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ABSTRACT

Purpose

There are several technologies positively impacting the management of construction projects. Building Information Modelling (BIM) is one such technology, slowly changing project delivery. However, enhancing knowledge transfer within the construction industry is crucial because of the characteristic slow uptake of innovation. Therefore, this study aims to establish the effectiveness of the knowledge transfer mechanism for BIM implementation in construction organisations.

Design/methodology/approach

The study adopted a quantitative research method where a structured questionnaire was distributed to construction professionals. A PLS-SEM path analysis was used to test the direct and indirect relationships of Computer Self efficacy (CS), Perceived Ease of Use (PEOU), Knowledge Transfer (KT), and BIM usage.

Findings

The study found that computer self-efficacy could improve knowledge transfer, which will, in turn, increase the implementation of BIM within construction organisations. However, in terms of knowledge transfer, individuals' confidence and ability to use BIM inspires them to share the knowledge of BIM they had received through training. Furthermore, the study found that the ease of interacting, learning, and being skilful with BIM may not necessarily ensure the actual transfer of knowledge.

Originality/value

This study provides valuable insights into knowledge transfers (BIM implementation) in the construction industry. It will enhance the use of BIM systems and related knowledge through effective training amongst construction practitioners. Other previous studies have focused on challenges and barriers to BIM implementation, this current study goes deeper into establishing the effectiveness of the knowledge transfer mechanism for BIM implementation in construction organisations.

Keywords: BIM, Knowledge Transfer, Training, and New Zealand.

Introduction

It is becoming increasingly difficult to ignore the importance of knowledge transfer within construction organisations. Construction organisations are often constrained by their unique characteristics, such as "fragmentation, use of low technology, antagonistic procurement policies, nature of contracts and the tight inspection process" (Nesan, 2005 p.48). Another defining feature is the short-term relationships between project teams (Gann and Slater, 2000; Yusof, Lai & Mustafa, 2017). Construction is also believed to be complex because many stakeholders from diverse disciplines are involved (Garcia & Mollaoglu, 2020; Mashali et al., 2022; Shehzad et al., 2019). These stakeholders must interact to achieve the defined task within scope and project objectives. These complex interactions involve bulk documentation and often fragmented information (Al-Ashmori et al., 2020), which impedes effective knowledge sharing in construction organisations, especially with the organisations' limited exposure to knowledge management literature (Nesan, 2005). According to Davenport and Prusak (1998), it is pertinent to involve people in knowledge-sharing processes in construction activities by motivating them to seek, transfer and use available knowledge. Thus, improving the performance of construction organisations through knowledge management is significant. Therefore, designing a knowledge-sharing system for construction organisations could consider changes to their organisational behaviours and work practices (Nesan, 2005).

An important tool that has been used to respond to the growing complex nature of construction projects is information and communication technology (ICT) (Ikediashi & Ogwueleka, 2016; Taxén & Lillieskõld, 2008). However, the construction industry has significantly shifted from ICT to Building Information Modelling (BIM) (Succar, 2009). BIM is being adopted on construction projects and practices to assist with managing construction projects and for geometric modelling of a building's performance (Bryde, Broquetas, & Volm 2013). BIM thus constitutes state of the art in digital design techniques. In the Industry 4.0 era, BIM represents a crucial mainstream for propelling the construction industry. The integration of BIM across the spectrum of construction processes, from design to operation, aligns with the built environment's sustainability aspirations, which has gained interest in recent fields of research development (Panteli, Kylili, & Fokaides, 2020). Considerable resources have been committed to training for BIM and other digital technologies (Olugboyega & Windapo, 2021; Puolitaival & Forsythe, 2016; Roslan et al., 2019). Knowing how much of this knowledge is being transferred within organisations is important. Such knowledge justifies resource commitment and sustained innovation in construction organisations (Al-Mohammad et al., 2021; Zhou, Yang & Yang, 2019). Several studies discussed general knowledge transfer within the construction industry (Owusu-Manu et al., 2018; Saini, Arif & Kulonda, 2020; Yap & Toh, 2020). However, there are insufficient studies to determine the extent of BIM knowledge transfer within construction organisations in New Zealand (Rotimi et al., 2019). Hence, this study aims to fill this knowledge gap by establishing knowledge transfer mechanisms for BIM in New Zealand construction organisations. The study investigates post-training knowledge transfer among BIM implementers in the construction industry, which is premised on Technology Acceptance Model (TAM) principles.

Literature review

Classification of Knowledge within construction organisations

North & Kumta (2014) explain knowledge as an experience gained within or outside a work environment, which can be through collective learning and /or personal experiences. Knowledge can similarly be described as intuition, judgments, and skills acquired through formal education and experience Chadha and Ritika (2012), Shelton (2001), and Pillania (2008). Through this, individuals are able to make informed decisions that could improve the effectiveness of their actions. Rotimi (2016) suggests that experiences are continually changing. They are non-static. Old knowledge is frequently replaced with new knowledge due to changes in business processes, operating environment, supply chain and stakeholder relationships and, importantly, the evolution of technology (see also Lee and Wong, 2015). Gottschalk (2005) also argues that knowledge combines all of the aforementioned. However, several aspects of knowledge management remain unexplored. The current study believes that knowledge is what an individual knows (Saini, Arif & Kulonda, 2020; Schroeder de Witt et al., 2019). If knowledge is properly harnessed, it can be valuable to individual groups and organisations because knowledge is reusable, renewable, and a cumulative resource. (Rotimi 2016). This notion is adopted for the current research, as it considers some of the knowledge characteristics that encompass the aspects of some of the definitions developed in extant literature.

Literature classified knowledge as tacit or explicit along a continuum (Woo, et al., 2004; Lee & Wong, 2015; Nonaka & Von Krogh, 2009). According to Nonaka & Von Krogh (2009), the knowledge continuum varies depending on how easy it is captured, recorded, and shared. Explicit knowledge is documented (Lee & Wong, 2015, p. 712) and can also be described as codified knowledge that is easily transferred or transmitted through formal and systematic language (Woo et al., 2004). In addition, Chou (2005) asserts that explicit knowledge could include declarative knowledge, data, facts, or information. Similarly, Dhanaraj et al. (2004) and Mårtensson (2000) describe explicit knowledge as being structured and containing fixed contexts that are readily available, exploitable, and shared. As a result, through information technology, the internet, documents, images, audio, printed manuals, or videos, explicit knowledge can be stored (Davenport & Prusak, 1998; Lee & Wong, 2015; Mårtensson, 2000).

Conversely, tacit knowledge refers to skills, experiences, insights, intuition, and ideas that reside in people's minds (Lee & Wong, 2015; Mårtensson, 2000; Ragab & Arisha, 2013). According to Nonaka & Von Krogh (2009), tacit knowledge is rooted in actions, emotions, ideas, procedures, routines, values, and commitment. Tacit knowledge is often gained from interactions and collaboration with colleagues, managers, customers, and suppliers (Mårtensson, 2000). Hence, the belief that tacit knowledge can be transferred or shared through socialisation, collaboration, and communication (McAdam & McCreedy, 1999). Lee & Wong (2005) explains that tacit knowledge is dependent on the value that is placed to generate and provide this form of knowledge internally (owner-managers and employees) and externally (customers and suppliers. Despite the belief that tacit knowledge is an integral part of construction organisations, little recognition has been given to it (Woo et al., 2004). Knowledge in the construction industry is often experienced-based and tacit due to the unique nature of construction projects. Throughout the life cycle of construction projects, organisations rely on their professional experiences, intuition, and/or other forms of tacit knowledge in the delivery of satisfactory projects (Woo et al., 2004).

Considering these discussions on the classification of knowledge in the construction industry, the current study takes the position that effective transfer of knowledge is significant to knowledge management in the construction industry. According to Fruchter and Demian (2002), effective knowledge transfer could provide competitive advantages through design improvements and efficient management of constructed facilities.

The interest of BIM within the construction industry

There has been an increasing interest in building information modeling within the construction industry. The increased interest could be attributed to benefits derived from BIM implementation within organisations. BIM implementation could deliver the best value for end-users by assisting construction organisations as they develop their business processes and products (Abbasnejad et al., 2021; Othman et al., 2021). Several countries such as Finland, Norway, Denmark, Netherland, and the UK recognise the benefits of BIM. They have implemented its use for their public sector buildings and/or government projects. Despite these derived benefits, BIM implementation is still believed to be at its early stages and rudimentary in New Zealand (Gu & London, 2010; Sebastian, 2011; Miller et al., 2013; Harrison & Thurnell, 2015). Recent literature offers confirmatory findings that the level of BIM implementation is comparatively low in New Zealand (NZ) (Doan et al., 2020; Ma et al., 2022). For example, Ma et al. (2022, p.8) suggest that the knowledge barrier is a major challenge to BIM implementation, and the industry will need to "know BIM, learn BIM, and be confident with using BIM." Similarly, Abbasnejad et al. (2021) indicated that BIM implementation could only be successful through a socio-technical system approach. An organisation requires "strategic initiatives, cultural readiness, learning capacity, knowledge capability and collaborative network relationships" in BIM implementation (Abbasnejad et al. 2021, p.426). Further, organisations must overcome the challenges around the financial outlay for BIM, as this was reported in several studies (Ghaffarianhoseini et al., 2017; Semaan et al., 2021). Also, in the context of facility management, BIM training is considered a significant barrier because of the cost outlay in NZ (Durdyev et al., 2022). Most literature on BIM in NZ extensively covers the challenges and barriers to its implementation, with training consistently highlighted (Durdyev et al., 2022; Doan et al., 2020; Rotimi et al., 2019). However, Rotimi et al. (2019) study are seminal in their focus on post-training knowledge transfer among BIM adopters in NZ.

Knowledge of BIM training transfer within the Construction Industry

The prevalent approach for improving and updating knowledge and skills within work environments is the training of individuals (Arthur et al., 2003; Rowold, 2007). Knowledge created by individuals, when amplified, connects with an organisation's knowledge system (Nonaka & Krogh, 2009). Training is equally crucial for BIM implementation because Its exploration requires end-users' associated skills, knowledge, experience, and capabilities (Rotimi et al., 2019). BIM training is focused mainly on updating construction parties' capacity and knowledge base. While it is challenging to determine end-users' skills and knowledge acquired from training, assessing the post-training performance and use of learning in the work environment is even more critical. The capability of end-users in the work environment to use acquired skills and knowledge evidence knowledge transfer (Rotimi et al., 2019). Holistically, knowledge transfer is the flow of information within organisations or the interchange of information between suppliers and receivers of knowledge (Szulanski, 2000). Two key elements are involved in knowledge transfer: transmission and absorption. Davenport and Prusak (1998) describe transmission as knowledge being transferred to potential receivers, while absorption is receiving knowledge. Both elements have to be in place for effective knowledge transfer (Oliva & Kotabe, 2019), which are central to the current study. Training becomes significant within construction organisations as it facilitates knowledge transfer and generates incentives for collaboration toward common goals. Therefore, training transfer measures the effectiveness of organised training interventions. It assesses how knowledge and skills are transferred and applied in the work environment.

Training transfer, being the goal of training interventions, improve the impact assessment of training on the performance of individuals and their organisations. Training is only meaningful when end-users take the knowledge and skills learned in training episodes and apply them to situations in their workplace (Arasanmi et al., 2016). End-users have to maximise their knowledge of different systems software associated with BIM, but users with the required skillset can only realise this. Jasperson, Carter and Zmud (2005) posit that the effective transfer of skills acquired through information systems training for whole systems benefit remains challenging. Therefore, this paper aims to establish knowledge transfer mechanisms for BIM in construction organisations.

Measures

As used in this study, BIM training transfer explains how practitioners who have received some form of training on BIM are sharing their BIM knowledge within their organisations. The measures described in this section relate closely to those contained in Technology Acceptance Model (TAM) principles (Davis, 1989) to understand post-training knowledge transfer among BIM implementers in the construction industry. The TAM model has been used in the construction industry in relation to BIM implementation (Ahmad et al., 2022; Azzran, Tah, & Abanda, 2018; Son et al., 2014; Lee et al., 2012). TAM continues to evolve but remains the major model for predicting human behaviour to accept or reject technology. This study contends that BIM end-users with increased computer self-efficacy from BIM knowledge will be more willing to apply the skills and knowledge they gained in a BIM task environment. Figure 1 depicts the model for the current study. Thus, two exogenous variables are computer self-efficacy and perceived ease of use, which are antecedents of knowledge transfer and transfer performance (BIM Usage). In the model, knowledge transfer is positioned as a mediating construct. The following subsections briefly describe the measures used in this study investigation.

Computer Self-efficacy (CS)

Computer self-efficacy is an adaptation of Bandura's (1982) concept of self-efficacy, which refers to an individual's abilities and beliefs about their abilities to perform a task. Thus, CS is defined in this study as the degree to which an individual believes they can perform specific tasks using computers (Wu et al., 2016). Son et al. (2014) state that an improved CS needs to be considered to make it conducive to BIM implementation. Further, the study by Son et al. (2014) produced results that corroborate the findings of the previous work in this field by Srour, Haas, & Borcherding (2006) on the importance of CS in the implementation of BIM by the various stakeholders within the project team and organisations in the construction industry. The successful implementation of BIM can be linked to the confidence that an individual has in being able to use BIM (Pikas, Sacks, & Hazzan, 2013; Son et al., 2014). Thus, we posit a relationship between CS and BIM implementation.

Hypothesis 1. Computer self-efficacy will influence (H1a) knowledge transfer and (H1b) BIM implementation among construction work teams.

Perceived Ease of Use (PEOU)

According to (Son et al., 2014, p. 3), perceived ease of use is "the degree to which a user believes that a technology will be easy to understand and will require no effort to use." Several studies have shown that perceived ease of use can significantly impact individuals' attitudes toward the implementation of BIM (Davis, 1989; Prihatono & Adi, 2021; Scherer, Siddiq, & Tondeur, 2019; Yuan, Yang, & Xue, 2019). One of the interesting findings from the articles by (Thong, Hong, & Tam, 2002) and (Wang & Song, 2017) is the indirect influence of PEOU on user acceptance of digital libraries. Also, Prihatono & Adi (2021) confirms PEOU's indirect effect on the intention to use BIM. Following Wang and Song (2017), it can be inferred that individuals would deem a system as valuable or useful if it is easy to use. Hence, importance was placed on the PEOU to be considered for BIM implementation in organisations within the construction industry (Prihatono & Adi, 2021; Wang & Song, 2017). PEOU of BIM can be improved if organisations are more flexible in accepting new technologies (Lee & Yu, 2016). Thus, we hypothesize that there is a relationship between PEOU and BIM implementation.

Hypothesis 2. PEOU will influence (H2a) knowledge transfer (and (H2b) BIM implementation among construction work-teams

Knowledge Transfer and BIM Implementation

BIM has been developed over the last three decades to capture, store, share and manage building information over the whole life cycle of a building (Jack & Cheng, 2015). However, industry stakeholders have not fully adopted BIM, and its full benefits have not been realised (Ghaffarianhoseini, 2017). BIM offers a better collaborative environment to stakeholders in the design and construction phase (Chong et al., 2016). Al-Saeed, Edwards, and Scaysbrook (2020) discussed the limited knowledge in implementing BIM amongst construction organisations, particularly among small to medium-sized enterprises (SMEs). Due to the complexities of the processes involved in technology adoption, training and support in its use are necessary to ensure conversant usage (Suebin & Gerdsri, 2009). This study assumes that the focus on knowledge transfer would harness BIM implementation in the construction industry.

Several articles (Arayici & Coates, 2012; Coates, Arayici, & Koskela, 2010; McClements, Cunningham, Comiskey, & McKane, 2017) have shown how the transfer of knowledge through the Knowledge Transfer Partnership (KTP) programme, developed in the UK, could be utilised within the construction industry through BIM implementation. However, these articles did not discuss the use of BIM as a knowledge transfer tool independent of the KTP. The article by McClements et al. (2017), in their analysis of 19 survey responses, concluded that there was a clear relationship between the levels of knowledge transfer within the construction sector and barriers that could hinder the use of the KTP in the implementation of BIM. The only article that addresses the direct relationship between knowledge transfer and BIM implementation is the article by Ismail (2020). Ismail's (2020) findings highlighted the importance of BIM as an automation system for knowledge transfer. Therefore, there is no clear association between knowledge transfer and BIM implementation in reviewing the literature. Thus, we hypothesize that:

Hypothesis 3. Knowledge transfer will influence BIM implementation among construction work teams.

Mediating Role of Knowledge Transfer (KT)

Knowledge transfer or sharing refers to the act of sending or receiving knowledge, irrespective of whether the knowledge is understood or used (Foss et al. 2010). Surakka (2006) explains that the construction industry is knowledge-based that relies heavily on the knowledge input of the different stakeholders and participants in project teams. Further, Carrillo and Anumba (2002) posit that the construction industry entails collaboration with and amongst clients and stakeholders, with various roles in projects. Each project team consists of random individuals who usually disband at the project's conclusion, often without discussing, distributing, or sharing the lessons learned (Carrillo & Anumba, 2002). Kamara et al. (2002) addressed the challenge of transferring knowledge to go beyond those experienced amongst the different project teams and the fundamental issues of transferring a client's business needs into technical specifications (design intent and rationale). Surakka (2006) challenged why knowledge management is in its infancy, given that the construction industry is known for continually repeating similar or the same costly mistakes across various projects. Surakka (2006) suggests that the industry does not leverage knowledge acquired from past projects or within different parts of organisations. BIM is one tool that could alleviate these challenges as it can be used to plan, design, construct, and operate facilities and, more importantly, encourage the integration of all stakeholders on a project (Al-Maabreh, 2019). Knowledge and information sharing are essential within construction industry both at the project, organisational and industry levels (Carrillo & Anumba, 2002). Under these circumstances, we expect that KT is a crucial measure for implementing BIM within construction organisations. We hypothesize as follows:

Hypothesis 4. Knowledge transfer will mediate the effect of (H4a) computer self-efficacy and (H4b) perceived ease-of-use on BIM implementation.

These hypotheses are conceptualized diagrammatically in Figure 1.

Figure 1: Proposed conceptual model

Research Method

Sample and survey

This study aims to establish the effectiveness of the knowledge transfer mechanism for BIM in construction organisations. Construction industry participants were recruited via an online survey to achieve this aim. The online questionnaire contains structured questions explicitly directed to previous BIM training participants within New Zealand construction organisations. The online questionnaire approach was chosen because it reduces time and human efforts for collecting and managing data and is more efficient due to fewer errors in data transfer (Regmi et al., 2016). The survey participants were construction practitioners who had received BIM training within the last two years. The participants were sampled from attendees of a private BIM training programme with 120 participants. We distributed the survey to 100 willing participants and received a 21% response rate (21 construction members responded to the survey).

The questionnaire consisted of two sections, one for collecting background information of the respondents and the second one for the data on variables in the theoretical research model. The participants' age, gender, level of education, and profession were the demographics included in the first section. In addition, the experience of the construction workers in BIM was obtained. In order to develop the theoretical framework, extant literature was studied to understand knowledge sharing within construction organisations. Guided by the literature, four hypotheses were developed. The four main theoretical model constructs are Computer Self Efficacy (CS), Perceived-Ease of Use (PEOU), Knowledge Transfer (KT), and BIM Usage (BIM). The measurement scales for these constructs were drawn from previous related studies, and these are given in the Appendix. CS, PEOU, and BIM had four indicators each, whereas KT had six indicators. To ensure consistency, all items in the study were measured using a five-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The face and content validity of the scales were confirmed by two subject experts. Subsequently, a pilot study was conducted with three participants to check the quality of the questionnaire and the feasibility of conducting the survey. However, this study did not suggest any significant change. A few revisions were made to the measurement scales during the reliability and validity assessment of the model constructs, which are explained under the measurement model evaluation section below.

Analysis of data

The descriptive statistical analysis on demographic variables: Age, Gender, Education, Experience (work experience with BIM in the construction industry), and industry was performed using SPSS. Hypotheses related to the BIM training effectiveness were tested using Partial Least Square Structural Equation Modeling (PLS-SEM) with SmartPLS software. Since this study examines causal relationships between latent constructs measured using multi-item scales, a structural equation modeling approach should be followed. PLS-SEM is a bootstrapping-based non-parametric structural equation modeling technique, which is thus free from distributional assumptions and has considerably low sample size requirements compared to conventional covariance-based structural equation modeling (Hair, Ringle, & Sarstedt, 2011). The total sample that could be obtained in this study was 21. However, this sample was adequate for the study as the data are of high quality (experienced BIM users and trainees). PLS-SEM's minimum sample size requirement is very low, especially where the respondents are highly knowledgeable in the field. In addition, the strictest procedures followed in the model validating process can also be considered as an additional justification for the adequacy of the sample.

Measurement model evaluation

The validity and the psychometric properties of the survey items were tested using relevant statistical criteria facilitated by SmartPLS. The internal consistency reliability of the variables was evaluated using composite reliability (CR) and Cronbach's alpha value. These values corresponding to all the model constructs are given in Table 1. The indicator reliability of the constructs was examined using factor loadings. All the CR values were higher than the minimum threshold (0.7), confirming the internal consistency of the four variables: CS, PEOU, KT, and BIM. In PLS-SEM, factor loadings greater than 0.6 adequately confirm the indicator reliability (Hair, Ringle & Sarstedt, 2011). There was only one item in each CS (CS3=0.581) and PEOU (PE2=0.523) constructs below the cut-off factor loading, which was removed from the final analysis. Construct validity of the measurement model was established through convergent and discriminant validity. Convergent validity is the degree to which individual items in a questionnaire measure the same underlying construct, and this can be evaluated using Average Variance Extracted (AVE) and CR (Hair et al., 2018). As shown in Table 1, the AVE of each research model construct is above 0.5, and all the CR values are above 0.7, which are the minimum thresholds. These results satisfactorily confirm the convergent validity of the construct.

Table 1. Reliability and convergent validity assessment

On the other hand, discriminant validity is a measure of the extent to which the individual items that are intended to measure one latent construct do not measure a different latent variable at the same time (Ronkko & Cho, 2022). In the current study, the discriminant validity of the four model constructs was tested using Heterotrait-Monotrait (HTMT) ratio. Due to the high sensitivity and specificity of the HTMT ratio relative to the alternative discriminant validity assessment criteria (Ab Hamid, Sami, & Sidek, 2017) was used in this measurement model evaluation. The ratios lower than 0.9 adequately confirm the discriminant validity. All the values shown in Table 2 are below this cut-off point, hence confirming a sufficient level of discriminant validity.

Table 2: Discriminant validity assessment

Results and Discussion

Sample profile

The sample's composition based on five demographic factors is shown in Table 3. According to this profile, around 86% of the survey participants were between 35 and 54 years of age, and around 90% were males. More than 90% of participants had the highest educational qualification above the Diploma level. The participants were well experienced in BIM systems, and more than 90% had more than one year of experience, and approximately 50% of participants had five or more years of BIM experience. The survey participants were from different areas of the construction industry, and more than 95% were from architecture, engineering, building construction, and project management backgrounds. These features of the sample profile indicate that the selected participants are adequately educated and experienced to provide relevant feedback on the knowledge transfer and technologies used in the construction industry.

Table 3: Demographic composition of the dataset

PLS-SEM path analysis

The PLS-SEM path analysis was used to test the previously described four main hypotheses (H1, H2, H3, and H4). These concerns the direct and indirect relationships between the following four variables. Computer self-efficacy CS, which explains the degree to which an individual believes they can use computers (in this case BIM systems) to perform specific tasks. In other words, successful implementation of BIM can be linked to individuals' confidence levels, which may be pivotal to their transfer of acquired knowledge to others within their workplace. The second variable, perceived ease of use PEOU refers to perceptions held by individuals on the value or usefulness of systems. Thus, BIM implementation may be influenced by such positive perceptions of BIM which could also be influenced by knowledge transfer. Knowledge transfer KT, which is the third within the construct, is a mediating variable that is crucial for implementing BIM within construction organisations. Also, it reflects the level of collaboration that exists within the workplace. Finally, BIM usage is the dependent variable which describes the level of implementation of BIM systems through knowledge transfer within NZ construction organisations.

To measure the direct and indirect relationships between the variables, hypotheses H1 had two sub-hypotheses, H1a and H1b, for the direct effects of CS on KT and BIM, respectively. In addition, H3 presumed a direct effect of KT on BIM, while H4a hypothesised a mediating effect of KT on the relationship between CS and BIM usage. Following the proper procedure of testing mediators, the model without the mediator variable (KT) was fitted first, resulting in a marginally significant direct effect of CS (p-value = 0.093) on BIM. In the next step, the mediator variable (KT) was added, and it provided the empirical model presented in Figure 2. According to this result, the direct effect of CS on KT (p-value = 0.010) and KT on BIM (p-value = 0.000), and the indirect effect of CS on BIM (p-value = 0.035) were highly significant. It is also noted that both direct and indirect significant path coefficients of CS are positive. Thus, hypotheses H1a, H3, and H4a related to the indirect impact of computer self-efficacy and the direct impact of knowledge transfer on BIM implementation are well-supported by the PLS results. However, the direct effect of CS on BIM was not significant in this final model, and hence H1b is not supported. This implies that KT fully mediates the relationship between CS and BIM. Therefore, computer self-efficacy would improve knowledge transfer, which will, in turn, increase BIM implementation. However, computer self-efficacy is not a factor that is directly involved in improving BIM usage in NZ.

Therefore, it can be concluded that the confidence and ability to use BIM inspires the NZ users to share their knowledge related to that technology. This knowledge transfer leads to frequent and intensive use of BIM training skills of users on their jobs resulting in higher implementation success of BIM among NZ construction work teams.

Figure 2: PLS-SEM Path Analysis Result

Table 4 summarizes the full hypothesis test results, including the path coefficients and the p-values corresponding to all the direct and indirect effects of CS and PEOU on BIM implementation.

Table 4: Results of hypothesis tests

**p-value < 0.10; **p-value < 0.05; ***p-value < 0.01*

Hypotheses H2a and H2b were formulated to test the direct effect of PEOU on KT and BIM, respectively. The initial path model fitted without the mediator provided a p-value of 0.496, indicating an insignificant effect of PEOU on BIM. In the final model (Figure 2), both H2a (p-value = 0.203) and H2b (p-value = 0.265) were not supported. This implies that there is no statistically significant direct effect of perceived ease of use on either knowledge transfer or BIM usage. Furthermore, the hypothesis concerning the mediated effect of perceived ease of use on BIM usage through knowledge transfer (H4b) is not supported (p-value = 0.238). According to these results, the ease-of-use of BIM technology has not been effective in transferring knowledge or increasing overall BIM usage within NZ construction organisations. This finding corroborates Abbasnejad et al.'s (2020) affirmation that learning capacities and knowledge capabilities are required for successful BIM implementation. Although this result is better recommended for further investigation considering the small sample used in this research, some possible explanations for the observed insignificant associations are found. The ease of interacting, learning, and being skillful with BIM may not necessarily ensure knowledge transfer. Rather, organisational factors such as trust and collaboration, support structures, and a high propensity to share knowledge have been identified as antecedents of effective transfer of technological knowledge (Goh, 2002). Transfer of tacit knowledge is crucial in construction projects where storing and reusing that tacit knowledge is a vital feature in BIM technology (Ho, Tserng, & Jan 2013). The complexity in transferring tacit knowledge through BIM may be indicated by the nonsignificant relationship between PEOU and KT. However, ease of using technology would usually increase the frequency and intensity of using that technology. Thus, the association between PEOU and BIM usage could be found significant in a future study utilizing a larger sample.

The structural model evaluation based on the coefficient of determination (R^2) and the cross-validated redundancy (Q^2) values are given in Table 5, and these values indicate a moderate level of predictive relevance of the path model fitted. In particular, knowledge transfer is more predictable (R^2 = 57.2%) than BIM usage (R^2 = 48.8%) based on the existing level of computer self-efficacy. However, the contribution of perceived ease of use in predicting both KT and BIM usage is not substantial as found in this NZ study.

Table 5: Evaluation of the structural model.

The findings of this study provide valuable insights for managing knowledge transfers in the NZ construction industry and in other similar jurisdictions. Particularly the ability to use BIM systems and effectively transfer related knowledge within construction organisations. The study shows that knowledge transfer is vital for the successful management of building construction projects and supply chains as quick and accurate modeling of project-specific information (as may be offered by effective BIM adoption) will be extremely useful in those projects. In the final section of this study the implications of the current NZ findings are elaborated.

Conclusion, Implications and Future Research

The current study aims to establish the effectiveness of the knowledge transfer mechanism for BIM in construction organisations. The research participants were construction industry professionals who had received previous BIM training through a private training organisation. This study identified the variables associated with the transfer of knowledge within organisations through extant literature based on technology acceptance model principles. A conceptual model was developed from which four hypotheses were formulated. The hypotheses were tested using Partial least square based structural equation modeling.

The study found that the knowledge transfer mechanism for BIM in construction organisations was effective, considering that the initial conceptual postulation was confirmed. Hence, BIM end-users with increased computer self-efficacy from BIM knowledge will be more willing to apply the skills and knowledge they gained in a BIM task environment. Computer self-efficacy could improve knowledge transfer, which will, in turn, increase the implementation of BIM within construction organisations. However, in terms of the transfer of knowledge, individuals' confidence and ability to use BIM inspires them to share the knowledge of BIM they had received through training. This assertion supports Ma et al. (2022), Pikas et al. (2013) and Son et al. (2014) about gaining confidence through knowing BIM and learning BIM. This study concludes that the above knowledge sharing leads to more frequent and intensive use of BIM training skills rather than the notion that computer self-efficacy directly influences BIM usage.

Research implications

These findings have implications for on-the-job training and workshops that could encourage knowledge transfer above and beyond knowledge acquisition of digital technologies in the construction industry. Training has been mentioned severally in previous studies as a major challenge and barrier in BIM implementation. A major insight from this current study is the inclusion of modules on knowledge management and knowledge transfer which can enhance current industry practice. Therefore, more investments into such targeted training for knowledge transfer are recommended. Moreso, BIM maturity levels have increased, and the benefits realisable for BIM implementation are better understood in the NZ construction industry. This study believes that this approach will justify the investment in training programmes in BIM.

An interesting finding also emerged from the current study. The significance of trust and collaboration support structures that could improve the propensity to share knowledge amongst BIM users came to the fore. This is particularly significant in NZ because of its relatively small industry size. There are closely knit relationships built on trust and collaborations, where project teams usually move from project to project in NZ. These close relationships could be leveraged upon toward BIM knowledge transfer.

Further, this study contends that the ease of interacting, learning, and being skilful with BIM may not necessarily ensure the actual transfer of knowledge unless organisational policies and structures around the collaboration of project teams are strategic and focused. In an industry where tacit knowledge is rife, a culture of knowledge transfer needs to be cultivated within organisations' members. This is crucial to effective knowledge management in construction organisations.

In summary, this study provides valuable insights into knowledge transfers (BIM implementation) in the NZ construction industry. It is hoped that the study findings will enhance the use of BIM systems and related knowledge through effective training amongst its construction practitioners. Being one of the few studies in NZ that goes deeper into establishing the effectiveness of the knowledge transfer mechanism for BIM implementation in construction organisations, it will be a valuable resource for future investigations. .

Future research

The current study has its limitations. Firstly, the sample size limits its generalisation across the whole construction industry without further future investigations. Despite this limitation, the current study provides a meaningful beginning to the exploration of effective knowledge transfer mechanisms in construction settings. Demonstrating the benefits accruable from training could enhance the much-needed innovation in digital technologies required by the construction industry. Secondly, other dimensions of the technology acceptance model could be explored critically to improve innovation adoption in the construction industry. We recommend that this could be explored beyond the training knowledge transfer that was the focus of the current study.

Appendix: *Operationalisation of variables*

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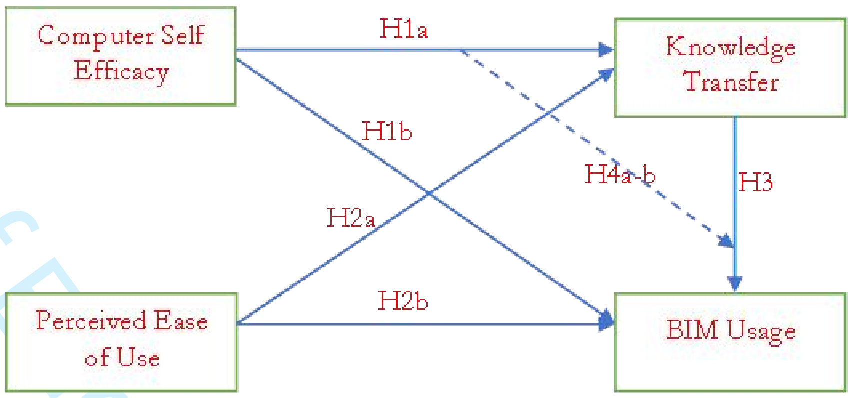

Figure 1: Proposed conceptual model

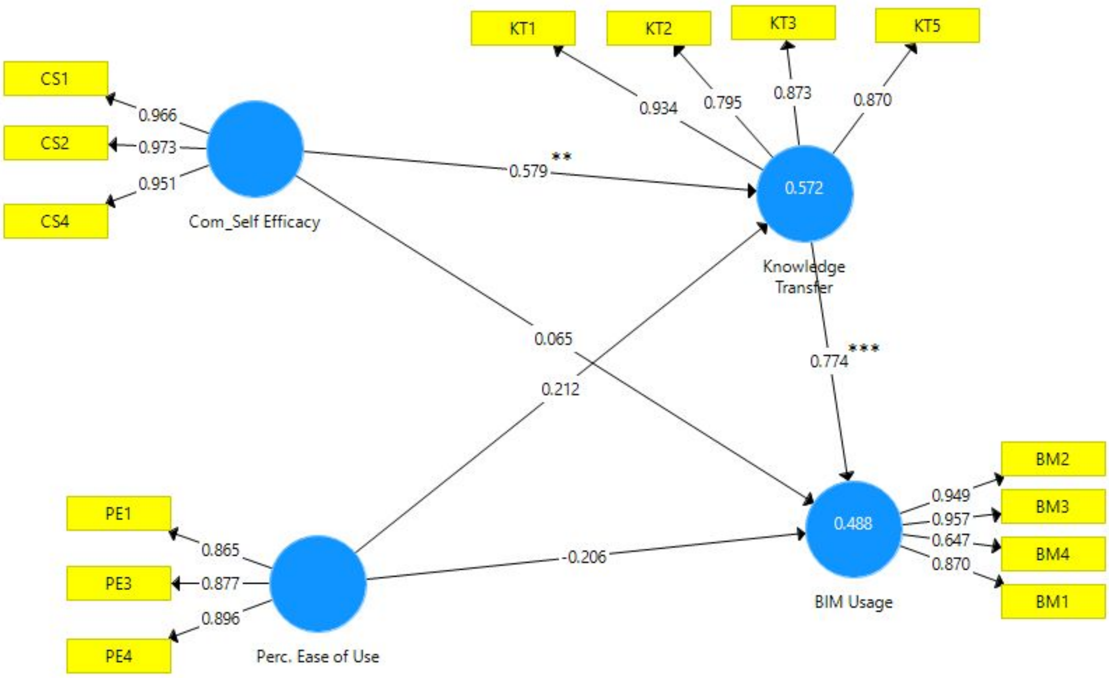

Figure 2: PLS-SEM Path Analysis Result

Table 1. Reliability and convergent validity assessment

Construct	Cronbach's alpha	Composite Reliability	AVE
Computer self-efficacy (CS)	0.961	0.975	0.928
Perceived ease of use (PEOU)	0.859	0.911	0.773
Knowledge transfer (KT)	0.891	0.925	0.756
BIM usage (BIM)	0.882	0.921	0.748

Table 2: Discriminant validity assessment

	BIM	CS	KT
CS	0.519		
KT	0.764	0.796	
PEOU	0.378	0.871	0.726

Table 3: Demographic composition of the dataset

Factor	Category	Percentage (N)
Age (Years)	25 – 34	4.76% (01)
	35 – 44	42.85% (09)
	45 – 54	42.85% (09)
	55 – 64	9.52% (02)
Gender	Female	9.52% (02)
	Male	90.48% (19)
Education	High School	9.52% (02)
	Certificate/Diploma	47.62% (10)
	Degree	23.81% (05)
	Postgraduate	19.05% (04)
BIM experience	< 1 year	9.52% (02)
	1 – 2 years	14.29% (03)
	2 – 5 years	23.81% (05)
	5 – 10 years	38.09% (08)
	>10 years	14.29% (03)
Profession	Architecture	19.05% (04)
	Engineering (civil, electrical,	28.57% (06)
	etc.)	19.05% (05)
	Construction (buildings)	15.79% (05)
	Project management	4.76% (01)
	Others	

Table 4: Results of hypothesis tests

Path	Direct effect (p-value)	Indirect effect (p-value)	Result
CS → KT	0.579** (0.010)		H1a is confirmed.
CS → BIM	0.065 (0.43)	0.448** (0.035)	H1b is not confirmed. H4a is confirmed
PEOU → KT	0.212 (0.203)		H2a is not confirmed.
PEOU → BIM	-0.206 (0.265)	0.164 (0.238)	H2b and H4b are not confirmed.
KT → BIM	0.774*** (0.000)		H3 is confirmed.

**p-value < 0.10; **p-value < 0.05; ***p-value < 0.01*

Table 5: Evaluation of the structural model.

Dependent variable	R^2	Q^2
KT	0.572	0.376
BIM	0.488	0.325

Appendix: Operationalisation of variables

Model construct	Indicator coding	Description
Computer Self-efficacy (CS)	CS1	I am very confident in my abilities to use BIM.
	CS2	I am very confident in my abilities to use BIM, even if I only have online instructions for reference.
	CS3	I am confident to use BIM if somebody shows me how to use it first.
	CS4	I can usually deal with most difficulties I encounter when using BIM.
Perceived Ease of Use (PEOU)	PE1	It is easy to do what I am doing using BIM.
	PE2	Learning to use BIM is clear and understandable.
	PE3	Interacting with BIM is easy.
	PE4	It is easy to become skilful at using BIM.
Knowledge Transfer (KT)	KT1	I frequently participate in BIM knowledge sharing activities.
	KT2	I spend a good deal of time conducting BIM knowledge sharing activities with my peers.
	KT3	I usually actively share my BIM knowledge with others.
	KT4	I usually involve myself in discussions about various BIM topics.
	KT5	My co-workers are now comfortable using BIM because of me.
	KT6	I usually involve myself in solving complicated BIM issues.
BIM Usage	BM1	I use BIM training skills on the job intensively every day.
	BM2	I use BIM training skills on the job frequently every day.
	BM3	I spend a lot of time using BIM training skills on the job.
	BM4	I strongly recommend the use of BIM training skills on the job.

Dependent variable	R^2	Q^2
KT	0.572	0.376
BIM	0.488	0.325

Manuscript ID JEDT-06-2022-0287 entitled "BIM Knowledge Transfer in Construction Industry: A Partial Least Square Analysis."

	Reviewers' Comments	Authors' Responses
	Reviewer 2	
1	**Methodology:** I still believe that the methodology is not innovative and the structure of the survey and the pilot study is burnt out; however that doesn't not prevent the current work to be published.	Thank you for your observations and for confirming that the paper can be published as is. We have made further improvements to the results section and the implication of the study to enrich the manuscript.
	Reviewer 3	
1	**Comments:** In general, despite the author(s) having improved the paper based on the comments, I believe the main point of the paper i.e. discussion on the construct of Bim knowledge transfer still lacking. More insight should be provided and it needs to be correlated with the NZ context. This could add to the BIM body of knowledge within a different geographical context.	Thank you for your feedback (see response below).
2	**Results** Are results presented clearly, correct technically and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper? Do the charts, tables and figures add value and enhance the interpretation of the results?: Despite more analysis has been included, I believe one main aspect that still missing is the discussion. I would suggest having a specific section on the discussion to discuss the model construct: i.e., Computer Self efficacy (CS), Perceived Ease of Use (PEOU), Knowledge Transfer (KT), and BIM usage. The discussion on these constructs also needs to be aligned with the NZ context.	Thank you for this feedback which follows on from your comments in (1) above. The model construct has been described in the opening paragraph of the 'PLS-SEM path analysis' subsection. We believe this provides a good lead into our presentation and discussion of the path analysis. We have gone further to improve the discussion by locating the findings within the NZ context. We believe there is now clarity on how this could add to the BIM body of knowledge within a different geographical context.
3	**Implications for research, practice and/or society:** Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: I would suggest having a separate section instead of combining it with the conclusion section.	Thank you for the feedback. Based on your suggestion, we have created additional two sub sections: *Research implication*, where we discussed the implications of the study, and *Future research* work, where we highlighted the limitations and area for future studies.