc.)	Bosch-Sijtsema et al. (2017)
Legal Barriers	L1	Lack of government financial support and subsidy for BIM	Ahuja et al. (2018); Juan et al. (2017); Rogers et al. (2015)
	L2	Lack of professional bodies/ management commitment for the encouragement BIM	Rogers et al. (2015)
	L3	Lack of mandatory requirements from government	Arunkumar et al. (2018); Rogers et al. (2015)
	L4	Lack of market requirements (e.g. Client's requirements, etc.)	Ahuja et al. (2018); Arunkumar et al. (2018); Bosch-Sijtsema et al. (2017); Rogers et al. (2015)

Table 2: Strategies for BIM implementation

Barriers	No.	Strategy Items	Categories
Knowledge Barriers	I1	Offer more training time and opportunities	Internal Strategies
	I2	Provide BIM and related IT training	
Cost Barriers	I3	Increase investment in hardware and software	
	I4	Increase investment in personnel training	
Willing Barriers	E1	Raise awareness in the construction field through the professional association	External Strategies
	E2	Remove the barriers between companies and individuals	
Technology Barriers	E3	Improve the complexity and integration of BIM platform	
	E4	Strengthen BIM system maintenance for data security	
Legal Barriers	E5	Publish policies to provide financial or legal support	
	E6	Mandate BIM for public investment projects	

4 Result

This section provides the information regarding the data collected in this study and the results of the analysis carried with this data. The sample of the NZ and Chinese groups is provided in Section 4.1, while the Exploratory Factor Analysis is illustrated in Section 4.2. Finally, the comparison between NZ and Chinese data is performed in Section 4.3.

4.1 Sample

The questionnaire allowed the collection of data from 146 respondents: 85 from NZ and 61 from China. Table 3 illustrates the characteristics of the NZ and Chinese groups. The data shows that the two groups show similarities in terms of gender, age, and role in the construction industry. The data indicates that most of the respondents are male with age below 40 years. Further, the sample is made of 45% of respondents who work as consultants and 36% as contractors, while the remaining 20% have a different construction occupation. This is confirmed by the Chi-squared tests[1], which show p-values greater than 0.05. The data also illustrates that the two groups have differences in education, working experience, and BIM experience. In fact, the Chinese sample has higher percentages of participants having bachelor degrees and smaller percentages of respondents with a diploma. Another difference is that the NZ sample has participants with a higher number of years of experience. Finally, the Chinese sample has a higher number of respondents who have experience in BIM.

Table 3: Description of the NZ and Chinese groups

Variable	**Value**	**Full sample**		**China**		**NZ**		**Chi square test**
Gender	Male	103	71%	39	64%	64	75%	0.138
	Female	43	29%	22	36%	21	25%	
Age	18-30	57	39%	22	36%	35	41%	0.987
	30-40	71	49%	30	49%	41	48%	
	>40	15	10%	6	10%	9	11%	
Role	Consultant	65	45%	27	44%	38	45%	0.138
	Contractor	52	36%	26	43%	26	31%	
	Other	29	20%	8	13%	21	25%	
Education	Master or PhD	39	27%	12	20%	27	32%	0.004
	Bachelor	78	53%	43	70%	35	41%	
	Diploma	27	18%	6	10%	21	25%	
Working Experience	0-5 years	26	18%	14	23%	12	14%	0.006
	6-10 years	73	50%	24	39%	49	58%	
	Above 10 years	41	28%	17	28%	24	28%	
BIM experiences	Yes	69	47%	41	67%	28	33%	0.000
	No	77	53%	20	33%	57	67%	

4.2 Exploratory Factor Analysis

The basic assumption of factor analysis is that underlying dimensions or factors can be used to explain complex phenomena (Norusis, 2008). An Exploratory Factor Analysis was used to investigate the underlying correlation between the 23 items on BIM barriers and 10 items on strategies for promoting BIM, which has been used to process and rank barrier factors for BIM applications in several studies (e.g., Wu et al. 2021. This analysis was carried out to identify and measure underlying factors (i.e. latent factors), which can explain the great part of the variance of the observed 33 items using the mathematical formulation introduced in Section 3.3.1. The analysis was carried out using the Maximum Likelihood method, and Varimax was selected to obtain a rotated solution. The results indicate that the Exploratory Factor Analysis had a KMO of 0.784

[1] The Chi-squared test is a statistical hypothesis test used for categorical variables. This test is used to assess the probability of association or independence between two categorical variables. The null hypothesis for this test is that there is no relationship between the two variables. As such, p-value lower than a chosen significance level indicates the existences of a relationship (Zibran, 2007).

while the Bartlett's test of Sphericity test has a p-value of 0.000 (lower than 0.05)[2]. As such, both tests indicate that the data used in this work are suitable for Factorial Analysis.

Table 4 illustrates the loading results of each item with the eight factors identified through the Exploratory Factor Analysis. Using these loading results, it was possible to interpret these factors. The first factor presents relatively high loads (i.e., greater than 0.5) with I1-I4. This indicates that Factor 1 is an indicator of respondents' belief in Internal Strategies required to implement BIM. The second factor shows high loads mainly with K1-K5; as such, Factor 2 represents respondents' belief of Knowledge Barrier. The third factor shows high loads with W1-W5, and it is the Willing Barrier. Factor 4, instead, has included C1-C3 and C5. As such, it represents the respondents' perception of the Cost Barrier. Factor 5 and 6 have a high load for T1-T4 and L1-L4, respectively. This indicates that Factors 5 measures respondents' perception of the Technical Barrier while Factor 6 the perception of the Legal Barriers. Finally, Factors 7 and 8 shows loads with E2-E3 and E4-E6. As such, both of them provide a measurement of respondents' belief of the External Strategies required to implement BIM. Focusing on the loads, it is possible to argue that Factor 7 focuses more on strategies to cope with Willing/Technology Barriers while Factor 8 on strategies to cope with Legal/Technology Barriers.

Table 4- Rotated factor matrix

Items	Factor and Loads							
	1	2	3	4	5	6	7	8
I1	0.909							
I2	0.810							
I4	0.788							
I3	0.645							
E1	0.466							
K3		0.868						
K2		0.750						
K1		0.739						
K4		0.556						
K5		0.496						
C4		0.469						
W3			0.907					
W4			0.774					
W2			0.742					
W5			0.686					
W1			0.448					
C2				0.874				
C3				0.765				

[2] The Kaiser-Meyer-Olkin (KMO) Test and Bartlett's Test of Sphericity are a traditional test used to assess if data are suitable for data reduction technique such as Factor Analysis. KMO can range from 0 to 1 and the accepted rule of thumb is to have a KMO greater than 0.7 while the p-value of from Bartlett's Test of Sphericity must be lower than a chosen significance level to have suitable data (Watkins, 2018).

C1				0.733				
C5				0.544				
T2					0.927			
T1					0.724			
T3					0.570			
T4					0.429			
L3						0.864		
L1						0.651		
L2						0.505		
L4						0.363		
E2							0.823	
E3							0.724	
E6								0.748
E5								0.566
E4								0.489

4.3 NZ and China Comparison

The factors identified in Section 4.2 are here used to compare the NZ and Chinese groups. As explained in Section 3 this is possible by estimating a score for each respondent related to the 8 factors listed in Section 4.2. In the following analysis, the scores are used as dependent variables for multilinear regressions, while the independent variables included in these regressions are:

1. *NZ* which is equal to 1 if a respondent is from New Zealand and 0 otherwise;
2. *MasterPhd* and *Bachelor* which are dummy variables describing the education of a respondent;
3. *Experience 0-5* and *Experience 6-10* which are dummy variables describing the year of working experience of a respondent, i.e., 0-5 years and 6-10 years;
4. *BIM in a real project* is a dummy variable equal to 1 if a respondent had experience with BIM in his/her job.

It is worth highlighting that the variables are necessary independent variables as the two groups have differences in education, working experience, and BIM experience (see Section 4.1). As such, including this variable in the following regression models allows excluding their impact when comparing the NZ and Chinese perception of BIM challenges and strategies.

Tables 5 and 12 show the results of the eight regression models (one for each factor). These models allow identifying if there is a different perception of barriers and strategies for BIM implementation by looking at the sign and p-value of the NZ variable in the model. Tables 5, 6, 9 and 12 show that there are differences between the two groups in terms of the perception of the Internal Strategy, Knowledge Barrier, Technology Barrier, and External Strategy (Legal/Technology viewpoint). In fact, in these cases, the p-values of the NZ variable is below the significant level of 0.05. In other words, the models are showing that NZ and Chinese respondents had a different perception of these strategies and barriers. A positive value of the B parameter indicates that the NZ sample provided a higher score than the Chinese sample, while a negative value shows the opposite trend.

Tables 6 and 9 illustrate that the NZ group has a stronger belief that Knowledge Barriers are among the major challenges related to the use of BIM than the Chinese group. However, the NZ group has a weaker belief that Technology Barriers are among the major challenges related to the use of BIM than the Chinese group.

Tables 5 and 12 illustrate that the NZ group has a stronger belief that the Internal Strategy and External Strategy (Legal/Technology viewpoint) are good strategies for promoting BIM than the Chinese group.

Table 5: Internal Strategy comparison

Dependent Variable: Internal Strategy					
	B	Std. Error	Beta	t	p-value
(Constant)	0.027	0.260		0.104	0.917
NZ	**0.556**	**0.180**	**0.286**	**3.085**	**0.002**
MasterPhD	-0.165	0.236	-0.076	-0.701	0.485
Bachelor	-0.425	0.220	-0.220	-1.929	0.056
Experience 1-5	0.032	0.115	0.027	0.281	0.779
Experience 5-10	0.088	0.196	0.043	0.451	0.653
BIM in a real project	-0.237	0.169	-0.123	-1.399	0.164

Table 6: Knowledge Barrier comparison

Dependent Variable: Knowledge Barrier					
	B	Std. Error	Beta	t	p-value
(Constant)	-0.430	0.260		-1.657	0.100
NZ	**0.494**	**0.180**	**0.260**	**2.740**	**0.007**
MasterPhD	0.102	0.236	0.048	0.431	0.667
Bachelor	0.165	0.220	0.088	0.750	0.455
Experience 1-5	0.008	0.115	0.007	0.074	0.941
Experience 5-10	-0.214	0.196	-0.106	-1.090	0.278
BIM in a real project	0.172	0.169	0.092	1.016	0.312

Table 7: Willing Barrier comparison

Dependent Variable: Willing Barrier					
	B	Std. Error	Beta	t	p-value
(Constant)	0.116	0.268		0.432	0.667
NZ	**0.139**	**0.186**	**0.072**	**0.746**	**0.457**
MasterPhD	0.135	0.244	0.063	0.555	0.58
Bachelor	-0.283	0.227	-0.149	-1.243	0.216
Experience 1-5	-0.003	0.119	-0.002	-0.023	0.982
Experience 5-10	-0.107	0.202	-0.052	-0.529	0.598
BIM in a real project	-0.088	0.175	-0.047	-0.506	0.614

Table 8: Cost Barrier comparison

Dependent Variable: Cost Barrier					
	B	Std. Error	Beta	t	p-value
(Constant)	-0.001	0.271		-0.002	0.998
NZ	**-0.094**	**0.189**	**-0.049**	**-0.496**	**0.621**
MasterPhD	0.12	0.247	0.056	0.485	0.628
Bachelor	-0.063	0.23	-0.033	-0.274	0.785
Experience 1-5	0.13	0.12	0.11	1.081	0.282
Experience 5-10	0.181	0.205	0.089	0.883	0.379
BIM in a real project	-0.142	0.177	-0.075	-0.804	0.423

Table 9: Technology Barrier comparison

Dependent Variable: Technology Barrier					
	B	Std. Error	Beta	t	p-value
(Constant)	-0.016	0.260		-0.063	0.949
NZ	**-0.367**	**0.180**	**-0.191**	**-2.035**	**0.044**
MasterPhD	0.518	0.236	0.242	2.195	0.030
Bachelor	0.252	0.220	0.133	1.144	0.255
Experience 1-5	0.084	0.115	0.071	0.733	0.465
Experience 5-10	0.180	0.196	0.088	0.920	0.360
BIM in a real project	-0.286	0.169	-0.150	-1.688	0.094

Table 10: Legal Barrier comparison

Dependent Variable: Legal Barrier					
	B	Std. Error	Beta	t	p-value
(Constant)	-0.301	0.263		-1.146	0.254
NZ	**0.021**	**0.183**	**0.011**	**0.115**	**0.908**
MasterPhD	0.148	0.239	0.072	0.621	0.536
Bachelor	0.151	0.223	0.082	0.677	0.500
Experience 1-5	-0.005	0.116	-0.005	-0.045	0.964
Experience 5-10	0.172	0.198	0.087	0.865	0.389
BIM in a real project	0.226	0.171	0.123	1.321	0.189

Table 11: External Strategy (Willing/Technology) comparison

Dependent Variable: External Strategy (Willing/Technology)					
	B	Std. Error	Beta	t	p-value
(Constant)	0.180	0.259		0.692	0.490
NZ	**-0.261**	**0.180**	**-0.141**	**-1.451**	**0.149**
MasterPhD	0.220	0.236	0.107	0.932	0.353
Bachelor	0.017	0.220	0.009	0.078	0.938
Experience 1-5	0.028	0.115	0.024	0.244	0.808
Experience 5-10	-0.090	0.196	-0.046	-0.460	0.647
BIM in a real project	-0.161	0.169	-0.088	-0.954	0.342

Table 12: External Strategy (Legal/Technology) comparison

Dependent Variable: External Strategy (Legal/Technology)					
	B	Std. Error	Beta	t	p-value
(Constant)	-0.491	0.248		-1.979	0.050
NZ	**0.370**	**0.172**	**0.205**	**2.147**	**0.034**
MasterPhD	0.492	0.225	0.244	2.184	0.031
Bachelor	0.457	0.210	0.256	2.174	0.032
Experience 1-5	-0.202	0.110	-0.181	-1.844	0.068
Experience 5-10	-0.145	0.187	-0.075	-0.775	0.440
BIM in a real project	0.116	0.162	0.065	0.716	0.475

5 Discussion

This study identified the main challenges of BIM implementation in China and New Zealand, including Knowledge Barriers (e.g., lack of experienced and skilled personnel), Cost Barriers (e.g., lack of investment in software and hardware), Willingness Barriers (e.g., reluctance to share information), technology Barriers (e.g., interoperability problems), and Legal Barriers (e.g., lack of mandatory requirements from the government). Considering the significant benefits brought by BIM implementation on the one hand and the considerable barriers to BIM implementation, we carried out an in-depth examination of the differences between the challenges of BIM implementation perceived by professionals in China and in New Zealand.

The results indicate that the respondents from New Zealand believe that knowledge is a more important challenge of BIM implementation than respondents from China. Another significant result is that respondents from New Zealand believe that technology is a less important challenge of BIM implementation than respondents from China.

These differences might root in the cultures of the two countries: New Zealand is more people-focused, and China believes that 'science and technology are the primary productive forces. For example, New Zealand construction companies tend to have lower costs, increased productivity, and improved quality by training their employees, whereas Chinese construction companies tend to lower costs, increase productivity, and improve quality by using new technologies.

These findings have several implications. From the government perspective, it is suggested that New Zealand government agencies should promote the use of BIM by offering plenty of opportunities for employees from the industry to know BIM, learn BIM, and be confident with using BIM. In contrast, it is suggested that Chinese government agencies should promote the use of BIM by offering subsidies for those who improve the complexity and integration of BIM platforms. From the industry perspective, construction companies in New Zealand are advised to spend more time and budget in training their employees to use BIM; nevertheless, Chinese construction companies are advised to allocate a high amount of budget to use the most advanced

BIM technology. BIM software companies targeting users in New Zealand should provide an unparalleled training system for their users, whereas those targeting users in China should offer more technical support.

It is further found that respondents with a master's degree or PhD believe that knowledge is a more important challenge of BIM implementation than the other respondents. The reason behind this result may be that respondents with postgraduate education are more familiar with technology and hence more emphasise its importance.

The potential solution for promoting the wide usage of BIM is investigated. Respondents from New Zealand believe that internal strategies, that is, improving employees' knowledge and increasing investment, and government support, such as legal support and mandating the use of BIM, are more effective solutions for promoting the wide usage of BIM than respondents from China. Moreover, respondents with a bachelor's degree, master's degree, or PhD believe that legal strategies, such as legal support and mandating the use of BIM, are more effective solutions for promoting the wide usage of BIM than the other respondents. These results all have significant implications for the government, construction companies, and BIM software providers.

Substantial efforts have been made on exploring the barriers of BIM adoption in both developed and developing countries. The international comparison of the barriers indicated that the most critical barriers were similar but ranked differently in different countries. Lack of related technical personnel in projects was identified as a top barrier in UK (Eadie et al. 2013). Apart from the main barriers, such as lack of support from clients and the capital-related factors, knowledge and skills are also critical factors, which is consistent with our study. Lack of incentive of BIM implementation was identified as the top barrier in the developing countries, such as Iraq (Hatem et al. 2018) and Saudi Arabia (Banawi 2017). Similar results were also found in a study that employed the network theory to examine BIM implementation in China. Insufficient government guidance and unwillingness to use BIM from the project manager are identified as main challenges in BIM adoption. To promote the wider adoption of BIM in developing countries, the government can promulgate policies that can facilitate the adoption of BIM on construction projects, just like the United Kingdom and other developed countries (Olanrewaju et al., 2020).

6 Conclusion

Nowadays, emerging information technologies, such as cloud computing, the Internet of Things, Artificial Intelligence, BIM, have penetrated into different life cycle stages of the building and take an essential role in construction management. BIM, creating and managing information on a construction project, are being increasingly adopted globally in the AEC industry. Different strategies have been used to promote BIM in several countries. However, many challenges have been reported which are delaying the full implementation of BIM in the industry.

This study investigated the barriers and possible strategies for BIM implementation. This work focuses on the comparison of the perception of these barriers and strategies between NZ and China. This was achieved by using a questionnaire with respondents from both countries collecting data from participants having different roles in the AEC industry. The findings show that there is a significant difference between New Zealand and Chinese professionals in the perception of the Knowledge and Technology Barriers, as well as in the perception of Internal Strategy and External Strategy (Legal/Technology viewpoint). Further, the results of this study do not show evidence of a significant difference in terms of Willing, Cost and Legal Barriers. Finally, there was no difference in the perception of External Strategy (Willing/Technology) between Chinese and NZ respondents.

The differences identified in this work offer important implications for government agencies to promote the use of BIM, for construction companies to use BIM, and for BIM service providers to better target the users in both countries, especially when trying to enhance the business relationship in the AEC industry. Further, the awareness of these different perceptions represent a useful insight for future construction collaborations and agreements between China and NZ

Regardless of the use of random sampling in this work, one limitation of this study is that the two groups have differences in education, working experience, and BIM experience. However, the analysis technique used to compare the two groups (i.e., regression analysis) managed to account for these differences avoiding this could have affected the results. Further studies are still required to investigate how other factors (e.g., the role in the AEC industry, working experience) might affect these perceptions.

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