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A SYSTEMATIC REVIEW OF TECHNOLOGY ACCEPTANCE MODELS AND THEORIES IN CONSTRUCTION RESEARCH

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SUMMARY: *Technology use in the construction industry fosters improvements in schedule, safety, cost, productivity, and quality. In this domain, the construction technologies adoption highly depends on stakeholders, who may exhibit some resistance to operational use. This underscores the importance of determining technology integration success using effective methods such as predictive and explanatory modelling. Although existing literature has provided some critical insight into the use of these models and theories, there is no domain-based synthesis on the utility of these models and theories as tools to facilitate the integration of emerging construction technologies. Therefore, this paper provides a systematic review and content analysis showcasing different methods and theories for investigating technology acceptance and generates insights expected to guide future technology acceptance studies. Using a three-phase systematic review process, 35 relevant articles were identified and analysed. This review identified perceived ease of use, perceived usefulness, social norm, attitude, perceived behavioural control, and facilitating conditions as key constructs impacting workers' intention to accept a construction technology. TAM, TPB, and UTAUT were identified as popular choices for developing hybrid models, while UTAUT provided a relatively higher predictive power. Finally, seven areas for further exploration were discussed. This study contributes to construction knowledge by providing a better understanding of technology acceptance research and generating fundamental insights needed to develop robust and effective predictive and explanatory models for advancing technology acceptance research which would support successful technology integration.*

KEYWORDS: *Construction management; Technology adoption; Predictive modelling; Explanatory modelling; Critical review; Content analysis. Acceptance model.*

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1. INTRODUCTION

The construction industry has historically underperformed due to multiple reasons such as project fragmentation, work complexity, dynamic operations, and reliance on human input (Ryu et al. 2020). According to Barbosa et al. (2017), productivity in the construction industry has remained relatively flat over the last three decades. Specifically, the construction industry has gained only 1% in productivity over this period, which is three times lower than all industries combined (Barbosa et al. 2017). The construction industry also underperforms with regards to worker safety. Recent data from the Bureau of Labour Statistics (BLS) indicates that while the construction industry employs about 6% of the workforce in the US, the industry accounts for over 20% of all work-related fatalities (BLS 2021a; 2021b). Moreover, the construction industry suffers from poor quality performance and records an astronomical level of waste. For instance, 1-20% of the project value is lost due to poor quality (Love et al. 2018) while the construction industry contributes 13-60% of the total waste in landfills (Luangcharoenrat et al. 2019).

Researchers and practitioners have posited that supplementing existing practices with technological advancements provides a viable opportunity to bridge the performance gap. When holistically considering technologies for construction management, it is important to note that there is an abundance of tools for data acquisition, progress tracking, quality improvement, and workers' safety management (Awolusi et al. 2018; Bock 2015; Choi et al. 2017; Okpala et al 2020; Valero and Adán 2016; Zou et al. 2017). Studies have shown that introducing enterprise resource planning systems and building information modelling (BIM) improves productivity significantly (Skibniewski and Ghosh 2009; Poirier et al. 2015), while other technologies have helped organizations improve communication and work quality (Perkinson et al. 2010; Ogunrinde et al. 2020). In addition, recent reports have posited that several technologies such as virtual reality, wearable sensing devices, and mobile devices can improve worker safety significantly (Nnaji and Karakhan 2020; Akinlou et al. 2020).

Although technologies used in the construction industry have shown significant potential to improve work performance, research suggests that workers (either field workers or those occupying management-related roles) may exhibit some resistance to technology use (Peansupap and Walker 2005; Wang et al 2020). Therefore, before investing significantly in a technology, it is critical to investigate end-user behaviour, and the use and impact of technologies to encourage extended use within the sector (Jin et al. 2019). The quest to salvage this situation has prompted researchers to continuously investigate factors critical to successful technology integration (Darko et al. 2017; Nnaji et al. 2019a; Ogunrinde et al. 2020).

Researchers have utilized explanatory and predictive models proven to be effective in information systems research to assess workers' technology acceptance behaviour (Chang et al. 2016; Chin et al 2020; Son et al 2015; Tarhini et al. 2015; Taherdoost 2018). Although construction researchers have over a decade of experience utilizing these models and theories to provide critical insight into factors that predict the acceptance of a variety of technologies used within this sector, there is no domain-specific synthesis on the utility of these models and theories as tools for facilitating the integration of emerging technologies. In contrast, other domains, such as healthcare (Omachonu and Einspruch 2010; Gucin and Berk 2015; Rahimi et al. 2018) and manufacturing (Taherdoost 2018), have conducted several syntheses on these models and theories. These reviews developed contextual insight aimed at guiding future research and development within their domain. Moreover, findings from these syntheses have been utilized by several domain-specific stakeholders to develop strategies for supporting technology integration, while researchers within these domains have built on the findings of the reviews. The absence of a synthesis robs the construction industry of the opportunity to significantly advance research on technology acceptance at the individual level.

Therefore, the goal of this paper is to (1) systematically review the body of knowledge regarding models and theories used to investigate technology acceptance in construction research, (2) summarize important domain-specific trends, (3) evaluate specific factors predicting technology acceptance within construction research, and (4) develop insights to guide future studies on technology acceptance. Utilizing a three-phase process, the present study presents a state-of-the-art review of construction technology acceptance modelling and offers a comprehensive analysis of the collected studies which should provide a valuable guide on how to assess the acceptance potential of technologies used in construction management. More specifically, the present review study aims to answer the following research questions:

RQ1: What are the main research trends (publication number, country, etc.) of the selected studies?

RQ2: What is the main research method used in the analysed studies?

RQ3: What are the technology application areas?

RQ4: What are the primary antecedent factors of technology acceptance within construction literature?

RQ 5: What are the relevant pair-wise relationships between key constructs?

RQ6: What acceptance models have high predictive validity?

2. BACKGROUND

2.1 Construction Technology Integration

The construction industry is unique and complex considering its project-based nature, the constant need for collaboration, inter-organizational activities, power distribution in practice, and established avenues for communication and data sharing (Harty 2005; Harty 2008). Although these characteristics have made innovation and other industry reforms a very challenging endeavour (Green 2011), researchers and practitioners continue to develop and implement technological solutions to improve work output on a regular basis (Mitropoulos and Tatum 2000; Sherratt et al. 2020). Another intrinsic justification for increasing technological innovation research and application in construction is the saturation reached with respect to traditional work programs aimed at improving key project success factors such as productivity and safety (Blayse and Manley, 2004; Esmaeili and Hallowell 2012; Miozzo and Dewick 2004). In comparison with other sectors, innovation integration and productivity rates within construction are relatively low (Agarwal et al. 2016; Ozorhon 2013) thus, underscoring the need for more work in developing and integrating technology into work practices (Dulaimi et al. 2002; Liu and Liu 2017).

Several studies have discussed technology applications in construction management in a variety of areas including safety and health management (Akinlolu et al. 2020; Zou et al. 2017; Okpala et al. 2020), performance and productivity (Chu et al. 2008; Kim et al. 2019), cost (Martínez-Rojas, et al. 2016; Niknam and Karshenas 2015), schedule (Jia et al. 2019; Uusitalo et al. 2017), and quality (El-Omari and Moselhi 2011; Ogunrinde et al. 2020). From these studies, some broad categories of technologies include enhanced information technologies [multimedia, email, voice-based tools, and handheld computing], geospatial technologies [QR coding, radio frequency identification, geographic information systems, and global positioning systems], imaging technologies (photogrammetry and laser scanning), immersive visualization technologies [Building information modelling, augmented reality and virtual reality], robotics and automation [unmanned aerial vehicles, single-task construction robots, and unmanned ground vehicles,], and wearable technologies [wearable sensors] (Awolusi et al. 2018; Choi et al. 2017; He et al., 2016). While these technologies are reputed to affect workers and project performance within construction, their integration and diffusion lag (Chen et al. 2020; Elshafey et al. 2020). To improve the technology integration process (TIP), it is essential to understand worker behavioural response to the introduction of a new technology. Predictive and explanatory technology acceptance models provide researchers and practitioners with an opportunity to generate credible and relevant contextual information on potential technology acceptance.

2.2 Predictive and Explanatory Technology Acceptance Modelling

Technology acceptance models and theories are computed and analysed using predictive and explanatory modelling processes (Hair et al. 2017; Shmueli and Koppius 2011). Over the past decades, productive outputs have been reported concerning the prediction and explanation of factors that influence technology acceptance at different levels in the construction domain (Tarhini et al. 2015). Explanatory modelling is focused on the investigation of causal relationships between constructs (portraying individuals, a project, or an organization), while predictive modelling allows for the forecasting of an end construct made possible by a combination of independent acceptance factors (Sainani 2014). In a bid to explain technology acceptance (behavioural intention or actual use) using independent variables (causal influences), the prediction must be accurate (Sutton 1998; Abbasi et al. 2015; Venkatesh and Zhang 2010). Inaccurate predictions could lead to suspect decision making, resulting in a failed TIP. Consequently, over the last 35 years, researchers in the information systems research domain have developed multiple models and theories for explaining and predicting user adoption and acceptance (Davis 1989). At the individual level, researchers have repeatedly and satisfactorily used the Technology Acceptance Model (TAM) (Davis, 1989; Davis et al. 1989; Lee et al. 2015), the Theory of Planned Behaviour

(TPB) (Ajzen, 1991; Lee et al., 2013; Liu 2020), and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Williams et al. 2015; Venkatesh et al., 2003) in modelling technology and system-based acceptance using a variety of technology attributes and contextual factors (Abubakar and Ahmad, 2019; Rahman et al., 2017; Sohn and Kwon, 2020; Yousafzai et al., 2010).

TAM, TPB, and UTAUT: In attempting to predict/explain technology acceptance, the TAM (Fig. 1a) is made up of key acceptance constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEU), Attitude (ATT), Behavioural Intention to Use (BI), and Actual Use (Davis et al. 1989), with behavioural intention standing out as the measure of actual technology use (Davis et al. 1989). Primary constructs, PEU and PU, attempt to influence the workers' attitude. These constructs are central in the prediction of BI, thus suggesting likely ways through which workers can be properly guided to eventually accept a new technology (Rahman et al. 2017). Also, PU has proven to directly influence the workers' BI to use the designated technology in question. These discoveries have led to additional research which attempted to extend the usefulness of the TAM model through the expansion of the number of constructs and relationships (Venkatesh and Davis 2000). For instance, researchers developed the extended-TAM, which replaces constructs "attitude" (workers' disposition towards accepting a new technology) and "subjective norm" (the level at which a worker can influence their colleagues to believe that they should use the new technology). However, since, researchers deduced that TAM portrayed a difficulty in the explanation/prediction of technology acceptance by individual workers, an additional variable, "Perceived Behavioural Control" was added (Chau and Hu 2001); further proving that a combination of individual and social factors do influence technology acceptance (Mun et al. 2006).

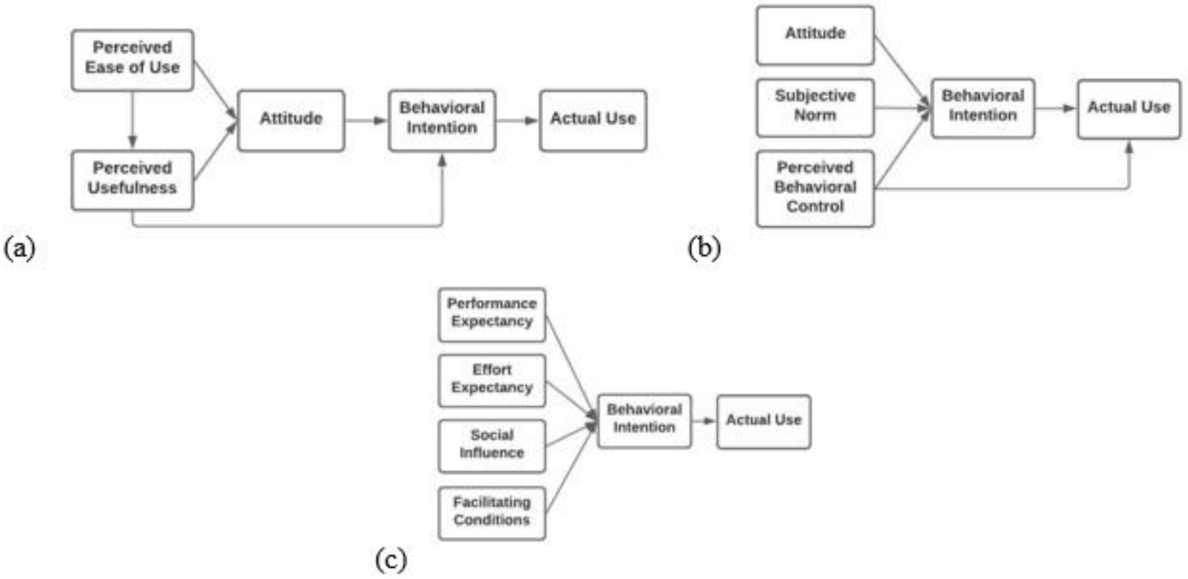

FIG. 1. Technology Acceptance Theories; (a) TAM; (b) TPB; (c) UTAUT [adapted from Tao et al. (2020)]

Furthermore, the UTAUT incorporates "facilitating conditions," a new construct which, in combination with the other four constructs, Performance Expectancy (PE), Behaviour and Actual Behaviour (Actual Use), Effort Expectancy (EE), and Social Influence (SI) (Venkatesh et al., 2003), capture workers' perception of availability of internal and external resources necessary for using a new technology (Tao et al. 2020). Venkatesh et al. (2011), based on workplace data on the adoption of several technologies, reported that the UTAUT outperforms eight individual models it envelopes. As reported by Tarhini et al. (2015), other existing predictive and explanatory models which can be utilized in construction include the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975; Zhang and Ng 2012), the extended TAM (TAM2) (Liu et al. 2018), the Task-technology fit model (Lee et al. 2015), the Motivational Model (Cocosila et al. 2009; Davis et al. 1992), the Diffusion of Innovation Theory (Rogers 2004); Awa and Ojiabo 2016), PESTEL analysis (Pan et al. 2019), Technology-Organization-Environment model (Pan and Pan 2020), Explanation-confirmation Model (Ma et al. 2020), change and knowledge management theory (Peansupap and Walker 2005), MITE (management, individual, technology and environment) (Peansupap and Walker 2005), and Social Cognitive Theory (Ratten and Ratten 2007; Wood and Bandura 1989). With the understanding that multiple models and theories can find extensive applications in construction, a conscious effort geared towards providing some insight on applying these models in construction is needed for better research planning and improved application success. To properly lay the framework for advancing the application of explanatory and predictive models in construction technology acceptance research, it is imperative that a domain-specific synthesis is considered. To the best of the authors' knowledge, this is the first study to systematically review literature on technology acceptance within the construction domain. Therefore, the study contributes to knowledge by providing critical trends and an intellectual structure and guidance at the intersection of technology acceptance and construction research from an objective perspective.

3. RESEARCH METHODOLOGY

The authors used a systematic search process to identify all relevant published articles related to technology acceptance in construction engineering and management research. As shown in Figure 2, the present study implemented a five-step process categorized into three-stage consisting of (1) Retrieval of Publications (2) Selection of Studies for Assessment, and (3) Content Analysis of data retrieved.

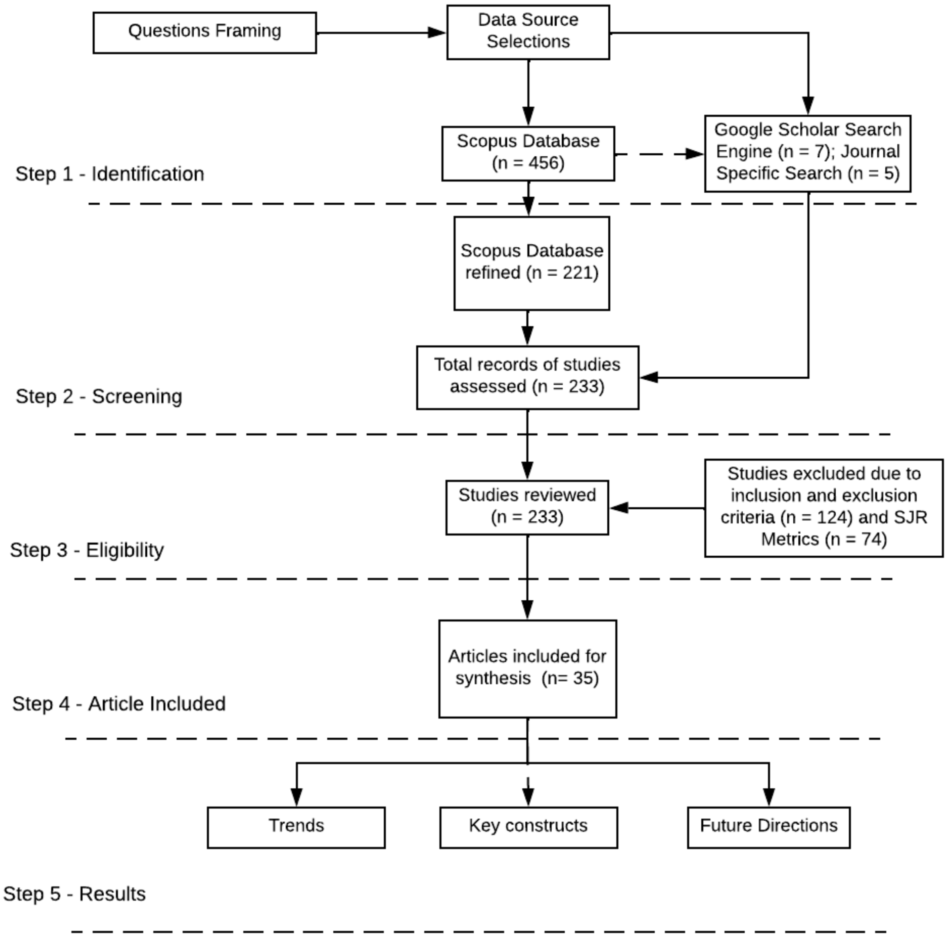

FIG. 2. PRISMA Flowchart for Systematic Review

To improve the quality of the review process and reduce bias during the data collection and analysis process, the review adapted the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) protocol guidelines (Tranfield et al. 2003; Ayodele et al. 2020) and the systematic classification of themes or patterns (Elo and Kyngäs 2008; Hu et al. 2019). Page et al. (2021) provided a 27-point checklist process to enhance the quality of the systematic review. This checklist – as described by Page et al. (2021) – includes 7 topics namely: (1) title; (2) abstract; (3) methods (including eligibility criteria, information sources, search strategy, data collection process, effect measures, synthesis methods, certainty assessment among others); (4) results (study selection, study characteristics, results of syntheses, among others); (5) discussion; and (7) other information (Registration and protocol, support, competing interests and availability of data, code and other materials). This form of research methodology is considered explicit and reproducible (Petticrew 2001), easily comprehendible (Shamseer et al. 2015) and of high quality considering the transparent document retrieval and selection process (Moher et al. 2009). Moreover, several construction engineering and management studies have applied this method (Ayodele et al. 2020; Hu et al. 2019; Mok et al. 2015; Siraj and Fayek 2019).

3.1 Retrieval of Publications (Steps 1 and 2)

In stage 1, a mainstream paper database, Scopus, was utilized to source for relevant publications in July 2021 (Ayodele et al. 2020; Babalola, et al. 2019; Okpala et al. 2020; Oraee et al., 2017; Pollack and Adler, 2015). This database is reputed to be very large and replete with information (article title, abstract, citation, and keywords) directly sourced from major building, construction, innovation, and project management journals (Falagas et al. 2008; Hu et al. 2019). The authors searched for articles within Scopus using relevant keywords/keyphrases appropriately combined. The broad keywords used by the authors for the initial search are displayed in Table 1. Four hundred and fifty-six articles were identified in Scopus using the following search string: *TITLE-ABS-KEY (Technology AND Acceptance AND Model OR TAM OR TPB OR UTAUT AND Construction OR "built environment").* To ensure that no article was left out, the authors conducted an advanced search in Google Scholar and within each journal initially flagged by Scopus. For instance, the authors searched the Journal of Construction Engineering and Management, and the Journal of Information Technology in Construction using the key words provided in Table 1. This additional search generated 13 articles. According to explicit examination criteria, the authors manually filtered papers by reading abstracts and extended summaries to exclude irrelevant papers. Two out of the four authors participated in the retrieval process to limit bias. The initial database search and screening yielded 233 viable articles.

Table 1: Terms used in the search

Keyword	Boolean	Additional keywords
Technology acceptance model (TAM)	AND	Construction
Technology acceptance model, TAM, Theory of Planned Behaviour, TPB, extended technology acceptance model, TAM2, TAM3, unified theory of acceptance and use of technology, UTAUT	AND	Construction, built environment, technologies, information systems, innovation, regression analysis, path analysis, structural equation modelling

3.2 Selection of Studies for Assessment (Steps 3 and 4)

In selecting and filtering the identified publications, the authors utilized several important criteria (Table 2) to assess the research papers for eligibility (Hu et al., 2019). For this endeavour, a preliminary literature search indicated that there are few studies that have applied explanatory and predictive models to investigate construction technology acceptance. All years of publication were considered (1985 – July 2021), and articles not critical to the study were eventually screened out using other criteria. This process involves the inclusion of only publications authored in English since with this, researchers can effectively evaluate their impact (Anwer et al. 2021). Also, only publications within the subject areas in Table 2 were considered; doing so allowed the authors to exclude publications centred on topics other than technology innovation, and acceptance models/theories to ensure that the research themes are correctly determined. At this stage, 109 articles were included for quality assessment.

Table 2: Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Should involve technology acceptance model theories (TAM [1,2,3] TPB, or UTAUT)	Technology acceptance model theories (TAM [1,2,3] TPB, or UTAUT) not used
Should be within the construction industry (design and operation inclusive)	Technology acceptance model theories (TAM [1,2,3] TPB, or UTAUT) are used but not in the context of the construction industry
Should be written in the English language	Papers that use languages other than English
Published between 1985 and 2021 (July)	Articles in Q3 and Q4 journals
Articles within the top 50% journals	Conference papers and reports

In addition, to ensure that only journal articles reputed to be of good quality were included in this study, the papers were assessed for quality and potential research impact on the research community using the journal metric as a proxy measure (Ayodele et al., 2020). Similar to existing studies (Brissi et al. 2021; Oswald and Dainty 2020; Royle et al. 2013; Zhu et al. 2018), the source journal SCImago Journal Rank (SJR) indicator was assessed in determining quality publications (those without study rating discrepancies), thus eliminating any bias during this systematic review. More specifically, the authors set a benchmark of top 50 percent of the impact factor rating (Q1 and Q2) SJR metric of journals. This method has been reliably utilized by Ayodele et al. (2020) and Crossan and Apaydin (2010). In the end, 35 of the selected articles were included in this review, thus excluding 74 papers that did not meet the established criteria for this study, and journals not found within the specified SCImago Journal Rank.

3.3 Content Analysis (Step 5)

In Stage 3, the content of selected articles was analysed in detail to (1) establish a description of the articles alongside their journal sources, publication year, and the spread by articles' country of origin; (2) trend different research methods and theories used for predicting technology acceptance; (3) identify specific factors predicting technology acceptance within construction research, and; (4) develop insight to guide the quality of future studies on forecasting technological applications in construction practice. Content analysis, as a research technique, has been utilized in multiple fields, and for determining major themes, trends, and other qualitative and quantitative metrics derived from messages (written, verbal, or visual), and depending on the project research problem to be solved (Chan et al. 2009; Krippendorff 2013; Siraj and Fayek 2019). In addition, to guide researchers with information on output hitherto obtained in the construction domain, the authors analysed the articles to compare explanatory (pairwise) relationships among antecedent variables and output data of the models. This includes the model goodness of fit indices, reliability (Cronbach alpha), and squared multiple correlations (r2), as utilized in existing technology acceptance research (Becker and Wu 2007; King and He 2006; Peterson and Brown 2005; Schepers and Wetzels 2007; Tao et al. 2020). Studies that have insufficient data and analysis, including conceptual models, were subsequently ignored when assessing pairwise relationships, goodness of fit, reliability, and predictive strength, in line with the PRISMA protocol (Page et al. (2021).

4. RESULTS AND DISCUSSION

The results from systematically reviewing the 35 identified articles are presented and discussed in this section according to the six research questions (RQ1-6).

4.1 RQ1: Publication Trends

The trend of publications by year (Figure 3) illustrates that there has been a marked increase in construction technology acceptance research output between 2009 and 2021. Over 75% of reviewed studies were published after 2015. This increase confirms the growing interest and value of technology acceptance modelling research in construction (Rahman et al 2017; Son et al., 2012: 2015), which could encourage more researchers to identify further research opportunities for future work.

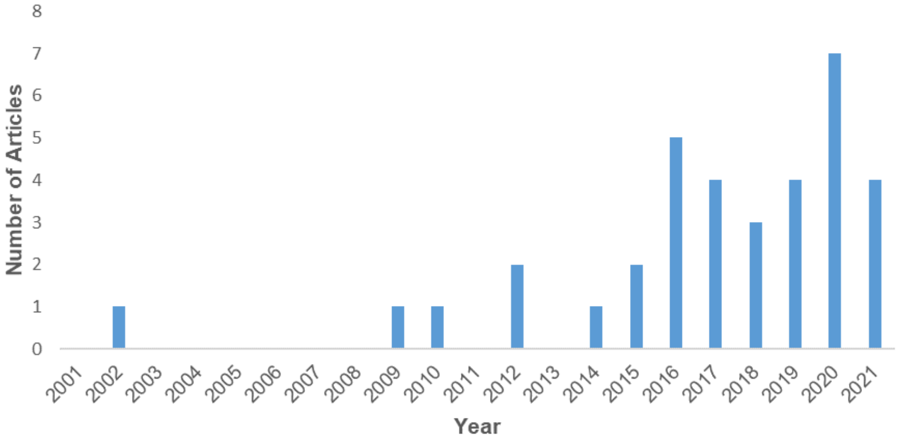

FIG. 3. Publication in Years

In addition, when considering the publication trend by countries or territories, Figure 4 displays the top ten origins (or locations) of publications (or research interests). South Korea tops the list with 12 publications followed by the United States (8), Australia (6), China (5), and the United Kingdom (3). This diverse spread is indicative of the appreciable level of effort and global interest in this topic, thus illustrating opportunities for cross-national measurement in view of technology-driven processes, and factual differences in sample sizes (Ayodele et al., 2020), industry behaviour (Cheng et al., 2020), and the types of technologies considered in different locations (Osei-Kyei and Chan, 2015).

It is also important to note that most studies focused on sampling engineers and management-related positions. This is likely driven by the skewed prevalence of studies focused on BIM and enterprise systems. These technologies are primarily utilized by individuals with either design, engineering, or management responsibilities. However, a few studies (15%), such as Okpala et al. (2021) and Choi et al. (2017), assessed frontline workers' perception of technology acceptance. Interestingly, previous studies did not investigate the perception of owners on technology acceptance.

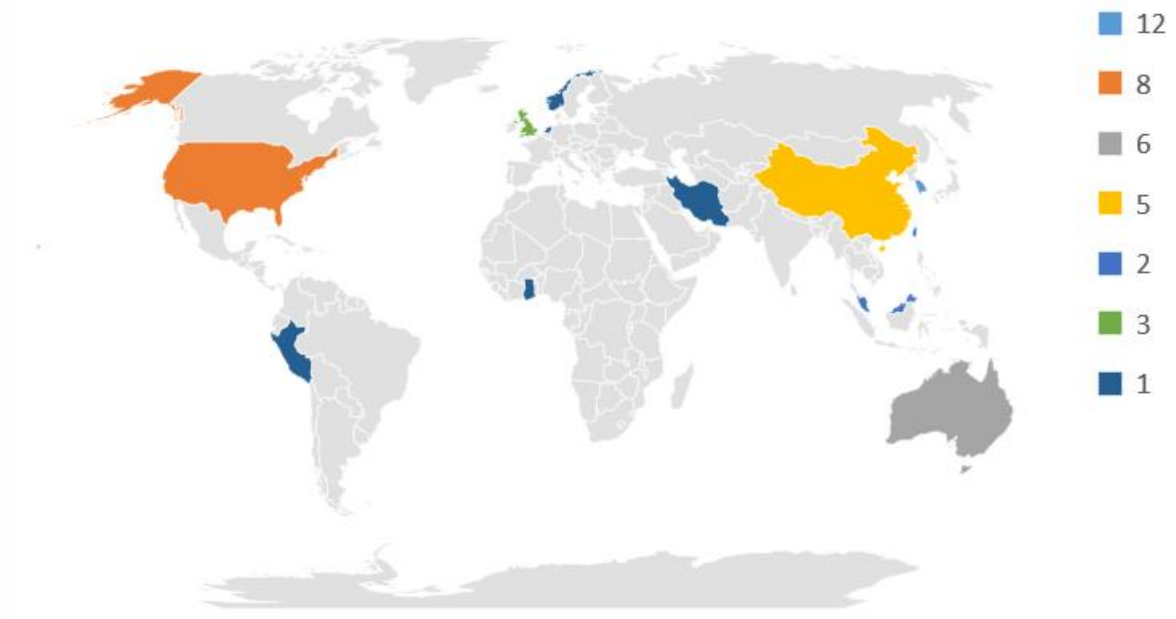

FIG. 4. Article Count by Countries/Territories

Thirty-five (35) articles reviewed were found across 12 journals (see Appendix). In terms of occurrence, the journal sources are led by Automation in Construction (AutCon) (6), Journal of Construction Engineering and Management (JCEM) (4), Journal of Information Technology in Construction (3), and Construction Innovation (3). This list of journals contains sources that are very well reputable in the field of construction engineering and management (Hu et al. 2019). This shows that researchers, in the field of technology acceptance in construction, publish in the top journals like the International Journal of Project Management (QI; H Index = 134), Automation in Construction (Q1; H Index = 107), and Journal of Construction Engineering and Management (JCEM) (Q1; H Index = 105). Table 3 summarizes high-level information from unique independent studies, such as countries of domicile, the primary application of the models, sample sizes, and methodologies utilized in the analysis reported, from the articles.

Table 3. Technology Acceptance Models and Theories in Construction Technology Research

Theories/Models	Technology Evaluated	Country	Scope	Sample Size	Methodology	Source
TAM Extension	BIM	South Korea	Industry	818	Survey, SEM, CFA	Park et al. (2019)
Hybrid Model (TAM and DeLone and McLean IS Success Model)	Wearable Technologies	USA	Industry	415	Survey, SEM, CFA	Okpala et al. (2021)
TAM Extension	Web-based Training	South Korea	Industry	408	Survey, SEM, CFA	Park et al. (2012)
Hybrid Model (TAM-IDT)	BIM	South Korea	Industry	303	Survey, SEM, CFA	Kim et al. (2016)
Hybrid Model (TAM and TPB)	Wearable Technologies	USA	Industry	298	Survey, SEM	Huang et al (2021)
TAM, TPB, and UTAUT (comparing models)	Wearable Technologies	USA	Industry	195	Survey, SEM, CFA	Okpala et al. (2021)
Hybrid Model (TAM and Equity Theory)	BIM	China	Projects	175	Survey, SEM	Wang et al. (2020)
TAM Extension	BIM	South Korea, United States	Industry	164	Survey, SEM, CFA	Lee and Yu (2016)
Hybrid Model (TAM and DeLone and McLean IS Success Model)	BIM	South Korea	Project	164	Survey, discriminant analysis	Lee and Yu (2017)
TAM Extension	BIM	South Korea	Project	162	Survey, SEM, CFA	Son et al. (2015)
TAM Extension	Smart Construction System	China	Organization	154	Survey, SEM, CFA	Yang et al. (2018)
Hybrid Model (TAM and Expectation-confirmation model)	BIM	China	Individual	151	Survey, SEM, CFA	Ma et al. (2020)

Theories/Models	Technology Evaluated	Country	Scope	Sample Size	Methodology	Source
TAM Extension	Mobile Computing Devices	South Korea	Industry	144	Survey, SEM, CFA	Son et al. (2012)
TAM	BIM	Ghana	Industry	125	Survey, Multiple regression	Acquah et al. (2018)
Hybrid Model (TAM and UTAUT)	Wearable Technologies	United States	Individual	120	Survey, Hierarchical regression analysis, CFA	Choi et al. (2017)
TAM Extension	BIM	South Korea	Organization	119	Survey, SEM, CFA	Lee and Yu (2020)
TAM Extension	BIM	South Korea	Organization	114	Survey, SEM, CFA	Lee et al. (2015)
TAM Extension	BIM	South Korea	Project	111	Survey, SEM, CFA	Hong et al. (2019)
Hybrid Model (TAM and IDT)	BIM	China	Project	98	Survey, regression analysis	Xu et al. (2014)
Hybrid Model (TAM and IDT)	Online project information management system (OPIMS)	Australia	Industry	88	Survey, SEM	Ishak and Newton (2016)
UTAUT	BIM	United Kingdom	Organization	84	Survey, SEM, CFA	Howard et al. (2017)
Hybrid (TAM and DeLone and McLean IS Success Model)	BIM	Australia	Organization	80	Survey, SEM, CFA	Hong et al. (2019)
TAM Extension	ICT	United States	Industry	76	Survey, regression analysis	Sorce and Issa (2021)
TAM	BIM	Peru	Industry	73	Survey, SEM, CFA	Sanchís-Pedregosa et al. (2020)

Theories/Models	Technology Evaluated	Country	Scope	Sample Size	Methodology	Source
TAM3 Extension	Augmented Reality and BIM	Malaysia	Industry	58	Survey, SEM, CFA	Elshafey et al. (2020)
Hybrid Model (TAM and IDT)	Building Management Systems	United Kingdom	Industry	58	Survey, regression analysis	Lowry (2002)
Hybrid Model (TAM and DeLone and McLean IS Success Model)	Enterprise Resource Planning (ERP) systems	South Korea, United States	Organization	57	Survey, SEM, CFA	Chung et al. (2009)
UTAUT	Internet of Things (IoT)	Taiwan	Industry	17	Survey, SEM, CFA	Chen et al. (2020)
Hybrid Model (TAM and TPB)	Prefabrication	Australia	Industry	14	Interview and Qualitative Analysis	Steinhardt and Manley (2016)
TAM Extension	Smart Construction Systems	Hong Kong	Organization	11	Interview, Action research	Liu et al. (2018)
TAM	BIM	Norway	Project	8	Interview, Case study, and Content analysis	Merschbrock and Nordahl-Rolfsen (2016)
Hybrid Model (TAM, TPB, and UTAUT)	Intelligent contract acceptance	Australia	Industry	7	Interview and Content Analysis	McNamara et al. (2020)
Hybrid Model (TAM, TPB, and UTAUT)	ICT	Netherlands	Organization	-	Review and Thematic analysis	Adriaanse et al. (2010)
Task–technology fit	Remotely piloted aircrafts	Australia	Project	-	Review and Thematic analysis	Golizadeh et al. (2019)
Hybrid model (TTF and UTAUT)	BIM	Australia	Project	-	Review and Thematic analysis	Hilal et al. (2019)

4.2 RQ2: Research Methods and Design for Investigating Technology Acceptance in Construction

Similar to previous reviews in other domains (Al-Emran et al. 2018), questionnaire surveys were the primary research method employed by researchers investigating technology acceptance within the construction industry. As shown in Figure 5, 77% of the studies utilized surveys and quantitative data analysis methods to investigate technology acceptance. Previous studies suggest that questionnaire surveys are the appropriate methods for assessing respondents' perceptions efficiently (Al-Emran et al. 2018) and determining the connections among constructs within a conceptual model (Malhotra and Grover 1998). Over 90% of studies sampled construction practitioners and utilized data obtained to test measurement models and obtain insights critical to understanding the behavioural intention to use technology, and actual use (Chung et al. 2009; Lee and Yu 2017). The sample size for questionnaire-based studies is 17 - 818, with about 50% of studies having a sample size of over 100. The sample size for interview-based studies ranged between 8 and 14 participants.

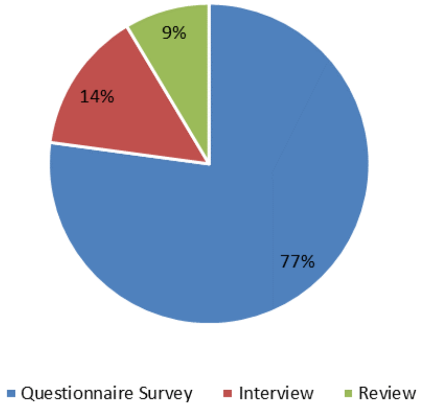

FIG. 5. Research Method Distribution

Relationships between constructs were assessed using either regression analysis or structural equation modelling (SEM). From the studies reviewed, the authors observed that for the quantitative analysis, only 21% of studies used multiple regression analysis as against SEM. Most studies utilized IBM AMOS or Smart-PLS software applications as primary tools for conducting SEM explanatory and confirmatory factor analysis. These software applications are widely used because they are accessible, easy to use, and effective (Son et al. 2012).

In addition to identifying the key constructs that impact technology acceptance, the authors believe that it is imperative that researchers and practitioners understand intrinsic population characteristics which can affect the outcomes of quantitative analyses aimed at predicting technology integration. Previous studies have highlighted the importance that demographic factors can play in technology integration (Wang et al. 2020); therefore, it is important for researchers to evaluate the effect these factors could have on the research outcome. Moderators are typically utilized to account for the potential impact of demographic factors. However, a close analysis of the articles revealed that only seven (20%) articles accounted for this critical component. It is also important to note that several studies highlighted the lack of a moderating analysis as a limitation in their studies and suggested that this should be investigated in future studies (Okpala et al 2021a; Park 2012; Lee and Yu 2016; Huang et al. 2021). The most prominent controls/moderators used in studies are age, gender, project size, organization type, experience using the technology, job title, and personal innovativeness.

4.3 RQ3: Distribution of Studies by Technology Application Domain

Regarding the technologies, Building Information Modelling (BIM) stands out as the technology frequently investigated. Over 50% of the publications (n = 18) focused on assessing the acceptance of BIM or other technologies integrated into BIM (e.g., Elshafey et al. 2020). The authors attribute this to the relatively high industry acceptance level BIM currently has when compared to other products (Son et al. 2012); thus, prompting investigations into workers' perceptions from different schools of thought. BIM is followed in a distance by wearable sensing technologies, which recorded four publications between 2016 and 2021. It is necessary to state that several existing technologies tested in the studies presented above (BIM, ICT tools, Mobile computing; Remotely piloted aircraft) are well past the development stage (Chen et al. 2020; Choi et al. 2017) and have begun to find increased construction use. This explains the absence of technologies like artificial intelligence, wearable robotics, single-task construction robots, and other emerging technologies that are still being developed and optimized for productive construction use.

4.4 RQ4: Models and Key Constructs for Assessing Technology Acceptance

An appraisal of the current theories and models utilized in construction integration research shows that TAM stands out as the foundational basis for developing conceptual models aimed at explaining and predicting technology acceptance. Researchers primarily relied on the original TAM and extensions of TAM (modified TAM model) when assessing technology acceptance (43% of published studies). There is a noticeable trend whereby researchers move to optimize the base TAM models to ensure that the measurement model closely represents real-life construction concerns (Lee et al. 2015). For instance, Choi et al. (2017) introduced the "Perceived Privacy Risk" construct with the understanding that regarding wearable technologies, one of the major barriers is skepticism towards the handling of personal information. Moreover, Son et al. (2015) included "Top Management Support" in the TAM model when assessing BIM acceptance given the important role that top management plays in construction technology adoption (Nguyen et al. 2015; Nnaji et al. 2019a; Mitropoulos and Tatum 2000).

Other studies combined TAM with other theories or models (hybrid models) such as the Diffusion of Innovation Theory (IDT), the Theory of Planned Behaviour (TPB), the Expectation-confirmation model (ECM), Task Technology Fit (TTF), and the DeLone and McLean are Success Model. The TPB, UTAUT, and IDT were the primary theories used to augment the different variations of TAM used in the reviewed studies. While most studies either used a standalone model, a modified model, or a hybrid model, one study compared the predictive strength of three models – TPB, UTAUT, and TAM (Okpala et al. 2021). The study concluded that UTAUT provides the best predictive performance (Okpala et al. 2021b). It is also important to note that very few studies complemented TAM with theories focused on inhibitors or resistance (Huang et al. 2021; Wang et al. 2020; Ishak and Newton 2016). While focusing on factors that encourage and enable the use of technology is worthwhile, investigating the inhibitors to technology acceptance through a theoretical lens is critical, especially in industries known to be resistant to innovation.

Researchers utilized several constructs to investigate technology acceptance within the construction domain. Although over 50 different constructs have been used, the key constructs used in these studies are provided in Table 4.

Table 4. Key Constructs Impacting Construction Technology Acceptance Decisions

Constructs	Definition	Models containing construct				
		TAM	TPB	TAM2	UTAUT	References*
Perceived Usefulness (Performance Expectancy) (PU/PE)	The extent of individual belief regarding how the use of a particular technology will enhance work performance	X	X	X	X	Choi et al. (2017); Lowry (2002); Son et al. (2012); Okpala et al. (2021)
Perceived Ease of Use (Effort Expectancy) (PEU/EE)	The extent of individual belief regarding how the use of a particular technology would be free of effort	X		X	X	Choi et al. (2017); Lowry (2002); Son et al. (2012)
Subjective Norm (Social Influence) (SN/SI)	Individual perception's perception regarding the extent to which an individual thinks that it is vital that others should utilize the new technology		X	X	X	Choi et al. (2017); Lowry (2002); Son et al. (2012)
Behavioural Intention (BI)	Behavioural intention is an estimate of the strength of an individual's intention to act in a specified way	X	X	X	X	Choi et al. (2017); Lee et al. (2015); Lowry (2002)
Actual use/Usage Behaviour (AU)	Actual behaviour of people using a system	X	X	X	X	Liu et al. (2018); Okpala et al. (2021b)

Constructs	Definition	Models containing construct				
		TAM	TPB	TAM2	UTAUT	References*
Attitude (ATT)	An individual's specific beliefs and degree of emotional attraction toward a system	X	X			Liu et al. (2018); Okpala et al. (2021b)
Perceived Behavioural Control (PBC)	The perceived ease or difficulty of an individual acting in a specified way		X			Choi et al. (2017); Lee et al. (2015); Lowry (2002)
Facilitating Conditions (FC)	Environmental factors designed to make an act easy to be carried out.				X	Hilal et al. (2019); Lowry (2002); Son et al. (2015)

*References provided are example sources that used these constructs and provided definitions for the constructs and models

Data in Table 4 contains well-defined critical constructs alongside models which frequently contain these constructs. These constructs were utilized in different variations in at least 50% of the published articles. This assessment connotes that since these constructs have been used successfully in previous studies, future studies will likely use these constructs as well. For instance, a factor to test is whether individual users think the new technology is useful (perceived usefulness) and easily operable (perceived ease of use). Moreover, if workers think the work environment (facilitating conditions) enables them to productively use the new tool, additional critical insights on whether they intend to use the technology (Behavioural Intention) or to continue using the technology (Actual Use) will be generated.

4.5 RQ5: Pairwise Relationships Between Model Constructs

Given that reviewed studies utilize several constructs, it is important to investigate the relationship between these constructs. This investigation will help identify meaningful relationships that should be considered when developing conceptual models to investigate technology acceptance in the construction industry. Table 5 shows pooled data from the reviewed studies. Each study was assessed and the Path Coefficients for the key construct were extracted to develop the ranges depicted in Table 5. In addition, information on the Confidence Interval and P-value was collated from each study as well.

Table 5: Pairwise Relations between Key Constructs

Constructs	Total Sample Size	Confidence Interval	Path Coefficients	P-value Range
PU →BI	775	90% - 99%	0.22 - 0.47	Supported (P<0.01, P<0.001)
PEU →PU	1518	95% - 99%	0.01 – 0.51	Supported (P<0.05, P<0.01, P<0.001)
PEU → ATT	125	90% - 95%	0.315	Supported (P<0.05)
ATT →BI	125	90% - 95%	0.573	Supported (P<0.05)
PEU → BI	775	90% - 99%	0.19 – 0.51	Supported (P<0.05, P<0.01, P<0.001)
SN → PU	306	95%	0.20 - 0.21	Supported (P<0.05)
PBC → BI	114	95%	0.24	Supported (P<0.05)
FC →BI	17	90%	-0.18	P = 0.039
FC →PEU	162	99%	0.44	Supported (P<0.001)
BI → AU	84	95%	0.22 - 0.88	Supported (P<0.001)
FC → AU	84	95%	-0.18 - 0.54	Supported (P<0.001)
ATT →AU	84	95%	0.13	P = 0.14

As listed in Table 5, the coefficients along the paths are mainly positive and significant, with confidence intervals ranging from 90% to 99%. The hypotheses tested along the paths binding the primary constructs from TAM, TPB, TAM2, and UTAUT models highlighted in Table 5 were supported in most cases. The paths PEU→PU, PU→BI, and PEU→BI are narrower than other paths (at 95% confidence intervals); indicating that these paths were robust and consistent across the studies. It is interesting to note that Attitude (ATT) is the strongest predictor of BI (0.573), followed by PU (0.216 - 0.473), and perceived behavioural control (0.239).

PU could be predicted by PEU (0.001 – 0.506) and subjective norm (0.20 - 0.212), while PEU could be predicted by facilitating conditions (0.44). More specifically, all pairwise relationships are positive and statistically significant, with the exception of path coefficients of FC→BI and FC→AU which are negative. Overall, Table 5, represents useful data for construction management researchers to consider when creating linkages between constructs in preparation for explanatory and confirmatory analysis in any of the models and theories considered. With a good understanding of commonly occurring relationships from previous domain-specific studies, the authors believe that better conceptual models can be created with better predictive performance.

4.6 RQ6: High Performing Models: Predictive Strength and Evaluation Metrics

The authors appraised the performance of models with the view of determining which models currently stand out (ability to explain total variance or predictive power). Each study was examined to identify articles that reported the amount of variance in the dependent construct (typically Behavioral Intention) explained by the model (R^2). About 69% of articles reviewed in this study reported R^2 values for the end construct. Table 6 provides a summary of the studies that reported R^2 values. The reported R^2 values were extracted alongside other key performance variables such as composite reliability and sample/construct ratio. The predictive and explanatory power of models (R^2) ranged between 0.10 and 0.91 (see Table 6). According to Hair et al. (2011), "R^2 values of 0.75, 0.50, or 0.25 for endogenous latent variables in the structural model can be described as substantial, moderate, or weak, respectively." As shown in Table 6, the predictive power of most models reviewed in this study is classified as moderate (R^2 value of 58% of studies reviewed falls between 0.5 and 0.75). This suggests that while significant gains have been achieved within the technology acceptance investigation in the construction industry, there is room for improvement.

The results in Table 6 illustrate that the TAM Extension and UTAUT outperform other models and theories in terms of the predictive power of the behavioural intention to use a new technology. Interestingly, when hybrid models are developed, the predictive strength is slightly lower compared to the TAM Extensions and UTAUT. However, the median predictive strength across each theory suggests that the difference between theories is not significant (all theories fall within moderate predictive strength). It is important to note that the predictive strength of each model could be impacted by various factors such as the number of participants, model design, number of constructs, etc. Therefore, these results should be interpreted with caution.

Table 6. High Performing Models: Predictive Power

Theory/Model	End Construct	Total Variance Explained (R^2)	Sample/Construct Ratio	Composite Reliability	Source
TAM Extension	Perceived Performance	0.670	13.09	0.86 – 0.95	Son et al. (2012)
Hybrid Model (IDT-TAM)	BIM Adoption	0.288	32.60	-	Xu et al. (2014)
Hybrid Model (TAM, TAM2, and UTAUT)	Intention to Adopt	0.680	17.14	0.84 – 0.950	Choi et al. (2017)
TAM Extension	Behavioral Intention	0.510	20.25	0.77 – 0.950	Son et al. (2015)
Hybrid Model (TAM, TAM2, TAM3, TPB, TTF, and UTAUT)	Behavioral Intention	0.552	12.60	0.73 - 0.841	Lee et al. (2015)
TAM Extension	Transfer of Training	0.724	40.8	0.777 – 0.860	Park et al. (2012)
Hybrid Model (TAM, TAM2, and DeLone and McLean IS Success Model)	Project success	0.84	30	0.915	Okpala et al. 2021a
TAM Extension	Behavioral Intention	0.616; 0.771	18.20	>0.7	Lee and Yu (2016)

Theory/Model	End Construct	Total Variance Explained (R^2)	Sample/Construct Ratio	Composite Reliability	Source
TAM Extension	Using Intention		12.83	0.691 – 0.947	Yang et al. (2018)
Hybrid Model (TAM and Equity Theory)	Behavioral Resistance to BIM Implementation	0.520	19.40	0.83 – 0.900	Wang et al. (2020)
UTAUT	Actual Behavior	0.675	2.83	0.787 – 0.803	Chen et al. (2020)
TAM	Behavioral Intention	0.350	31.25	0.75 – 0.810	Acquah et al. (2018)
TAM Extension	Intention to Use	0.780	102.25	0.932 – 0.959	Park et al. (2019)
UTAUT	Behavioral Intention	0.700	12.00	0.766	Howard et al. (2017)
Hybrid Model (TAM, TAM2, and DeLone and McLean IS Success Model)	Individual Intention	0.716	11.10	0.675 – 0.906	Hong et al. (2019)
TAM, TPB, UTAUT	Actual Use	0.89; 0.9; 0.91	48.8; 39; 32	-	Okpala et al. (2021b)
TAM	Actual Use	0.647	19	0.79	Sanchís-Pedregosa et al. (2020)
Hybrid Model (TAM, UTAUT SNT, DOI)	Resistance	0.484	5.87	-	Ishak and Newton (2016)
Hybrid Model (TAM and IDT)	Actual Use	0.288	16.3	-	Huier et al (2014)
TAM Extension	Behavioral Intention	0.437	11	-	Hong et al. (2019)
TAM Extension	Behavioral Intention	0.488	12.1	0.70 – 0.93	Lee and Yu (2020)
TAM	Behavioral Intention	0.10; 0.273; 0.361	31.25	-	Acquah et al. (2018)
Hybrid model (TAM and TPB)	Behavioral Intention	0.533	24.8	0.817 – 0.904	Huang et al. (2021)
Hybrid model (TAM and IDT)	Behavioral Intention	0.163	37.9	>0.7	Kim et al. (2015)

Another important performance and quality check for technology acceptance modelling is the sample-construct ratio. A widely accepted rule of thumb is to sample at least 10 participants for each construct assessed (10:1) (Nunnally and Bernstein, 1967 quoted by Wang and Wang, 2012). However, some studies suggest that this threshold is flexible, and could be reduced to 5:1, depending on the context (Dimitrov, 2012; Lingard and Rowlinson 2006). As shown in Figure 6, UTAUT had a higher median prediction power, regardless of the lower median sample-construct ratio. In line with this finding, it was observed that the majority of models reviewed in these studies that utilized smaller sample sizes (Hong et al. 2019; Howard et al. 2017) performed slightly better in terms of the prediction of endogenous constructs. This finding suggests that utilizing a relatively large sample for analysis may not necessarily improve the performance of the model, and lower sample-construct ratios may be acceptable in construction technology acceptance research since they did not impact the predictive power of the model. The authors recognize that these findings may not be generalizable at this time, and additional robust research and sensitivity analysis is needed to verify this assertion.

Analysis of the composite reliability (CR) from the reviewed studies indicates that the CR of the technology acceptance models ranges from 0.675 – 0.950. This suggests that the models are valid and performed well given that the CRs are higher than 0.7 (Lee et al. 2015). This finding indicates that when developing new or testing existing models to investigate technology acceptance in the construction industry, the inclusion of TAM and UTAUT constructs as foundational variables will enhance prediction.

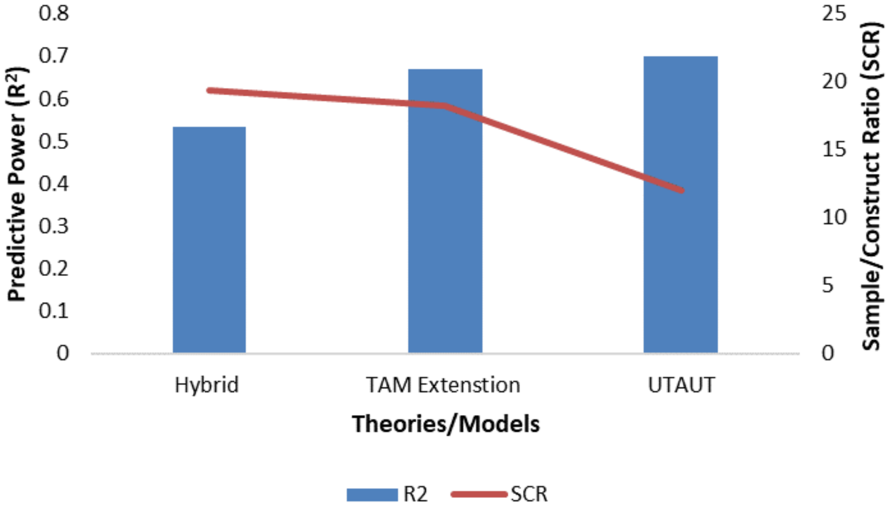

FIG. 6. Predictive strength and sample-construct ratio for different theories

A critical aspect of explanatory and prediction modelling is the assessment of model fit. Previous IS studies have utilized several Goodness of Fit Indices (GFI) to assess the quality of technology acceptance models (measurement model). Table 7 shows the GFIs obtained from the reviewed studies, however, for brevity, only a sample of studies is listed in the table. A close observation of the GIF across these studies unravelled a high level of inconsistency in the selection and use of GFI in the evaluation of measurement models. For instance, Park et al. (2012) reported seven Indices of fit while Kim et al. (2016) reported two. Previous studies posit that at a minimum, chi-square-degree of freedom ratio (x^2/df), root mean square error of approximation (RMSEA), Root Mean Square Residual (RMSR), and the Comparative Fit. Index (CFI) should be reported (Kline 2015). Therefore, the authors recommend that construction studies should use these four Fit Indices, at a minimum.

In addition to the number of fitness indices, it is also paramount to utilize the appropriate thresholds for determining the appropriate fit. It was observed that the indices value for each study varied greatly. For example, the four critical indices – x^2/df, RMSEA, RMSR, and CFI – have bands of 1.41 – 6.78, 0.05 – 0.12, 0.03 – 0.18, and 0.59 – 0.99, respectively. While future researchers could utilize these ranges as a guide when conducting future construction technology acceptance research, it is important to compare these values to accepted thresholds for assessing the measurement model fit. Following a critical assessment of the reviewed studies, the authors uncovered that about 65% of the studies reported at least one fitness index that did not meet the threshold [Chi-squared (Chisq) P-VALUE >0.05; GFI/AGFI >0.95; NFI/NNFI/TLI >0.9; CFI >0.9; RMSEA <0.08, non-significant p-value; RMR/SRMR <0.08; RFI>0.8; IFI >0.9; PNFI >0.5]. Figure 7 shows the compliance rate of studies that utilized the different indices (number of studies reporting each index with a value greater than the threshold/total number of studies reporting each index). As depicted in Figure 7, CFI and Chi-squared reported the lowest compliance rate (~50%), while RMSEA recorded the highest compliance rate (92%).

To facilitate construction technology integration, it is imperative that researchers keep exploring the use of technology acceptance theories. These explanatory and predictive models and theories can find very productive applications as decision-support tools in construction organizations ready to explore and possibly adopt novel work strategies and technological advancements. It is also important to preserve and continue seeking ways to improve upon existing quantitative predictive and explorative modelling methods. A summary of the key findings from the systematic review is presented in Table 8 below.

Table 7. High Performing Models: Goodness of Fit Indices

Theory/Model	x2/df	PNFI	RMSR	GFI	PGFI	AGFI	RFI	NNFI/TLI	CFI	RMSEA	Source
TAM Extension	1.412	-	0.066	-				0.938	0.945	0.054	Son et al. (2012)
Hybrid Model (TAM, TAM2, and UTAUT)	1.43		0.034	-	-	-	-	0.99	0.99	0.062	Choi et al. (2017)
TAM Extension	2	-	-	0.825	-	-	-	0.904	0.921	0.079	Son et al. (2015)
Hybrid Model (TAM, TPB, TTF, and UTAUT)	2.184		0.181	-	0.511	-	-	0.726	0.745	0.097	Lee et al. (2015)
TAM Extension	2.257	-	0.066	0.862	-	0.831	-	0.933	0.942	0.056	Park et al. (2012)
Expectation-confirmation model (ECM)	6.915	-	-	-	-	-	-	0.537	0.586	0.199	Ma et al. (2020)
Hybrid Model (TAM-IDT)	-		-	0.902	-	-	-	0.934	-	-	Kim et al. (2016)
TAM Extension	2.570		-	0.936	0.941	-	0.937	0.912	-	0.072	Yang et al. (2018)
UTAUT	2.057		0.071	0.796	-	0.783	-	-	-	0.097	Chen et al. (2020)
TAM Extension	6.784		-	0.857	-	0.807	0.898	0.912	0.923	0.078	Park et al. (2019)
UTAUT	2.659	-	-	0.585	-	-	-	-	0.774	0.148	Howard et al. (2017)
Hybrid Model (TAM and Success Models)	2.08	-	0.145	-	0.504	-	-	0.73	0.75	0.095	Hong et al. (2019)

Where RMSR = root mean square residual; NNFI = non-normed fit index; PGFI = parsimony goodness-of-fit index; AGFI = adjusted goodness-of-fit index; RFI = relative fit index; TLI = TuckerLewis index; CFI = comparative fit index

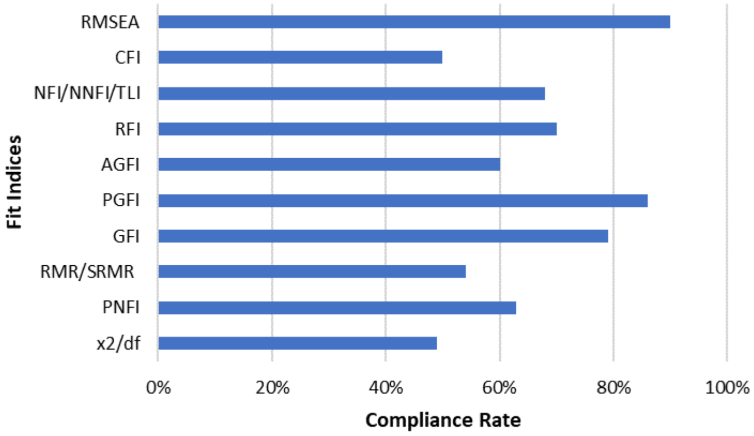

FIG. 7. Measurement Model Compliance rate

Table 8: Research Summary

Research Question	Key findings
RQ1: Key Research Trends	Over 75% of reviewed studies were published after 2015, suggesting increasing interest in technology acceptance modelling
	Most publications emanated from South Korea and USA (57%)
	The top three publication avenues are Automation in Construction, Journal of Construction Engineering and Management, and Journal of Information Technology in Construction
RQ2: Research Method	About 77% of the studies utilized surveys and quantitative data analysis methods to investigate technology acceptance
	Relationships between constructs were assessed using either regression analysis or structural equation modelling (SEM).
	The most prominent controls/moderators used in studies are age, gender, project size, organization type, experience using the technology, job title, and personal innovativeness.
RQ3: Technology Application Areas	Over 50% of the publications (n = 18) focused on assessing the acceptance of BIM or other technologies integrated into BIM
	About 85% of the studies focused on assessing technology acceptance from management-level employees' perspective
RQ4: Key Models and Constructs	Researchers primarily relied on the original TAM and extensions of TAM (modified TAM model) when assessing technology acceptance (43% of published studies).
	The TPB, UTAUT, and IDT were the primary theories used to augment the different variations of TAM used in the reviewed studies
	Key antecedent factors affecting acceptance of technology in the construction industry are Perceived Usefulness (Performance Expectancy) (PU/PE), Perceived Ease of Use (Effort Expectancy) (PEU/EE), Subjective Norm (Social Influence) (SN/SI), Attitude (ATT), Perceived Behavioural Control (PBC), Facilitating Conditions (FC), Behavioural Intention (BI), and Actual usage Behaviour (AU).
RQ5: Pair-wise Relationship	The paths PEU→PU, PU→BI, and PEU→BI are narrower than other paths (at 95% confidence intervals); indicating that these paths were robust and consistent across the studies.
	Attitude (ATT) is the strongest predictor of BI (0.573), followed by PU (0.216 - 0.473), and perceived behavioural control (0.239).
RQ6: Models with High Predictive Validity	The predictive and explanatory power of models (R^2) reviewed in this study ranged between 0.29 and 0.93. Most models have moderate predictive power.
	The TAM Extension and UTAUT outperform other models and theories in terms of the predictive power of the behavioural intention to use a new technology, although not significantly.
	The four critical goodness of fit indices are x^2/df, RMSEA, RMSR, and CFI, and the ranges reported in the reviewed study are 1.41 – 6.78, 0.05 – 0.12, 0.03 – 0.18, and 0.59 – 0.99, respectively.

5. FUTURE WORK ON CONSTRUCTION TECHNOLOGY ACCEPTANCE IN PRACTICE

To ensure the productive exploration of technology integration research in practice, the authors hereby provide eight (8) possible areas that require further investigation:

I. Results from the systematic review indicate that most studies focused on using models that rely on enabling constructs. However, the construction industry is reputed to be one of the most technology-averse industries. To provide a more holistic assessment of technology acceptance, future studies should integrate resistance theories (Laumer and Eckhardt 2012). For instance, researchers could utilize theories such as the Innovation Resistance Theory (Kaur et al. 2020), The Psychological Reactance Theory (Knowles and Line 2004; Ngafeeson 2015), the Theory of Status Quo (Shirish and Batuekueno 2021; Kim and Kankanhalli 2009), Passive resistance misuse theory (Marakas and Hornik 1996), IT Identity Threat (Craig et al. 2019) and The Resistance to IT Implementation Theory (Lapointe and Rivard 2005) to supplement TAM, TPB, and UTAUT.

II. Given that technologies have different characteristics, it is essential that researchers adapt acceptance models to incorporate constructs that are more pertinent to the technology of interest. While some studies successfully integrated technology-specific constructs, several studies failed to incorporate these constructs. Future studies should ensure that appropriate constructs that extend the traditional TAM constructs are included within the models to ensure these models are technology-specific. Ideally, end-user interviews should be conducted to help inform the development of a conceptual model that incorporates technology-specific constructs.

III. In optimizing conceptual models to improve predictive power and relevance, researchers are encouraged to utilize moderators. Moderators such as age, gender, education, project size, organization type, experience using the technology, job title, and personal innovativeness should be utilized in future studies to control for the potential impact of demographic factors on the participants' behavioural intention (BI) or actual use (AU). The choice of moderators should be driven by the type of technology and the goal of the study. For instance, researchers should utilize age, gender, education, and experience when evaluating a technology at the individual level. It is expected that this approach to technology acceptance research will allow for more accurate findings

IV. It is imperative that construction integration research considers the technology pre-and-post-adoption behaviour of workers. Most of the studies evaluated in this review focused on pre-adoption behaviour, however, successful technology implementation is dependent on sustained use (post-adoption). Post-adoption assessment could incorporate individual coping mechanisms. These mechanisms take into consideration the emotional state of the workers and their ability to quickly adapt when there is a change to traditional techniques of work execution. Utilizing coping theories such as user adaptation (Beaudry and Pinsonneault 2005) can enhance our understanding of how individual coping behaviour can influence the extended use of technologies in the construction industry (Okpala et al. 2021a).

V. Although a few studies incorporated IS success models into foundational acceptance models (TAM, for instance), integrating effective success models such as the IS-Impact Measurement model (Gable eta l. 2008), Success Model of Innovation Adoption (Kishore and McLean 1998), and extensions to Delon and McLean's success model (Seddon 1997) would provide researcher s great opportunity to investigate technology integration at multiple levels. Specifically, by developing construction-specific or domain-specific success models, researchers would be able to measure implementation success indicators of technology acceptance and unravel the connection between technology acceptance and performance at project and organization levels. An understanding of the perceived benefits of adoption and improvement of success factors at the individual, project, and organizational levels can go a long way in convincing top management to push for the introduction of existing and emerging construction technologies.

VI. With the globalization of construction and the increase in international projects and joint ventures involving companies from different countries, researchers should develop and test models that cut across national boundaries. These models could include moderators for potential cultural differences to ensure model efficacy. This approach will generate relevant theoretical and practical insights and provide practitioners involved in international projects with a tool for assessing the technology acceptance intention before making a significant investment in new technology.

VII. As research on technology acceptance continues to grow within the architectural, engineering, and construction domains, future studies could explore developing technology-centric reviews. For instance, future studies could review technology acceptance studies focused on BIM. This review will provide unique insight that could inform research and practice at the nexus of BIM and technology integration.

VIII. The studies evaluated in this review effort focused primarily on using acceptance theories and models to assess technology acceptance at a point in time. However, to better understand the impact of the interaction between workers and the dynamism within the construction industry, future studies could consider exploring technology acceptance using top-down simulation approaches such as agent-based modelling (Nnaji et al 2019b; Huang et al. 2021; Pakravan and MacCarty 2021). This approach would provide researchers and organizations the opportunity to model technology acceptance at different levels and also provide an opportunity to conduct what-if and sensitivity analyses. Utilizing this modelling approach would provide management opportunities to test the potential impact of strategies before investing heavily in those strategies.

6. CONCLUSIONS AND LIMITATIONS

Technology integration has emerged as a necessary process in the push for significant improvements in the construction sector in terms of productivity, safety, cost and schedule, and quality. To achieve this improvement, there is a pressing need for construction researchers and practitioners to work towards the conceptual development, optimization, and usage of empirical tools to foster the effective integration of technologies into construction operations. Enhancing technology integration requires a proper understanding of factors that influence the behavioural intention to use, and actual usage of construction technologies. Relying on a systematic review, this study has offered a state-of-art review of the current state of development and usage of explanatory and predictive models to forecast technology acceptance. The present review study points out 13 new findings and presents seven areas worthy of future exploration. This study contributes to practice and knowledge by (1) systematically reviewing the body of knowledge regarding models and theories used for technology acceptance research in construction. This review creates a firm foundation for advancing knowledge within the construction technology acceptance domain; (2) evaluating the specific factors that can predict the acceptance of technologies in construction research and their pairwise relationships. Investigating these factors (constructs) and identifying the critical ones and their relationships allows for an expanded understanding of construction practitioners' inherent behaviours that are critical to technology integration decision-making, and; (3) developing critical insight needed to guide the quality of future studies on forecasting technology acceptance in construction. With a good understanding of the finding espoused in this study, the authors believe that better conceptual models can be created with better predictive performance.

As with every review study, this study has some limitations. First, while the study followed a detailed process to identify useful papers within the scope of the present study, some relevant articles could have been inadvertently missed. Also, this study focused on journal papers with an established quality criterion, hence, some useful conference papers, reports, and online materials that could have provided additional insights into technology acceptance were ignored. Additional databases could also be explored to potentially expand the pool of studies. Notwithstanding these identified limitations, this research contributes to an excellent understanding of the current state of construction technology integration.

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APPENDIX

Table 8: Journals and Articles Included in the Review

S/No	Journal	SJR (Q1 – Q2)	Journal H-Index	Number of Articles	Reference
1	International Journal of Project Management	Q1	134	1	Howard et al. (2017)
2	Automation in Construction	Q1	107	6	Choi et al. (2017); Lowry (2002); Xu et al. (2014); Son et al. (2012); Son et al. (2015); Park et al. (2012)
3	Journal of Construction Engineering and Management	Q1	105	6	Liu et al. (2018); Adriaanse et al. (2010); Lee and Yu (2016); Okpala et al. (2021); Chung et al. (2009); Huang et l. 2021
4	Journal of Management in Engineering	Q1	62	2	Lee et al. (2015); Ma et al. (2020)
5	Engineering, Construction and Architectural Management	Q1	54	2	Hong et al. (2017); Park et al. (2019)
6	Journal of Civil Engineering and Management	Q2	43	3	Yang et al. (2018); Chen et al. (2020); Wang et al. (2020)
7	Journal of Information Technology in Construction	Q2	42	5	Elshafey et al. (2020); Acquah et al. (2018); Merschbrock and Nordahl-Rolfsen (2016); Source and Issa (2021); Sanchís-Pedregosa et al. (2020)
8	Construction Innovation	Q1	36	4	McNamara et al. (2020); Hilal et al. (2019); Golizadeh et al. (2019); Okpala et al. (2021)
9	Applied Sciences (Switzerland)	Q1	35	2	Lee and Yu (2020); Hong et al. (2019)
10	KSCE Journal of Civil Engineering	Q2	31	2	Lee and Yu (2017); Kim et al. (2016)
11	Construction Economics and Building	Q2	18	2	Steinhardt and Manley (2016); Ishak and Newton (2016)