Have we reached a technological plateau? A situational awareness approach to overcome the barriers limiting the development of BIM-based plugins

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Abstract

Purpose: The construction industry has embraced Building Information Modelling (BIM) as a practical methodology towards digitalisation. However, critics believe BIM has reached a plateau in addressing distinctive construction challenges. As a result, literature has seen an increase in the development and use of BIM-based plugins. Overall, the plugins have been critical in delivering custom-built solutions to longstanding construction challenges. The objective of this study is to empirically investigate this trend and the potential barriers undermining the wider development of BIM plugins, by that contributing to a stimulating research topic and a growing knowledge gap.

Design/methodology/approach: Methodologically, the study utilised a quantitative approach to collect data through a carefully designed questionnaire. The study achieved a sample size of 39 experts who have been involved in developing, experimenting, and publishing BIM-based plugins for specific construction activities.

Findings: The findings led to the identification of the key barriers to using BIM-based plugins and the identification of the key strategies to overcome them across the three Situational Awareness (SA) phases. Results also suggest that the development and use of plugins are destined to increase, and the research community can now rely on the insights of this paper as a departure point to address the technological plateau in BIM-related research.

Originality/value: This is the first study to empirically identify and assess the barriers undermining the wider development of BIM-based plugins. The study contributes to theory by building on SA, by challenging existing wisdom and fostering new knowledge around strategies to overcome the evaluated barriers.

Keywords: Building Information Modelling (BIM), BIM-based plugins, Construction industry, Built Environment

Introduction

The construction industry, like all other major industries, is pressured to exploit digital innovations to realise technological advancement. Over a decade ago from writing, the adoption of Building Information Modelling (BIM) signalled a departure point for a substantial transformation, which has since led to key enhancements in various areas (Gledson, 2022). Predominantly, areas include enhanced productivity (Manzoor, Othman and Pomares, 2021), collaboration (Bakhshi et al., 2022; S.L. Zulu et al., 2023), and decision-making (Schneider and Leyer, 2019; Gledson et al., 2023). Nonetheless, despite BIM's popularity, which was not kept unnoticed by the wider research community, an argument exists to challenge this perception. Koutamanis et al. (2023, p.8) propose an interesting argument, challenging the popular acuity that 'BIM is the goal' in Architecture, Engineering, Construction and Operation of buildings (AECO), and state that "BIM points the way to the future of AECO computerisation, but BIM should not be considered the goal. We should learn from BIM and move on in theoretically as well as practically more innovative ways".

Over the years, vast literature explored BIM in construction, recording undeniable evidence of its critical transformational role (Demirkesen and Tezel, 2022), and irrefutable advantages offered to a traditionally longstanding change-resistant social system (S. Zulu et al., 2023). It has been described as "a paradigm shift in the way buildings are designed, constructed and maintained" (Elmualim and Gilder, 2014, p.197). However, fears exist around the post-BIM adoption era, and the research community needs to be decisive in predicting the future of BIM in construction management (Smyth et al., 2017), calling BIM's sustained efficacy in addressing emergent construction challenges into question. To respond to such calls, it is imperative to explore the criticism around the propensity of BIM to sustain its dominating role as a critical technological solution to contemporary construction challenges. Accordingly, this study investigates whether the complexities of modern construction practices have caused a technological plateau in BIM.

A belief exists among critics that an imbalanced pace between the evolvement of BIM and that of complex construction challenges has led to outstripping the ability of the former to address the impacts of the latter. For instance, to name a few, shortcomings of BIM have been evident in instances like those presented by Hwang et al. (2019), Smyth et al. (2017), and Wu et al. (2014). These studies specifically underline challenges related to BIM's limitations in dealing with human and organisational errors, addressing specific contextual demands and complexities, and tackling issues concerning data exchange and automation, respectively. Such discourse has been challenged by the increasing trend of developing and using BIM-based plugins (Saad et al., 2022). The term plugins, sometimes referred to as add-ins (Ali et al., 2020), resemble a behaviour to defy the perceived inadequacies of BIM, initiating a paradigm of endless possibilities to overcome the ever-increasing nature of construction challenges. Nonetheless, knowledge around this trend is limited, necessitating research to understand and assess their flow of development and use.

Further to the research by Saad et al. (2022), who have systematically reviewed the plugins' areas of practice and prospects, this study aims to empirically investigate the barriers undermining the broader use of BIM-based plugins in construction, and the indicative strategies to overcome these barriers, thereby contributing to the advancement of knowledge in this area by underscoring the importance of addressing the barriers to adopting BIM-based plugins in construction to maximise the benefits of such a technology. The following sections introduce the reader to the existing relative body of knowledge, and subsequently conceptualise current research efforts against the Situational Awareness (SA) theory. This is then followed by elaborating the adopted methodology, and finally the discussion of the results in contrast to prevailing knowledge. The study is believed to be a pioneering empirical attempt to seek an understanding of the trend of using BIM-based plugins in construction management research.

BIM's technological plateau: In search of the problem

The capabilities of BIM have been argued to be powerful and effective, yet critics are wary about future endeavours. In a recent extensive review of innovations in construction, Wang et al. (2023, p.12) infer that BIM is projected to spark innovative practices across the sector, yet guidance is still lacking towards achieving a "BIM-enabled construction innovation". Similarly, Gao et al. (2022, p.438) explain that elevating BIM applications is by enhancing the relative capabilities to realise a "virtuous circle of investment-return, thereby promoting BIM application". The intention of this section is hereby to present a review of BIM's perceived shortcomings.

Because "nothing is perfect" (Suhir et al., 2015, p.69), even BIM is prone to attain shortcomings when research looks "beyond technological optimism" (Sackey and Akotia, 2017, p.274). For instance, Gonzalez-Caceres et al. (2019, p.272) declare the effectiveness of BIM, but state that "not everything is working fluently, some aspects demand additional tasks and others represent challenges", and Hwang et al. (2019, p.5) state that "BIM is unable to resolve human and organisational errors". Other indicated challenges argued are related to "automation of data capture", "maintenance of information", and "modelling of uncertain data" (Volk et al., 2014, p.124), alongside "BIM information overload storage problem" and "security of BIM information sharing" (Ding and Xu, 2014, p.3). Unlike the views of technological optimists, arguments confirm that BIM shortcomings exist (Saad et al., 2022), yet a clear proposition for a relatively effective solution does not yet exist, advocating Dainty et al. (2017, p.706), who state that “too much technocratic optimism could have damaging consequences for the industry”. Therefore, challenging current understanding involves uncovering the necessary practices aimed at rectifying the limitations of BIM.

Sackey and Akotia (2017, p.290) call for future research to provide “better clarity on the challenges that may confront the construction organisational boundaries across time as BIM mutates into the realm of development, deployment and utilisation”. Interestingly, these challenges may not always undermine implementation, as Khosrowshahi and Arayici (2012, p.633) rather perceive this as an opportunity by stating that “this issue has on the one hand become a battleground for major BIM providers to bid for supremacy, but on the other hand facilitated their collaborative working”. Such an opportunity can be contemplated by the emerging trend of BIM plugin development that drives researchers to improvise custom-built solutions for the bespoke challenges faced across the sector (Juliano Lima da Silva et al., 2017). This brings into line the statement by Rodrigues et al. (2021, p.253), who share that the development of their relative plugin is driven by "the lack of BIM objects" dedicated to specific construction challenges. These arguments are carefully sewn, firmly discussed, and conceptualised in the following sections.

BIM-based plugins: In search of a solution

An emerging trend meant to address BIM's limitations and shortcomings is the development and use of BIM-based plugins. The trend gained popularity in 2014 and has since then progressed to drive the interest of the construction community (Saad et al., 2022). Plugins are believed to excel in key construction areas such as design

(Sameer and Bringezu, 2021), automation (Zhao and He, 2021), health and safety (Pham et al., 2020), communication (Ma et al., 2017), planning (Chileshe et al., 2019), life cycle (Gao et al., 2019), and maintenance (Liu and Issa, 2014). Hence, this section aims to reinforce the arguments that BIM-based plugins can offer endless possibilities for BIM to address its shortcomings.

BIM-Based Life Cycle Cost Analysis (BIM-LCCA) has been developed to enable BIM users to specify the exact location of the project through a map interface (Rad et al., 2021). Similarly, BIM-Based Claims Management System (BIM-CMS) has been developed so that BIM capabilities can be utilised to manage the extension of time claims in the construction industry (Ali et al., 2020). Additionally, a tool that integrates BIM with Web Map Service (BIM-WMS) has been developed to help users' informed decision-making in the planning activities of construction material, leading to enhanced cost and transportation (Chen and Nguyen, 2019). Finally, Liu and Issa (2014) developed a plugin called the Accessibility Checker Add-in to satisfy users' requirements, and Sameer and Bringezu (2021) enhanced the process of design in BIM by utilising the LCA plugin which is intended to add new functionality for the same purpose. Hence, plugins can be seen to excel in various areas, predominantly achieving bespoke and specific tasks, and by that, creating a wider potential for BIM in the industry.

Despite that the trend of developing and using plugins stems from the intention of seeking digital advancement, barriers yet exist to limit the wider spread of such behaviour in construction. For instance, Liu and Issa (2014, p.158), who developed a plugin to enable particular accessibility tasks, state that "it requires the user to have some coding experience". Also, Pärn and Edwards (2017, p.18) who developed 'FinDD', which is a plugin that integrates BIM and facilities management through totems, note that specific illustrations may be needed "to better describe functionality to future users who are less familiar with its development". This issue is further illuminated as Ali et al. (2020) describe the manual need for inserting information when using their developed plugin, reiterating the implicit of the required familiarity and knowledge. Another issue described by Das et al. (2015, p.19), is the dependency of certain plugins on the "internet bandwidth and the reliability of the cloud service providers" as well as having "issues of ownership of data as different parties are involved". Therefore, a technological behaviour exists towards developing BIM-based plugins, yet these attempts are undermined by various barriers, which demand further investigation.

Situational awareness: In search of a theoretical foundation

In the previous sections, the authors intended to guide readers' attention to an increasing and recent trend of developing and using BIM-based plugins in construction. Additionally, the authors attempted to highlight the areas of use, as well as the barriers prohibiting the broader presence of these plugins across various construction activities. Due to the complexity of the topic, which demands a holistic understanding of human behaviours and interactions with digital innovations, it is imperative to build on a robust theoretical foundation. This section, therefore, aims to establish a priori rationale for selecting the situational awareness theory to envision the future of plugin development and use, and most importantly, realise the corresponding change by investigating the strategies needed to address the key identified barriers.

Endsley (1995) records the initial use of the term 'situational awareness' and develops a key relative theory that is utilised in this study. The term has been defined as the perception of elements within a particular non-static environment (Endsley, 1995). It has been described as the indicative reaction of individuals to a presumed spectrum of unfolding events (Kankanamge et al., 2019). This theoretical foundation is believed to be "extremely beneficial for the first responders and decision-makers to develop strategies" (Lamsal, 2021, p.2790). The theory proposes three key pillars of awareness of a changing reality, namely, a) how the situation has been perceived, b) existing comprehension of the meaning and understanding of the situation, and c) future projections in relation to the situation (Endsley, 1995). Lappalainen et al. (2021) explain these three phases to be linked to a) decision-making, b) action, and c) feedback loop as outer functions of the theory. Therefore, the essence of the theory is “to support human decision-making in a dynamically changing environment” (Lappalainen et al., 2021, p.2200).

In construction-related research, there are various instances of the use of the SA theory to advance relative knowledge. Studies largely utilise the theory to improve safety (Ibrahim et al., 2023), planning (Martinez et al., 2023), and project management (Ghimire et al., 2016). Overall, Lappalainen et al. (2021, p.2201) state that only a “small body of literature focuses on SA in the construction sector”. Nonetheless, studies like Oke et al. (2021), who explore the benefits of cloud computing in construction, provide evidence that the use of situational awareness leads to the enhancement of digital technologies in construction management. Notably, SA has been argued as highly effective in creating novel opportunities around exploiting BIM (Garcia et al., 2021). Hence, it is here integral to relate the use of the SA theory to the challenges faced when developing and using BIM-based plugins.

The intention to develop and use BIM-based plugins has been explained by the driver of supporting BIM “to maintain a lead in the changing and highly competitive construction industry" (Akanbi et al., 2019, p.395). Several plugin developers admitted the perplexity of developing such tools. On account of application variety and being case-dependent (Saad et al., 2022), the use of BIM plugins presents an additional set of complexities to the BIM workflow. In some cases, interoperability issues are present in the process of converting various file formats to applicable ones (Liu and Issa, 2014). In this context, Jalaei et al. (2020) confirmed the need for inputting the data manually to alleviate this compatibility issue. Furthermore, case-specific knowledge is indispensable for BIM plugins to be employed (Yuan et al., 2019). This indicates that, in case of a lack of relative experience, extensive learning or training might be needed to develop and use plugins successfully. Therefore, neither the barriers undermining the development and use of these plugins, nor the strategies believed to overcome these barriers, are fully recognised by scholars of relevant literature, forming the premise of this paper to unravel such a gap in knowledge.

In this study, the authors build on the situational awareness theory by evaluating the practices that have already been conducted towards the effective development and use of BIM-based plugins (first SA phase), the practices indicative of current comprehension of these plugins (second SA phase), and projecting the needed strategies to sustain an effective practice (third SA phase). Subsequently, the study assesses the identified strategies and their importance in overcoming the most significant barriers undermining the development and use of BIM-based plugins. Hence, the aim of this paper is to build a holistic situational picture around the upcoming changes to BIM by being situationally aware of the barriers undermining broader plugin development and use, and the strategies needed to overcome them.

Methodology

Research approach

This research adopts a post-positivist philosophical stance using a quantitative approach, which enables the objective exploration of the barriers to develop and use BIM-based plugins and the strategies that may effectively address these barriers. This research approach is widely utilised in the built environment context (Aghimien et al., 2022) and in BIM-related studies (Al-Saeed et al., 2019). A cross-sectional research design has been adopted to collect data from diverse participants, with the objective of assessing the current state of BIM-based plugins. Data is analysed by a twofold research process of establishing the most important barriers and strategies through a mean ranking approach, and subsequently examining the relationship between each of the identified barriers and their corresponding strategies that are perceived the most effective, which is realised by applying Pearson corelation.

Sampling method

Takyi-Annan and Zhang (2023) justify using purposive sampling for questionnaire surveys, asserting that it is highly advantageous when examining a specific domain, as its intrinsic bias enhances effectiveness and ensures reliability. Purposive sampling is non-probabilistic and non-random (Saad, Dulaimi and Zulu, 2023), a choice that does not rely on a previously set number of participants (Etikan, 2016). Instead, it positions the qualities of participants at the forefront of the sampling process (Arogundade et al., 2024), where the researchers can approach the most suitable sample to respond based on their expertise and evidenced knowledge (Saad, Dulaimi, Arogundade, et al., 2023).

Therefore, because of the nature of this study, being largely contemporary and focusing on a niche research topic, a purposive sampling technique has been utilised to gather relevant information from BIM-based plugin experts. More precisely, the individuals invited are those responsible for research contributions to this area of expertise, the authors have then applied a selective process to include participants based on a specific criterion of a) expert position, and b) high engagement in the field, which are metrics that ensure the credibility and functionality of the collected data (Wilkins, 2011).

Target population

The data has been gathered through an online survey utilising Google Forms, minimising biases that stem from in-person surveys. The questionnaire has been sent to 178 professors, academics, researchers, developers, and BIM experts, individually. Of those, 39 respondents have returned a fully completed questionnaire, constituting a 21.9% response rate deemed acceptable in comparable research (Nawrocka and Parker, 2009; Ormazabal et al., 2018). The sample size could be attributed to the limited existence of specialists in the area of this study. Nonetheless, this number of respondents is not unaccustomed to the built environment, such as Muleya et al. (2020) and Ahmed and Arocho (2022), with 27 and 29 participants, respectively. Similar to Asadi et al. (2022), this sample size can be justified by the status of respondents, who are not merely users in the area, but are rather distinguished experts. Therefore, a solid standing exists to argue that a sample size of 39 experts is sufficient to investigate a highly understudied topic and proceed forward in this timely exploration. In addition, most participants hold doctorate degrees, with 81% having over 6 years of industry experience, and 68% having direct hands-on experience in developing BIM plugins; such characteristics indicate the quality of their inputs (Dulaimi, 2022). Overall, the role of plugins in reshaping prevailing reality is advocated by 92% of the experts, who confidently acknowledge that the future of BIM will include broader development and use of plugins. Information relating to the participants characteristics are shown in Figures 1 and 2.

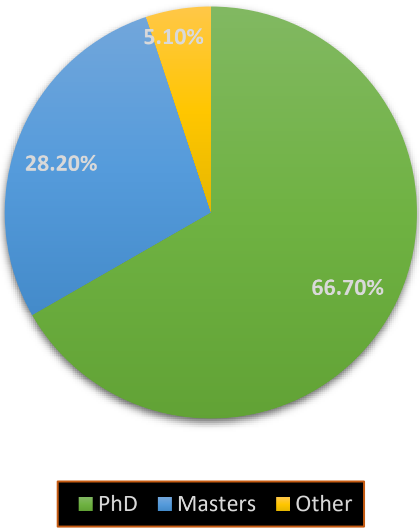

Figure 1. Participants education level

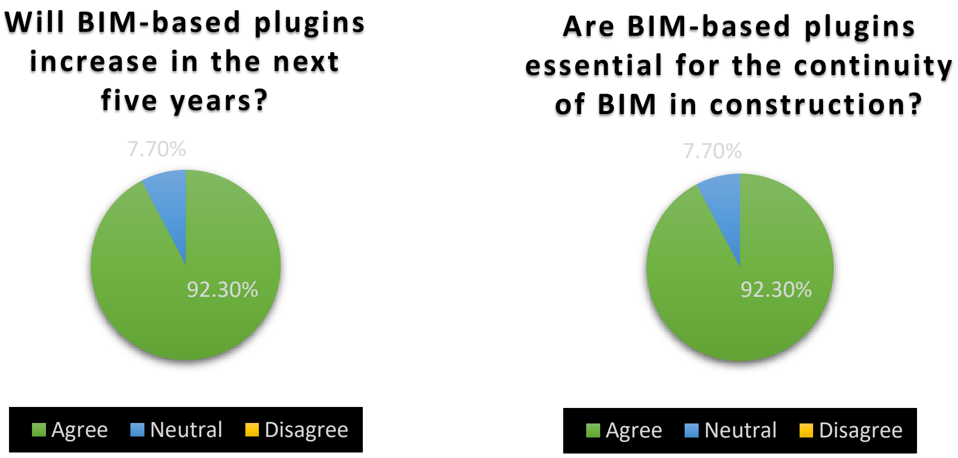

Figure 2. Participants' reflection on the future impact of BIM-based plugins

Results

The study subscribes to Gonzalez-Caceres et al. (2019, p.272), who emphasise "the importance of using measurements instead of assumptions to scientifically determine causes". To achieve this, respondents have been asked to assess the barriers to the development, the barriers to the use, and the important SA strategies for an effective process of plugins' development and use, with a 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree". As illustrated in **Tables 1** and **2**, the eight barriers (four for use, and four for development), and nine strategies (three for SA phase one, three for SA phase two, and three for SA phase three), have been identified from past literature and previous research efforts relating to plugins. These have then been prioritised according to their mean rank, which is an effective indicator for the centre of distribution (Lin et al., 2021).

Table 1. Mean ranking for the most significant barriers.

Barriers to the development and use of BIM-based plugins	**All Respondents**			
	Category	Mean	Rank	Source
1. BRU2: BIM plugins can complicate BIM applications in construction	Barrier of plugin use	3.76	1	(Singh et al., 2020)
2. BRU3: BIM plugins misalign with employees' past experience in BIM	Barrier of plugin use	3.5	2	(Liu and Issa, 2014)
3. BRU4: BIM plugins demand extensive learning curve for successful application	Barrier of plugin use	3.18	3	(Yuan et al., 2019)
4. BRU1: BIM plugins are difficult to understand and use among construction professionals	Barrier of plugin use	3.13	4	(Saad et al., 2022)
5. BRD1: Lack of an effective BIM plugin development framework to guide broader application	Barrier of plugin development	2.84	5	(Saad et al., 2022)
6. BRD3: BIM plugin developments misalign with the existing skills and talents of construction professionals	Barrier of plugin development	2.5	6	(Yuan et al., 2019)
7. BRD4: BIM plugin developments demand	Barrier of plugin development	2.45	6	(Jalaei et al., 2021)

extensive investments in time and money				
8. BRD2: BIM plugin developments demand an extensive background and experience in informatics and programming	Barrier of plugin development	2.39	7	(Saad et al., 2022)

Source: Authors' Data

Table 2. Mean ranking for the most significant strategies

Strategies to overcoming the barriers of using BIM-based plugins	All Respondents			
	Category	Mean	Rank	Resource
1. SAF3: Ensure all relevant software and hardware utilised are up to date for continued optimisation	Situational future projection (SA phase three)	4.290	1	(Manzoor, Othman, Gardezi, et al., 2021)
2. SAF1: Ensure the availability of tech support in case of any sudden disruption	Situational future projection (SA phase three)	4.260	2	(Gholami et al., 2013)
3. SAF2: Assess the return on investment of BIM-plugins in construction	Situational future projection (SA phase three)	4.180	3	(Saad et al., 2022)
4. SAB3: Continued investigation and awareness of the opportunities presented by BIM plugins	Situational prior coherence (SA phase one)	4.130	4	(Saad et al., 2022)
5. SAD2: Setup a reporting and monitoring mechanism to track the effectiveness of developed plugins	Situational present comprehension (SA phase two)	4.130	4	(Choi et al., 2018)
6. SAD3: Regularly confirm the effective implementation of BIM plugins in construction organisations by experts	Situational present comprehension (SA phase two)	4.130	4	(Manzoor, Othman, Gardezi, et al., 2021)
7. SAD1: BIM plugin rationale for development is setup in accordance with construction organisations' needs	Situational present comprehension (SA phase two)	4.000	5	(Manzoor, Othman, Gardezi, et al., 2021)
8. SAB1: Upskilling and training of construction employees in accordance to plugin use and development	Situational prior coherence (SA phase one)	3.970	6	(Walasek and Barszcz, 2017)
9. SAB2: Ensure the computational capabilities and suitability among employees	Situational prior coherence (SA phase one)	3.950	7	(Singh et al., 2020)

	exist to foster plugin use and development	

Source: Authors' Data

Barriers and strategies with a mean score lower than three have been excluded from further analysis (BRD1, BRD2, BRD3, and BRD4). This is attributed to the insignificance of their relative importance based on the severity index, which is less than 0.6 on a 5-point Likert scale, where values equal to or greater than 0.6 are considered of a medium to high importance (Chen et al., 2010). This condition has led to the removal of the four barriers of development from further analysis due to their unimportance as indicated by the participants. The maximum and minimum skewness and kurtosis values are 0.843 and -1.581 (see **Table 3**), indicating the normality of the data as the values are between -2 and 2 (Collier, 2020). Based on this, Pearson correlation analysis has been used to establish the relationships among the barriers and strategies (Schober et al., 2018). This technique allowed the identification of significant associations of monotonic relations between the variables, providing insights into how effective the perceived important strategies can influence the perceived important barriers (see **Table 4**). Bradauskiene et al. (2023, p.20) note the effectiveness of such an analysis method which is used "to evaluate possible relationships". Similarly, Guo et al. (2023, p.64) explain that Pearson correlation analysis can be used to "select the most significant variables".

Table 3. Descriptive Statistics for Correlation Reliability

Descriptive Statistics									
	N	*Min.*	*Max.*	*Mean*	*Std. Deviation*	*Skewness*		*Kurtosis*	
				Statistic			*Std. Error*	*Statistic*	*Std. Error*
BRU1	39	1	5	3.13	1.189	-0.267	0.383	-0.848	0.75
BRU2	39	2	5	3.76	0.913	-0.395	0.383	-0.497	0.75
BRU3	39	1	5	3.5	0.98	-0.273	0.383	-0.104	0.75

BRU4	39	1	5	3.18	1.182	-0.066	0.383	-0.766	0.75
SAB1	39	1	5	3.97	0.944	-0.759	0.383	0.843	0.75
SAB2	39	2	5	3.95	0.868	-0.156	0.383	-1.091	0.75
SAB3	39	3	5	4.13	0.811	-0.251	0.383	-1.428	0.75
SAD1	39	2	5	4	0.9	-0.469	0.383	-0.648	0.75
SAD2	39	3	5	4.13	0.844	-0.26	0.383	-1.557	0.75
SAD3	39	3	5	4.13	0.777	-0.237	0.383	-1.278	0.75
SAF1	39	3	5	4.26	0.795	-0.52	0.383	-1.209	0.75
SAF2	39	3	5	4.18	0.865	-0.376	0.383	-1.581	0.75
SAF3	39	3	5	4.29	0.768	-0.559	0.383	-1.062	0.75

Source: Authors' Data

Table 4. Pearson Correlation

	Correlation	**BRU1**	**BRU2**	**BRU3**	**BRU4**
SAB1	Pearson Correlation	0.027	.337*	.365*	0.295
	Sig. (2-tailed)	0.871	**0.038**	**0.024**	0.072
SAB2	Pearson Correlation	0.033	0.291	0.127	0.273
	Sig. (2-tailed)	0.844	0.077	0.447	0.097
SAB3	Pearson Correlation	0.01	.335*	0.119	0.115
	Sig. (2-tailed)	0.954	**0.04**	0.476	0.492
SAD1	Pearson Correlation	-0.025	.394*	.429**	0.305
	Sig. (2-tailed)	0.88	**0.014**	**0.007**	0.063
SAD2	Pearson Correlation	-0.125	0.217	0.049	0.219
	Sig. (2-tailed)	0.453	0.191	0.77	0.187
SAD3	Pearson Correlation	-0.019	.350*	0.089	0.12
	Sig. (2-tailed)	0.909	**0.031**	0.596	0.473
SAF1	Pearson Correlation	-0.095	.349*	-0.035	0.005
	Sig. (2-tailed)	0.571	**0.032**	0.836	0.978
SAF2	Pearson Correlation	-0.208	.364*	0.08	0.072
	Sig. (2-tailed)	0.21	**0.024**	0.634	0.669
SAF3	Pearson Correlation	0.016	.409*	-0.054	0.029
	Sig. (2-tailed)	0.922	**0.011**	0.748	0.863

Source: Authors' Data

As demonstrated in **Table 4**, the results reveal that for a confidence level of 95%, nine key relationships exist as significant. Namely, from the first SA phase; SAB1↔BR2U (β=.337*), SAB1↔BRU3 (β=.365*), and SAB3↔BRU2 (β=.335*). From the second

SA phase; SAD1↔BRU2 (β=.394*), SAD1↔BRU3 (β=.429**), and SAD3↔BRU2 (β=.350*). And finally, from the third SA phase; SAF1↔BRU2 (β=.349*), SAF2↔BRU2 (β=.364*), and SAF3↔BRU2 (β=.409*). Hence, it is fair to state that adopting these strategies across the different SA phases can adequately address the key barriers.

Discussion

The aim of this paper was to explore and assess the situational awareness strategies that may address the significant barriers undermining BIM-based plugin development and use (see **Figure 3**). At this point in writing, the transformational role of the trend of developing and using plugins has been made clear, and such behaviour is seen to be in disguise of myriad opportunities in the field of construction management. It may be reasonable to accept the argument that BIM is not the absolute technological answer (Koutamanis et al., 2023), but it is also important to acknowledge that BIM plugins may resemble the nearest realistic ideal (Saad et al., 2022). This study is the first to predict that the distant future of BIM will comprise challenges that will make the construction industry susceptible to downfalls, and that the proposed indefinite solution to overcoming these challenges is by developing custom-built plugins to evolve as situations worsen.

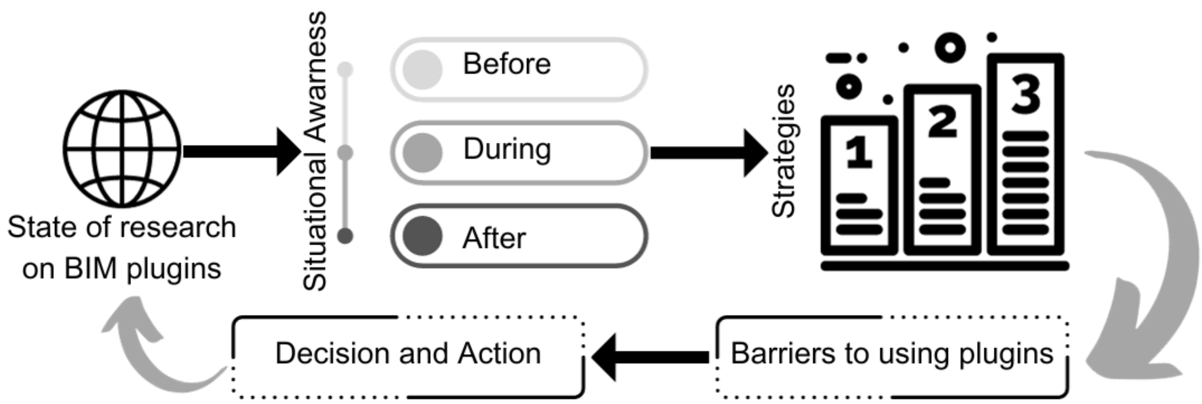

Figure 3. Illustration of the study's SA approach

The findings suggest that the strategy of upskilling and training construction employees in accordance with plugin development and use (SAB1) can effectively address the two critical barriers of BIM's overall complexity because of plugins, and employees' past BIM experience. It is here important for the research community to uncover the pressure points of the learning process, how much is already offered in literature, and the present condition of existing guidelines. These arguments confirm the statement by Lappalainen et al. (2021, p.2215), who infer that "we need further research to focus on how the information found in BIM may be better utilised as an integral part of the SA model in project activities". Moreover, the identified strategy, i.e. SAB1, belongs to the first phase of the SA theory, i.e. prior knowledge on the foreseen unfold of events, providing an implicit around the importance of technological readiness on innovative behaviours (Walasek and Barszcz, 2017). From the same SA phase, continued investigation, and awareness of the trend of plugin development and its use has been identified as an important strategy that addresses the barrier of extended complexity (Saad et al., 2022). Hence, the two key strategies from the first SA phase on addressing the key barriers for BIM-based plugin development and use are related to a) upskilling and training, and b) continued education and awareness.

The findings also indicate that overcoming the two significant barriers of BIM overall complexity because of plugins, and employees' past BIM experience, is by building a robust rationale for plugins in line with the specific needs. The argument here is that if a rationale is adequate, and concise, the innovation would be less complicated (Rogers, 2003; Manzoor, Othman, Gardezi, et al., 2021), and better aligned with employees' past BIM experience (Zulu and Khosrowshahi, 2021). Additionally, the influence of consulting experts' strategy from the same SA phase has as well been identified as significant, i.e. phase two, on making the process of developing and using

BIM-plugins less complex. This aligns with the SA theory, according to Lappalainen et al. (2021, p.2215); “the theory assumes that an individual’s ability in a dynamic environment is limited”. Therefore, the two key strategies from the second SA phase on addressing the key barriers for BIM-based plugin development and use are related to a) having a robust rationale, and b) consulting experts during the development and use of BIM-based plugins.

Finally, results suggest that to overcome the barrier of BIM extended complexity because of plugins’ development and use, the three strategies of ensuring the availability of tech support to address sudden disruptions (Gholami et al., 2013), continuous assessment of the return on investment (Gao et al., 2022; Saad et al., 2022), and ensuring all software and hardware utilised are up to date (Manzoor, Othman, Gardezi, et al., 2021), are all indicated as significant. This is suggestive of the importance of projecting the post development and use practices in the SA theory on the effectiveness of innovation-implementation (Avsec et al., 2022). Namely, these results are believed to provide an implicit of the importance of attaining a “working memory” to expand humans’ cognitive resources in SA (Pooladvand and Hasanzadeh, 2023, p.3). Hence, all strategies meant for the post-development and use are addressing the most significant barrier to making BIM more complicated.

The implications of this study are three-fold. Firstly, it underpins the emerging role of developing and using plugins as a behaviour and trend that can reshape the future of BIM in reacting to bespoke and situation-specific construction challenges. Secondly, it identifies and empirically evaluates the barriers undermining broader development and use of BIM-based plugins. Finally, the study assesses the significance of a spectrum of strategies in addressing the key identified barriers, offering a concept-problem-solution process that would highly benefit academics, practitioners, and developers to sustain the digital supremacy of BIM by capitalising on its potential to technologically evolve as challenges become more complex.

Conclusion

BIM-based plugins may have different meanings to different construction experts in pursuit of different objectives, yet what commonly transpires is the leading role of the plugin development trend to contest contemporary construction challenges. Overall, this study proceeded with a motive to narrow the discourse of an emerging trend by simultaneously assessing the three pillars of the SA theory in overcoming the barriers of developing and using BIM-based plugins. Without specific literature to unravel the dynamics involved in such a trend, the topic would have remained understudied and thereby not stimulating future research on a highly needed capability.

The paper contributes to construction management literature by extending evidence around the trend of developing and using BIM-based plugins. It can be concluded that the behaviour of seeking additional BIM capabilities through plugins is effective but is mostly research focused and research-led, portraying the contemporary nature of this occurrence, and acting as a critical implicit to what may be the future ramifications on the prevailed understanding of BIM today. Despite the very modern nature of such a trend, limited empirical research represents a challenge, specifically because experts interpret varied expectations when referring to these plugins, demanding an approach that can objectify this research topic. Such an approach has been adopted and has led to findings summarised as follow:

- BIM is not an absolutely flawless commodity, as per the popular opinion of technological optimists, and should not be treated as such.

- The trend of developing and using BIM-based plugins is destined to increase, scholars are encouraged to explore the trend in future research.
- Upskilling and training employees towards broader digital competency should consider the development and use of plugins to enable them to create custom-build solutions.
- Continued investigation and awareness of the trends lead to simplifying the complexity of these plugins on the BIM process.
- Building a robust rationale that aligns with emerging needs leads to overcoming complexities and aligning with employees' past BIM experience.
- Confirming the implementation of BIM-based plugins with experts is a key strategy during the development and use of plugins in the current coherence phase of the SA theory.
- Ensuring the availability of tech support, monitoring the return on investment, and ensuring all software and hardware are up to date are the most important strategies of the future projection phase of the SA theory that overcome the barrier of added complexity.

Despite realising the paper's objectives, two key limitations exist to challenge future research. Firstly, it is important to note that the procedure followed to collect responses has been fully electronic. This procedure has led to the collection of 39 responses from an arguably very limited population experienced in BIM-based plugins. Despite the popularity and convenience of the approach, it may have been beneficial to personally visit universities and research institutions and traditionally collect additional responses, as this may have led to a higher response rate. Thus, it is suggested that a qualitative research approach can contemplate the results of this paper and provide an extended investigation around the potential of these plugins. The second limitation is the exclusion of the barriers to the development of BIM-based plugins, which have been indicated as insignificant by the experts. Despite this being a positive outcome inferring that these do not undermine broader development, the limitation here is due to the scarce amount of literature on BIM-based plugins that prohibited locating and assessing the significant barriers. Finally, it is imperative to deal with the results of this study with caution particularly when generalising these in different geographical areas and settings. However, this may provide scope for future research and thus encourage efforts to address an understudied area.

References

Aghimien, D., Aigbavboa, C.O., Thwala, W.D., Chileshe, N. and Dlamini, B.J. 2022. Help, I am not coping with my job! – A work-life balance strategy for the Eswatini construction industry. *Engineering, Construction and Architectural Management*.

Ahmed, S. and Arocho, I. 2022. Implementing a Choosing-by-Advantages Decision-Making Method to Evaluate the Critical Success Factors of Mass-Timber Building Materials in the US. *Journal of Construction Engineering and Management*. **148**(10).

Akanbi, L.A., Oyedele, L.O., Omoteso, K., Bilal, M., Akinade, O.O., Ajayi, A.O., Davila Delgado, J.M. and Owolabi, H.A. 2019. Disassembly and deconstruction analytics system (D-DAS) for construction in a circular economy. *Journal of Cleaner Production*. **223**, pp.386–396.

Al-Saeed, Y., Parn, E., Edwards, D.J. and Scaysbrook, S. 2019. A conceptual framework for utilising BIM digital objects (BDO) in manufacturing design and production. *Journal of Engineering, Design and Technology*. **17**(5), pp.960–984.

Ali, B., Zahoor, H., Nasir, A.R., Maqsoom, A., Khan, R.W.A. and Mazher, K.M. 2020.

BIM-based claims management system: A centralized information repository for extension of time claims. *Automation in Construction*. **110**(December 2019).

Arogundade, S., Dulaimi, M., Ajayi, S. and Saad, A. 2024. Contractors' carbon reduction behaviour: UK construction professionals' perspective. *Construction Innovation*.

Asadi, S., Nilashi, M., Iranmanesh, M., Ghobakhloo, M., Samad, S., Alghamdi, A., Almulihi, A. and Mohd, S. 2022. Drivers and barriers of electric vehicle usage in Malaysia: A DEMATEL approach. *Resources, Conservation and Recycling*. **177**(October 2021), p.105965.

Avsec, S., Jagiełło-Kowalczyk, M. and Żabicka, A. 2022. Enhancing Transformative Learning and Innovation Skills Using Remote Learning for Sustainable Architecture Design. *Sustainability (Switzerland)*. **14**(7).

Bakhshi, S., Chenaghlou, M.R., Pour Rahimian, F., Edwards, D.J. and Dawood, N. 2022. Integrated BIM and DfMA parametric and algorithmic design based collaboration for supporting client engagement within offsite construction. *Automation in Construction*. **133**(August 2021), p.104015.

Bradauskiene, V., Vaiciulyte-Funk, L., Martinaitiene, D., Andruskiene, J., Verma, A.K., Lima, J.P.M., Serin, Y. and Catassi, C. 2023. Wheat consumption and prevalence of celiac disease: Correlation from a multilevel analysis. *Critical Reviews in Food Science and Nutrition*. **63**(1), pp.18–32.

Chen, P.H. and Nguyen, T.C. 2019. A BIM-WMS integrated decision support tool for supply chain management in construction. *Automation in Construction*. **98**(November 2018), pp.289–301.

Chen, Y., Okudan, G.E. and Riley, D.R. 2010. Sustainable performance criteria for construction method selection in concrete buildings. *Automation in Construction*. **19**(2), pp.235–244.

Chileshe, N., Jayasinghe, R.S. and Rameezdeen, R. 2019. Information flow-centric approach for reverse logistics supply chains. *Automation in Construction*. **106**(January).

Choi, M., Cho, S., Lim, J., Shin, H., Li, Z. and Kim, J.J. 2018. Design framework for variable refrigerant flow systems with enhancement of interoperability between BIM and energy simulation. *Journal of Mechanical Science and Technology*. **32**(12), pp.6009–6019.

Collier, J.E. 2020. *Applied Structural Equation Modeling Using AMOS*. Routledge.

Dainty, A., Leiringer, R., Fernie, S. and Harty, C. 2017. BIM and the small construction firm: a critical perspective. *Building Research and Information*. **45**(6), pp.696–709.

Das, M., Cheng, J.C. and Kumar, S.S. 2015. Social BIMCloud: a distributed cloud-based BIM platform for object-based lifecycle information exchange. *Visualization in Engineering*. **3**(1).

Demirkesen, S. and Tezel, A. 2022. Investigating major challenges for industry 4.0 adoption among construction companies. *Engineering, Construction and Architectural Management*. **29**(3), pp.1470–1503.

Ding, L. and Xu, X. 2014. Application of cloud storage on BIM life-cycle management. *International Journal of Advanced Robotic Systems*. **11**(1).

Dulaimi, M. 2022. The climate of innovation in the UAE and its construction industry.

Engineering, Construction and Architectural Management. **29**(1), pp.141–164.

Elmualim, A. and Gilder, J. 2014. BIM: Innovation in design management, influence and challenges of implementation. *Architectural Engineering and Design Management*. **10**(3–4), pp.183–199.

Endsley, M.R. 1995. Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. **37**(1), pp.32–64.

Etikan, I. 2016. Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*. **5**(1), p.1.

Gao, H., Zhang, L., Koch, C. and Wu, Y. 2019. BIM-based real time building energy simulation and optimization in early design stage. *IOP Conference Series: Materials Science and Engineering*. **556**(1).

Gao, Y., Liu, X., Zhang, S., Zhang, J. and Guo, Q. 2022. BIM application and collaboration in construction projects: a perspective of the Chinese construction market. *Construction Management and Economics*. **40**(6), pp.429–441.

Garcia, G., Golparvar-Fard, M., de la Garza, J.M. and Fischer, M. 2021. Measuring Progress and Productivity in Model-Driven Engineering for Capital Project Delivery. *Journal of Construction Engineering and Management*. **147**(4).

Ghimire, S., Luis-Ferreira, F., Nodehi, T. and Jardim-Goncalves, R. 2016. IoT based situational awareness framework for real-time project management. *International Journal of Computer Integrated Manufacturing*., pp.1–10.

Gholami, E., Sharples, S. and Shokooh, J.A. 2013. Exploiting BIM in Energy Efficient R efurbishment : A paradigm of future opportunities. . **2**(September).

Gledson, B. 2022. Enhanced model of the innovation-decision process, for modular-technological-process innovations in construction. *Construction Innovation*. **22**(4), pp.1085–1103.

Gledson, B., Zulu, S.L., Saad, A.M. and Ponton, H. 2023. Digital leadership framework to support firm-level digital transformations for Construction 4.0. *Construction Innovation*.

Gonzalez-Caceres, A., Bobadilla, A. and Karlshøj, J. 2019. Implementing post-occupancy evaluation in social housing complemented with BIM: A case study in Chile. *Building and Environment*. **158**(April), pp.260–280.

Guo, N., Wu, Q., Shi, C. and Shu, R. 2023. Geographical discrimination of Cyclocarya paliurus tea for origin traceability based on multielement analysis by ICP-OES and chemometrics multivariate. *Chinese Herbal Medicines*. **15**(1), pp.63–68.

Hwang, B.-G., Zhao, X. and Yang, K.W. 2019. Effect of BIM on Rework in Construction Projects in Singapore: Status Quo, Magnitude, Impact, and Strategies. *Journal of Construction Engineering and Management*. **145**(2).

Ibrahim, A., Nnaji, C., Namian, M., Koh, A. and Techera, U. 2023. Investigating the impact of physical fatigue on construction workers' situational awareness. *Safety Science*. **163**, p.106103.

Jalaei, F., Zoghi, M. and Khoshand, A. 2021. Life cycle environmental impact assessment to manage and optimize construction waste using Building Information Modeling (BIM). *International Journal of Construction Management*. **21**(8), pp.784–801.

Jalaei, Farzad, Jalaei, Farnaz and Mohammadi, S. 2020. An integrated BIM-LEED application to automate sustainable design assessment framework at the conceptual stage of building projects. *Sustainable Cities and Society*. **53**(November 2019), p.101979.

Juliano Lima da Silva, Andréa Quadrado Mussi, Lauro André Ribeiro and Thaísa Leal da Silva 2017. BIM Software Plug-ins: An Alternative to Optimize Design Processes from the Perspective of Performance and Sustainability. *Journal of Civil Engineering and Architecture*. **11**(3).

Kankanamge, N., Yigitcanlar, T., Goonetilleke, A. and Kamruzzaman, M. 2019. Can volunteer crowdsourcing reduce disaster risk? A systematic review of the literature. *International Journal of Disaster Risk Reduction*. **35**(September 2018), p.101097.

Khosrowshahi, F. and Arayici, Y. 2012. Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*. **19**(6), pp.610–635.

Koutamanis, A., Dainty, A., Kvan, T. and Turk, Ž. 2023. The Enigma of BIM. *Architecture, Structures and Construction*. **3**(1), pp.1–9.

Lamsal, R. 2021. Design and analysis of a large-scale COVID-19 tweets dataset. *Applied Intelligence*. **51**(5), pp.2790–2804.

Lappalainen, E.M., Seppänen, O., Peltokorpi, A. and Singh, V. 2021. Transformation of construction project management toward situational awareness. *Engineering, Construction and Architectural Management*. **28**(8), pp.2199–2221.

Lin, T., Chen, T., Liu, J. and Tu, X.M. 2021. Extending the Mann-Whitney-Wilcoxon rank sum test to survey data for comparing mean ranks. *Statistics in Medicine*. **40**(7), pp.1705–1717.

Liu, R. and Issa, R.R.A. 2014. Design for maintenance accessibility using BIM tools. *Facilities*. **32**(3), pp.153–159.

Ma, Y.P., Hsu, C.C. and Lin, M.C. 2017. Combine BIM-based and mobile technologies to design on-site support system for the communication and management of architectural heritage conservation works. *Proceedings of the 2017 IEEE International Conference on Applied System Innovation: Applied System Innovation for Modern Technology, ICASI 2017*. (c), pp.307–310.

Manzoor, B., Othman, I., Gardezi, S.S.S., Altan, H. and Abdalla, S.B. 2021. BIM-Based Research Framework for Sustainable Building Projects: A Strategy for Mitigating BIM Implementation Barriers. *Applied Sciences*. **11**(12), p.5397.

Manzoor, B., Othman, I. and Pomares, J.C. 2021. Digital technologies in the architecture, engineering and construction (Aec) industry—a bibliometric—qualitative literature review of research activities. *International Journal of Environmental Research and Public Health*. **18**(11).

Martinez, J.G., Yeung, T., Sacks, R., Shahaf, Y. and Sharoni, L.-O. 2023. Situational Awareness in Construction Using a Serious Game. *Journal of Construction Engineering and Management*. **149**(3).

Muleya, F., Zulu, S. and Nanchengwa, P.C. 2020. Investigating the role of the public private partnership act on private sector participation in PPP projects: a case of Zambia. *International Journal of Construction Management*. **20**(6), pp.598–612.

Nawrocka, D. and Parker, T. 2009. Finding the connection: environmental management systems and environmental performance. *Journal of Cleaner Production*. **17**(6), pp.601–607.

Oke, A.E., Kineber, A.F., Al-Bukhari, I., Famakin, I. and Kingsley, C. 2021. Exploring the benefits of cloud computing for sustainable construction in Nigeria. *Journal of Engineering, Design and Technology*. **21**(4), pp.973–990.

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R. and Jaca, C. 2018. Circular Economy in Spanish SMEs: Challenges and opportunities. *Journal of Cleaner Production*. **185**, pp.157–167.

Pärn, E.A. and Edwards, D.J. 2017. Conceptualising the FinDD API plug-in: A study of BIM-FM integration. *Automation in Construction*. **80**, pp.11–21.

Pham, K.T., Vu, D.N., Hong, P.L.H. and Park, C. 2020. 4D-BIM-based workspace planning for temporary safety facilities in construction SMES. *International Journal of Environmental Research and Public Health*. **17**(10), pp.1–22.

Pooladvand, S. and Hasanzadeh, S. 2023. Impacts of Stress on Workers' Risk-Taking Behaviors: Cognitive Tunneling and Impaired Selective Attention. *Journal of Construction Engineering and Management*. **149**(8), pp.1–14.

Rad, M.A.H., Jalaei, F., Golpour, A., Varzande, S.S.H. and Guest, G. 2021. BIM-based approach to conduct Life Cycle Cost Analysis of resilient buildings at the conceptual stage. *Automation in Construction*. **123**(January), p.103480.

Rodrigues, F., Antunes, F. and Matos, R. 2021. Safety plugins for risks prevention through design resourcing BIM. *Construction Innovation*. **21**(2), pp.244–258.

Rogers, E.M. 2003. *Diffusion of innovations* 5th editio. New York, NY: Free Press.

Saad, A., Ajayi, S.O. and Alaka, H.A. 2022. Trends in BIM-based plugins development for construction activities: a systematic review. *International Journal of Construction Management*. **0**(0), pp.1–13.

Saad, A.M., Dulaimi, M., Arogundade, S., Zulu, S.L. and Gorse, C. 2023. Modern methods of construction (MMC) and innovation negativism in the UK public sector. *Built Environment Project and Asset Management*.

Saad, A.M., Dulaimi, M. and Zulu, S.L. 2023. Broader use of the Modern Methods of Construction (MMC) in the UK public sector: A Business Model Canvas (BMC) perspective. *Journal of Open Innovation: Technology, Market, and Complexity*. **9**(2), p.100035.

Sackey, E. and Akotia, J. 2017. Spanning the multilevel boundaries of construction organisations: Towards the delivery of BIM-compliant projects. *Construction Innovation*. **17**(3), pp.273–293.

Sameer, H. and Bringezu, S. 2021. Building information modelling application of material, water, and climate footprint analysis. *Building Research and Information*. **0**(0), pp.1–20.

Schneider, S. and Leyer, M. 2019. Me or information technology? Adoption of artificial intelligence in the delegation of personal strategic decisions. *Managerial and Decision Economics*. **40**(3), pp.223–231.

Schober, P., Boer, C. and Schwarte, L.A. 2018. Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia & Analgesia*. **126**(5), pp.1763–1768.

Singh, M.M., Singaravel, S., Klein, R. and Geyer, P. 2020. Quick energy prediction and comparison of options at the early design stage. *Advanced Engineering Informatics*. **46**(December 2019).

Smyth, H., Anvuur, A.M. and Kusuma, I. 2017. Integrated solutions for total asset management through “RIVANS”. *Built Environment Project and Asset Management*. **7**(1), pp.5–18.

Suhir, E., Lini, S., Bey, C., Salotti, J.M., Hourlier, S. and Claverie, B. 2015. Probabilistic modelling of the concept of anticipation in aviation. *Theoretical Issues in Ergonomics Science*. **16**(1), pp.69–85.

Takyi-Annan, G.E. and Zhang, H. 2023. Assessing the impact of overcoming BIM implementation barriers on BIM usage frequency and circular economy in the project lifecycle using Partial least Squares structural Equation modelling (PLS-SEM) analysis. *Energy and Buildings*. **295**, p.113329.

Volk, R., Stengel, J. and Schultmann, F. 2014. Building Information Modeling (BIM) for existing buildings - Literature review and future needs. *Automation in Construction*. **38**, pp.109–127.

Walasek, D. and Barszcz, A. 2017. Analysis of the Adoption Rate of Building Information Modeling [BIM] and its Return on Investment [ROI]. *Procedia Engineering*. **172**, pp.1227–1234.

Wang, N., Xu, Z. and Liu, Z. 2023. Innovation in the construction sector: Bibliometric analysis and research agenda. *Journal of Engineering and Technology Management - JET-M*. **68**(March), p.101747.

Wilkins, J.R. 2011. Construction workers’ perceptions of health and safety training programmes. *Construction Management and Economics*. **29**(10), pp.1017–1026.

Wu, S., Wood, G., Ginige, K. and Jong, S.W. 2014. A TECHNICAL REVIEW OF BIM

BASED COST ESTIMATING IN UK QUANTITY SURVEYING PRACTICE, STANDARDS AND TOOLS. *Journal of Information Technology in Construction*. **19**, pp.534–563.

Yuan, J., Li, X., Xiahou, X., Tymvios, N., Zhou, Z. and Li, Q. 2019. Accident prevention through design (PtD): Integration of building information modeling and PtD knowledge base. *Automation in Construction*. **102**(January), pp.86–104.

Zhao, P. and He, X. 2021. Research on dynamic data monitoring of marine bridge steel structure building information based on BIM model. *Arabian Journal of Geosciences*. **14**(4).

Zulu, S., Saad, A.M. and Dulaimi, M. 2023. Digital leadership enactment in the construction industry: Barriers undermining effective transformation. *Engineering, Construction and Architectural Management*. **In press**.

Zulu, S.L. and Khosrowshahi, F. 2021. A taxonomy of digital leadership in the construction industry. *Construction Management and Economics*. **39**(7), pp.565–578.

Zulu, S.L., Saad, A.M. and Ajayi, S.O. 2023. Determinants of an effective digital transformation in construction organisations: A qualitative investigation. *Built Environment Project and Asset Management*. **Under revi**.