Status and gap identification on Technology adoption studies based on Technology innovation acceptance frameworks in construction.

Emmanuel Eze[1] and Ernest Ameyaw[2]

[1,2] Department of Architecture and Built environment, Northumbria University, Newcastle, UK
[1]emmanuel2.eze@northumbria.ac.uk

Abstract

Digital technologies adoption and acceptance in the construction industry is low and this has been blamed for the inefficiencies and poor productivity problems in the sector. The purpose of this study was to examine research on technology adoption in construction, with a focus on those based on technology acceptance frameworks (TAF), to understand the status and trends, and existing gaps and suggest future research direction. This study through scientometrics and content evaluation methods, reviewed 103 technology adoption studies in construction that have utilised any of the technology adoption(acceptance) models and theories. The Scopus database was used for the retrieval of bibliographic data and VOSviewer software was utilised in the science mapping of knowledge. It was found that studies on technology adoption have maintained a continuous increase since 2009, and the Journal of Construction Engineering and Management (JCEM), Construction Innovation (CI) and Engineering Construction and Architectural Management (ECAM) were the prominent sources of these studies. A large proportion of the issues came from China, Australia, the USA, South Korea, and the UK, and Technology acceptance theory (TAM) and hybrid (TAM & TOE-technology organisation and environment) are the most utilised standalone theory and the hybrid models respectively. Building information modelling (BIM) is the most widely studies digital technology, and the larger percentage of the 103 studies focused on organisational and industry levels adoption. This study is limited to 103 data obtained from Scopus database. The leading outlets, authors and countries reported herein will help future researchers in the choice of collaboration and leading outlet to publish their works. The Recommendations were made for future studies to further propel technology innovation penetration in the construction sector.

Keywords

Digital technologies, User behaviours, Technology adoption, Innovation acceptance, Scientometrics analysis.

1. Introduction

The construction industry has remained backwards in technological innovation adoption compared to other economic sectors, and this has been part of the reasons for the inefficiencies, poor productivity and dissatisfactory cost, time and health and safety performance records (Eze et al., 2019). The predominance of the traditional approach and the conservative attitudes of the industry have further kept the industry at the bottom of the technology adoption curve. Technology adoption has been advocated to be the leading sustainable measure to mitigate these problems associated with traditional practices. Digital technologies implementation is beneficial to improving the competitive advantage of organisations, better documents, and information management, enhancing worker safety and productivity and the ways of working, thus, disrupting the traditional practices, and promoting the upgrading of the construction sector at large (Nnaji et al., 2023; Zhang et al., 2023).

The attainment of these benefits is dependent on the adoption of digital technologies, and this is associated with the decisions of the stakeholders and a change towards the acceptance of digital tools to drive construction operations. In addition, global advancements in technology do not only impact projects' lives but also users' personal and professional lives. These have made the questions on the decision to accept or reject technological innovation unanswered (Marangunic´ and Granic, 2015) despite the numerous predictive and explanatory models that have been developed over the decades. This calls for a detailed understanding of the forces driving the technology acceptance or rejection decision.

Several empirical studies utilized different predictive and explanatory models and theories to explore innovation acceptance and diffusion in construction (e.g., Source and Issa, 2021; Chen et al., 2020; Attencia and Mattos, 2022; Zhou et al., 2023),

there is the dearth of review works on technology acceptance in the construction domain. The available ones either focused on one theory and specific technology(ies) or a few documents and theories. For instance, Sepasgozar et al. (2021) focused on studies that utilized only technology adoption theory (TAM) to determine the key factors affecting users' intention to adopt Mixed reality and digital Twin (MRDT). Nnaji et al. (2023) utilized the Scopus database and extracted 35 documents that focus on 3 theories (TAM, TPB-theory of planned behaviour, and the Unified Theory of Acceptance and Use of Technology (UTAUT)). There are numerous theories and models for predicting users' technology acceptance or rejection behaviours. Technology innovation acceptance requires consideration of more diverse and integrated theoretical approaches for better decisions (Taherdoost, 2018). It is based on this knowledge that this study via a scientometric, and content analysis approach carried out a detailed review of studies on technology adoption that used technology acceptance theories and models to investigate users' technology acceptance/adoption behaviour. The study went further to consider more technology acceptance theories and models over what was used in existing research. Thereby providing a base for future research. The purpose of this study was to examine research on technology adoption in construction, with a focus on those based on technology acceptance frameworks (TAF), to understand the status and trends, and existing gaps and suggest future research direction.

2. Technology acceptance/adoption and its theories.

Innovation acceptance is the outcome of an optimistic decision by the stakeholders to utilise new technology or continue to use existing technologies. The literature review reveals that several frameworks and models have been developed to predict users' acceptance and adoption of new technologies and methodologies. This section briefly describes some of the leading and foundational models and frameworks used for predicting stakeholders' technology acceptance behaviours for new technologies, techniques, or methodologies in construction.

Theory of Reasoned Action (TRA) - this theory was introduced in 1975 by Ajzen and Fishbein and has served as the foundation for the technology acceptance model (Davis et al., 1989). TRA holds that the actual behaviour of an individual to accept innovation is shaped by behavioural intention, which is influenced by attitude and subjective norms. This theory believes such behaviour should be voluntary, systematic, and rational (Taherdoost, 2018).

Theory of Planned Behaviour (TPB) - this is the outcome of the extension of TRA by (Ajzen, 1991) means to overcome the drawback of TRA in mandatory situations. The TPB hold that 'perceived behavioural control (PBC)', attitude, social norms, and intentions influence actual behaviour.

Technology acceptance model (TAM) – TAM was developed from TRA, and it describes how users' acceptance of innovation is motivated by perceived usefulness (PU), perceived ease of use (PEU), and attitude toward use. TAM has gained increased empirical support in the past decades and has remained the most used, cited technology adoption framework by researchers and academics (Taherdoost, 2018). TAM is flexible as it also considers external variables that can be modified to suit the specific technology and environment of intended adoption. This flexibility has led to its extensions to improve its adaptability, specificity, and predictive/explanatory powers (Maillet et al., 2015). Consequently, led to TAM2, TAM3, and the ease of integrating TAM with other models in a hybrid framework.

Innovation diffusion theory (IDT) – This theory is useful to both organisation and individual levels, as well as provides theoretical backing to discuss the global adoption of the technologies (Taherdoost, 2018). The IDT was developed in 1995 by Rogers (Rogers, 1995), and it provides five determinants of innovation acceptance and adoption: relative advantages, trialability, compatibility, complexity, and observability.

The technology organization environment (TOE)- theory is consistent with the IDT and was developed by (Tornatzky & Fleischer, 1990). Its use in predicting the adoption of new technology has increased over the years. It holds that the acceptance and adoption of new technologies are determined by three broad factors (technology, organisation, and environment).

Unified Theory of Acceptance and Use of Technology (UTAUT) - this is a unification model developed by Venkatesh et al. (2003), and it is made of eight technology adoption frameworks (TRA, TAM, TPB, motivational model, IDT, Social cognitive theory, combined TAM-TPB, and the model of PC initialization). The UTAUT has performance expectancy, social influence, effort expectancy and facilitating conditions as determinants of innovation acceptance. While age, gender, voluntariness, and experiences are moderators (Alomary and Woollard, 2015).

3. Research and Methodology

To determine the status, trends, and gap in the existing literature on research on technology adoption theories and models in construction, the scientometrics and content analyses approach were adopted. Overall, the research followed a 3-step process of (1) data collection, (2) data screening and (3) analysis-scientometrics and content analyses. Scientometrics is part of the bibliometrics approach that allows for the quantitative examination of scientific and technology-based publications (Hawkins, 2001), and unlike the traditional review approach, it makes it practicable to identify patterns and concepts in existing studies (Zhong et al., 2019). There is evidence of the use of the scientometrics approach in previous review-based technology research (Darko et al., 2020), however, such evidence is lacking about the mapping of existing knowledge on technology acceptance models and theories studies. Thus, a gap in research methods, and another premise for this review.

Quantitative Data retrieval and refinements of data for Scientometrics: The Scopus database was leveraged in this study as it offers a multi-disciplinary publication from diverse subjects (Aghimien et al., 2020). Multiple databases were not used to avoid wasting time in sorting and removing duplicates and overlapping documents across different databases. Using appropriate keywords based on the research purpose, the initial search of the Scopus database was executed in May 2023, and this led to the identification of 549 documents. The search was further refined to journal articles published in the English language only, then, to some select subject areas ("Engineering", "computer science", "business, management and accounting", "Social sciences" and "Environmental sciences"), which produced 295 documents (See Table 1). The choice of journal articles is premised on the high-quality knowledge they provide due to the rigorous review processes they go through before publications. Since, the number of studies in the architectural, engineering and construction (AEC) industry is still growing, the search was not limited to any time limit so that vital documents are not lost and to avoid distorting the historical trends of publications of interest. The 295 documents were downloaded into the "comma-separated values (CSV)" file format which works well with VOSviewer software utilised for the scientometric analysis.

Data Screening: The downloaded file was opened in Excel format and the titles, abstracts, and keywords were skim-read. Only construction context articles were retained. Further, the ranking of the document sources was checked and only 103 documents rated Q1 and/or Q2 in the SCImago journal ranking metrics and were retained (Table 1). This inclusion and exclusion criterion approach is in line with (Nnaji et al., 2023).

Table 1: Data search protocols and document synthesis

Database & Search string	Scopus: "((TITLE-ABS-KEY (*"Technology" OR "digital Technology" OR "digitalisation" OR "industry 4.0") AND TITLE-ABS-KEY ("Theory of Diffusion of Innovations" OR "DIT" OR "Theory of Reasonable Action" OR "TRA" OR "Theory of Planned Behaviour" OR "TPB" OR "Decomposed Theory of Planned Behaviour" OR "Technology Acceptance Model" OR "TAM" OR "TAM2" OR "TAM3" OR "extension of TAM" OR "Unified Theory of Acceptance and Use of Technology" OR "UTAUT" OR "Institutional Theory" OR "Institutional Theory Isomorphic pressure" OR "Motivation Model" OR "technology-Organisation-Environment-Theory" OR "Technology Organisation Environment theory" OR "TOE") AND TITLE-ABS-KEY (construction OR "Construction projects" OR "Construction organisations" OR "Construction industry" OR "Built environment*"))	549
Refinement 1: Language and Documents type	Journal articles in the English language	340
Refinement 2: Subject area	Engineering", "computer science", "business, management and accounting", "Social sciences" and "Environmental sciences"	295
Data screening 1	Skim-read Title/abstract & keywords: Articles on construction context only	121
Data screening 2	Only Journals ranked **Q1 & Q2 in SCImago Journal Ranking (SJR)** metrics	103
Analysis	Use for final analysis (Scientometrics and contents analyses)	103

Source: Authors' creation

4. Analysis, Results and Discussion

4.1 Publications per year: a sustained growth in the number of studies utilizing one technology adoption theory or model, was observed. The analysis of the 103 documents showed that they span between 2009 and 2023, and starting from 2009, there was at least a publication on technology acceptance. 90% of the studies were published between 2016 and 2023 when the search was carried out. The peak was in 2022 with 29 documents representing 28% of the entire publications retained. As of May 2023, when the search was done, there were already 11 documents, and this indicates that more studies were on the way. This growing interest observed is in line with existing studies (Nnaji et al., 2023).

4.2 Publications distribution by country: citation analysis was used to determine the most productive countries. The minimum number of documents from a country was set at 3 of the 33 countries, only 12 countries met the threshold. China

(f=42; citations=1102), Australia (f=17; citations=429), the United States (f=16; 606), South Korea (f=15; citations=1173), and the United Kingdom (f=11; 288) were the most productive countries in technology acceptance studies. Further, a closer examination of the 33 countries showed that no publication came from South America, thus, indicating a gap in literature and a call to action for the government to fund technology-driven research that will influence innovation acceptance and diffusion in the region.

4.3 Publication per source: A criterion of at least 3 documents and 5 citations from a source was used to determine the most productive journal. Of the 32 journals, only 10 met these criteria as shown in figure 1. The top cited sources found in this section support the report of previous construction technologies studies (Babalola et al., 2023; Saka and Chan, 2020).

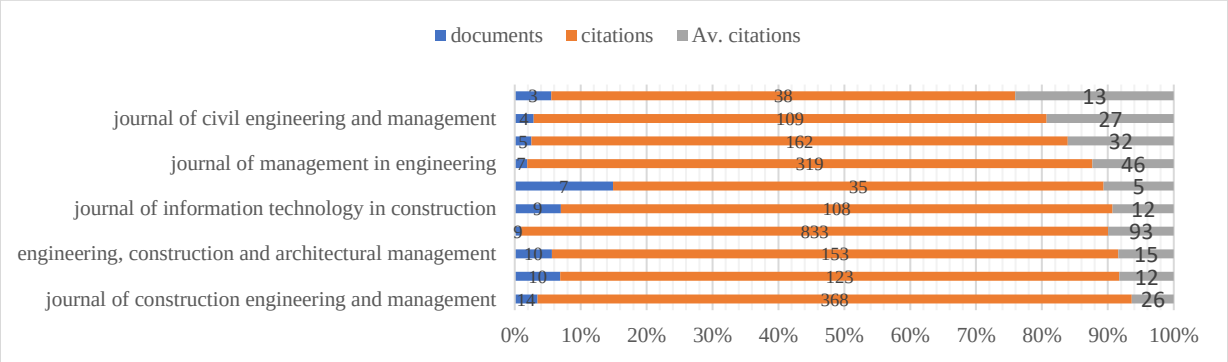

Figure 1: The most productive outlets for technology acceptance Studies

4.4 Most frequently cited technology acceptance studies: 55 of the 103 documents have been cited at least 10 times. However, the top six most frequently cited studies and their citation counts are shown in Table 2. Most of these studies were focused on BIM technology innovation.

Table 2: Top frequently cited documents

Author(s)	Documents title	citations
Lee et al. (2015)	BIM acceptance model in construction organizations	177
Son et al. (2012)	Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model	159
Son et al. (2015)	What drives the adoption of building information modelling in design organizations? An empirical investigation of the antecedents affecting architects' behavioural intentions	154
Park et al. (2017)	Comprehensive Approaches to User Acceptance of the Internet of Things in a Smart Home Environment	147
Choi et al. (2017)	What drives construction workers' acceptance of wearable technologies in the workplace? Indoor localization and wearable health devices for occupational safety and health	143
Xu et al. (2014)	Users-orientated evaluation of building information model in the Chinese construction industry	104

4.5. Keywords co-occurrence network analysis and content analysis

To determine the focus of existing studies and the most frequently used keywords, the co-occurrence analysis was executed using 4 as the minimum number of occurrences of a keyword. The analysis was done using 'all keywords' as against 'authors keywords' that are commonly used in most review studies. This was to avoid the effects of authors' bias and dependence on their experiences and knowledge of the choice of keywords (Darko et al., 2020). 60 of the total keywords of 835 met the criteria and formed 5 clusters with 777 links and a total link strength (TLS) of 1720 (figure 2). The modal keyword is "construction industry" with the largest node (f=61, TLS =345), the technology acceptance model (TAM) is the second frequently used keyword (f=44, TLS = 249), "Architectural design" is the third largest node with (f=32, TLS =236). Building information modelling (BIM) occurred repeatedly in 3 of the 4 clusters (i.e., red, green, and blue). This further reinforced the previous findings that BIM is the most studied construction technology.

The co-occurrence keywords networks analysis was used to show the general picture of the major keywords used in technology adoption studies. The content analysis was used to establish the distribution of technology acceptance models/theories, constituents of the hybrid models/theories, technology of focus, the scope of application of Models and theories, and the research methods adopted in the assessed studies.

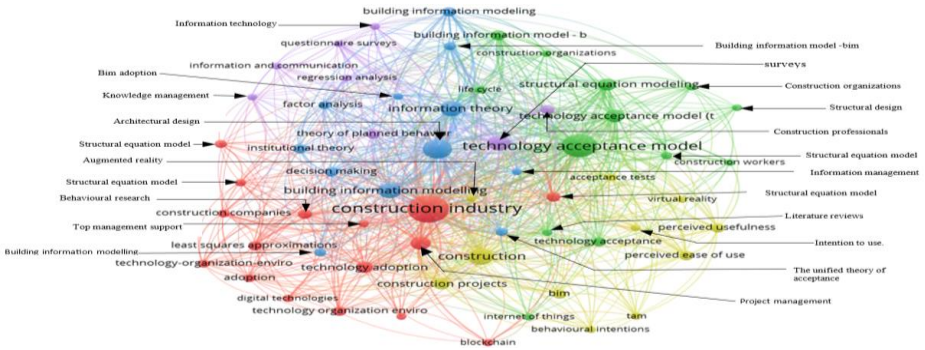

Figure 2: Co-occurrence visualization network of all keywords

5. Content analysis results

5.1 Distribution of technology acceptance models/theories: From the analysis results in Figure 3, 39.81% of the 103 studies utilized hybrid models/theories as it has better user predictive powers. Technology Acceptance Theory (TAM) and its extensions were used in 34.95% of the studies as a standalone theory/model to predict users' acceptance of technology. TOE (Technology-Organization-Environment) Framework was used in 14.56% of the studies and it is the second most widely used standalone model after TAM. The unified Theory of Acceptance and Use of Technology (UTAUT) and its extensions were used in 8.74% of the assessed articles to predict users' behaviour towards technology in construction. The Theory of Planned Behaviour (TPB) is the 4th most used standalone theory for predicting behaviours regarding technology acceptance.

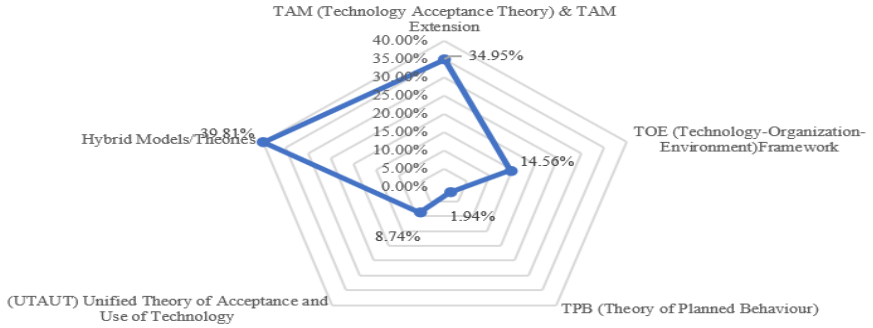

Figure 3: Adopted Technology acceptance models/theories.

5.2 Distribution of the Technology theories in the Hybrid models/theories: A further assessment of the hybrid models led to 7 groupings based on the constituents' theories/models. Hybrids with one frequency were grouped as 'other models/theories combination' (e.g., Wang et al. 2020 (TAM & Equity theory)), and among others. Those with a least 2 occurrences were also equally displayed. In all categories, theories such as TAM, TPB, UTAUT and IDT were utilised as the base for underpinning the numerous hybrid models. Furthermore, based on the reviewed papers, TAM was integrated with other theories to form the hybrid models/theories (Figure 4).

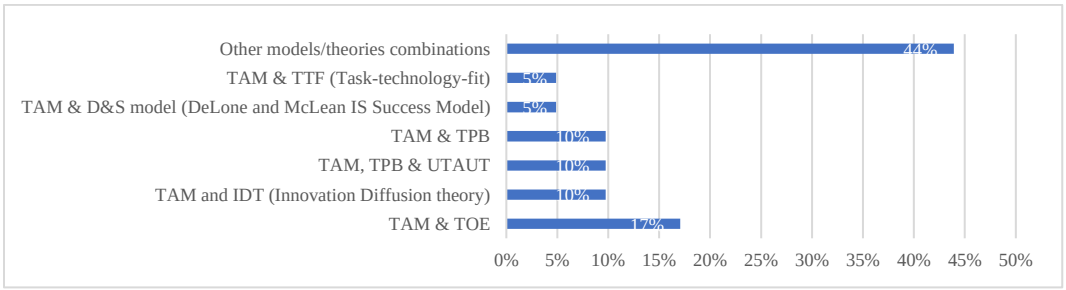

Figure 4: Distribution of Hybrid models/theories

5.3 Distribution of digital technology of focus: From Figure 5, BIM is the most investigated technology among researchers and academics in the AEC industry as 44 of the 103 documents focused on various subjects of BIM adoption/acceptance or

BIM integrations with other technologies. This finding is consistent with the report of (Nnaji et al., 2023). BIM is the most accepted and advanced technology that has been used among stakeholders in the AEC industry. Design firms have a profound influence on BIM acceptance and adoption, and it is a major innovation in the AEC industry (Cui et al., 2021). 16 of the assessed studies focused on digital technologies generally, 14 were on information and communication technologies (ICT), and 10 of the studies focused on Blockchain and Smart/iContracts. Further analysis of the 44 BIM studies showed that 36% of them focused on BIM adoption at the individual level, 27% were on organizational level adoption, 21% were on the project level (21%), and 16% were on industry level. The focus on individual and organisational-level adoption may not be dissociated with the roles of design experts and design organisations in the AEC industry (Young et al. 2008; Qin et al., 2020).

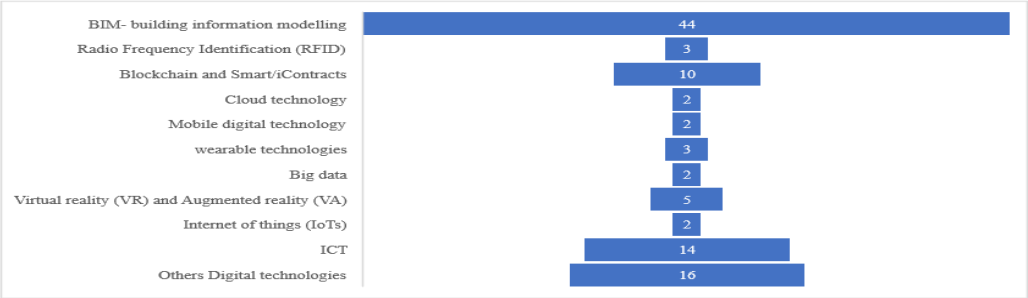

Figure 5: Technology application domain

5.4 Scope of application of Models and theories: Of the 103 documents, 40.78% of them were focused on organisation-level adoption, 25.24% focused on Industry-level application, 18.45% were on the project level and 15.53% were on an individual level. This finding in this section supports the report of (Nnaji et al., 2023). The capital-intensive investment requirements of digital technologies could be the reason why organizational-level adoption was the highest focus of the studies. If innovation acceptance or usage is made mandatory by companies, individual employees will increase their level of use and acceptance of the technology.

5.5 Research methods adopted in the assessed studies: Of the 103 studies, 74 of them used a questionnaire survey as the primary means of data collection and for validation of models. 12 of them used interviews, case study research was 10 and review studies were 7. This finding supports the reports of (Al-Emran et al., 2018; Nnaji et al., 2023). Furthermore, CFA, SEM and regression analyses were the most used data analysis method in assessed studies.

6. Identified gaps for future studies

6.1 Technologies adoption framework for PPP projects: Construction management literature revealed that TAM, TOE, UTAUT and TPB were the most prominent standalone technology adoption models and theories employed by researchers and academics to study users' behaviours in adopting innovative technologies in the construction industry. However, the adoption of these models and theories in PPP projects has not been considered in detail. TPB was used by Luo et al. (2022) to develop a framework for drivers of public participation in PPP projects. The study did not include the technology aspects. A study that will examine the various elements of the digitalisation of PPP projects, particularly the adoption of modern transformative technologies like blockchain and smart contracts, should be undertaken using any standalone technology adoption theories. Furthermore, a hybrid model should be developed and considered to study public or private sector acceptance behaviours to the adoption of modern digital disruptive technologies in PPP projects. Hybrid models have better predictive powers and have been used in a lot of studies focusing on technology adoption in the traditional construction approach, other than the PPP approach. This is a critical literature gap that requires the attention of academics and researchers. PPP implementation faces a lot of forces at both organisational and institutional levels, and even individual behaviours could impact the adoption of novel production technologies in infrastructure projects. Studies that will explore and compare the behaviours of stakeholders at individual, organisational, and industry levels should be undertaken. PPP is known to be risk-laden, and digitalisation has its risks. IT implementation resistance theory (Lapointe and Rivard, 2005) and Innovation resistance theory (Kaur et al., 2020) could be combined with TAM or other foundational theories to investigate the critical risks of Digitalisation of PPP contracts and projects. BIM improve knowledge and information management in PPP projects. Also, BIM induces some level of flexibility and enhances the performance of BIM-based PPP projects during construction (Xu et al., 2022), thus leading to effective inter-organisational collaboration and relationships among the many stakeholders involved. The enablers and influencing factors of BIM adoption in PPP projects remain a gap for future investigation.

6.2 Integration of BIM and other innovative methodologies: No doubt BIM has gained greater acceptance, and it is the most studied digital technology in construction. BIM also has a strong association with sustainability and, thus, could help drive the adoption of circular construction (CE) or modular construction (MC). Studies on the predictors of BIM and CE or MC integration acceptance among stakeholders in the AEC industry are missing and, thus, require investigation.

6.3 A multicriteria approach to technology adoption studies: While CFA, SEM and regression analyses are common with previous studies on technology adoption, studies incorporating a multi-criterion analytical approach should be undertaken. Such studies could incorporate hybrid models to determine their effectiveness in determining stakeholders' technology acceptance behaviour in multicriteria settings.

6.4 Other: Based on the analysed data, studies using one or more of the technology adoption models or theories are limited in Africa, and it is zero in South America. Studies that could use a standalone or hybrid of technology adoption models and theories should be undertaken in South America and African continents to understand users' technology acceptance determinants to improve penetration in these regions.

7. Conclusions

This study found that there has been a growing interest in technology adoption in construction, evident in the yearly growth of publications utilising one or a combination of technology acceptance models/theories since 2009. China, Australia, USA, South Korea, and the UK, have the most mature market in construction technologies, as most of the assessed studies emanated from them. The most productive sources of construction technology adoption studies are "The Journal of Construction Engineering and Management (JCEM)", "construction innovation (CI)" and "Engineering Construction and Architectural Management (ECAM)". Further, BIM is the most studied technology in construction, and TAM and its extension are the most utilised standalone technology adoption theory in construction management literature. The hybrids of TAM and TOE theories were the most adopted hybrid theories/models for determining user behaviour towards the acceptance of technology innovation in construction, with a focus on organisational-level acceptance. The questionnaire is the most used tool for data collection for the validation of models and establishing end-users' technology acceptance behaviours, and CFA, SEM and regress analysis are the most used analysis methods for establishing the relationships between predictive constructs.

This study made some significant contributions to knowledge and identified some pertinent areas that require investigation. A crucial research direction for future studies will be on the drivers and factors that influence the adoption of modern, transformative digital technologies (e.g., smart contracts, blockchain, etc.) in PPP projects, to enhance project performance and partnerships commitment to projects and better services delivery to the public. Another one is the factors determining the adoption of BIM-driven Circular economy (CE) or modular construction (MC) adoption and acceptance need to be investigated using either a standalone or hybrid model. Innovation resistance models and theories should be used to understand the underlying factors responsible for the low uptake and penetration of Industry 4.0 technologies in PPP projects. This will help policymakers design a sustainable mitigation measure to improve acceptance in the industry. More studies are expected to be undertaken in South America and African continents to understand users' technology acceptance determinants to improve penetration in these regions.

With the leading journal outlets, authors and countries reported herein, future researchers and new entrants in the academia will leverage this study when making choice of collaboration and leading outlets to consider for the publication of their works. Construction experts and other stakeholders would be guided in the selection of the suitable technology adoption frameworks for use in the planning of new technology innovation adoption in their organisations or projects. This will help determine how the potential users or even employees will react in the quest to accept or use such technologies in the project life cycle. This study can also find use in the teaching and learning of technology adoption and associated behavioural theories/models to construction students in higher institutions. Like other studies, this study regardless of its significant contributions, has some limitations that could impact the generalisation of the findings. Firstly, it relied solely on the Scopus database, leaving out other important databases (e.g., Web of Science, PubMed, IEEE Xplore, ScienceDirect, etc,). While acknowledging the considerable overlaps between the databases and Scopus, similar research utilising a combination of other databases could confirm the findings reported herein or report new knowledge.

References

Aghimien, D.O., Aigbavboa, C.O., Oke, A.E. and Thwala, W.D. (2020). Mapping out research focus for robotics and automation research in construction-related studies: A bibliometric approach. *Journal of Engineering, Design and Technology*, 18(5), 1063-1079. https://doi.org/10.1108/JEDT-09-2019-0237

Ajzen, I. (1991). The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50(2), 179–211.

Al-Emran,M., Mezhuyev, V., and Kamaludin, *A. (2018).Technology Acceptance Model in M-learning context: A systematic Review*. Computers & Education, 125, 389–412. https://doi.org/10.1016/j.compedu.2018.06.008

Alomary, A. and Woollard, J. (2015). How is technology accepted by users? a review of technology acceptance models and theories. Proceedings of The IRES 17th International Conference, London, United Kingdom,pp.1-14.

Attencia G., and Mattos C. (2022). Adoption of digital technologies for asset management in construction projects. *Journal of Information Technology in Construction*, 27, 619-629. DOI:10.36680/j.itcon.2022.030

Babalola, A., Musa, S., Akinlolu, M.T. and Haupt, T.C. (2023). A bibliometric review of advances in building information modeling (BIM) research. *Journal of Engineering, Design and Technology*, 21(3), 690-710. https://doi.org/10.1108/JEDT-01-2021-0013

Chen J.-H., Ha N.T.T., Tai H.-W., Chang C.-A. (2020). The willingness to adopt the internet of things (IoT) conception in Taiwan's construction industry. *Journal of Civil Engineering and Management*, 26(6), 534-550. DOI:10.3846/jcem.2020.12639

Cui, Q., Hu, X., Liu, X., Zhao, L., and Wang, G. (2021). Understanding Architectural Designers' Continuous Use Intention Regarding BIM Technology: A China Case. *Buildings*, 11(10), 448. https://doi.org/ 10.3390/buildings11100448

Darko, A., Chan, A.P.C., Adabre, M.A., Edwards, D.J., Hosseini, M.R. and Ameyaw, E.E. (2020). Artificial intelligence in the AEC industry: scientometric analysis and visualisation of research activities. *Automation in Construction*, 1121-19. doi: 10.1016/j.autcon.2020.103081

Davis, F.D., Bagozzi, R.P., and Warshaw, P.R. (1989). User acceptance of computer technology: a comparison of two theoretical models. Management Science, 35(8), 982–1003.

Eze, E. C., Sofolahan, O., Adegboyega, A. A., & Saidu, K. J. (2019). Factors Limiting the Full-scale Adoption of Process and Product Innovation in the Nigerian Construction Industry. *SEISENSE Journal of Management*, 2(3), 67-81. doi:10.33215/sjom.v2i3.145

Hawkins, D.T. (2001). Bibliometrics of electronic journals in information science. Information Research, vol. 7 No. 1, p. 1. Available at: https://informationr.net/ir/7-1/paper120.html

Kaur, P., Dhir, A., Singh, N., Sahu, G., and Almotairi, M. (2020). An innovation resistance theory perspective on mobile payment solutions. *Journal of Retailing and Consumer Services*, 55, 102059.

Lapointe, L., and Rivard, S. (2005). A multilevel model of resistance to information technology implementation. *MIS quarterly*, 461-491.

Luo, Z., Li, J., Wu, Z., Li, S., and Bi, G. (2022). Investigating the Driving Factors of Public Participation in Public-Private Partnership (PPP) Projects—A Case Study of China. International Journal of Environmental Research and Public Health, 19,5192. https://doi.org/10.3390/ijerph19095192

Maillet, É., Mathieu, L., and Sicotte, C. (2015). Modeling factors explaining the acceptance, actual use and satisfaction of nurses using an Electronic Patient Record in acute care settings: An extension of the UTAUT. International Journal of medical informatics, 84(1), 36-47

Marangunic´,N., and Granic, A. (2015). Technology acceptance model: a literature review from 1986 to 2013. *Universal Access in the Information Society*,14,81-95. DOI 10.1007/s10209-014-0348-1

Nnaji, C., Okpala, I., Awolusi, I., and Gambatese, J. (2023). A systematic review of technology acceptance models and theories in construction Research. *Journal of Information Technology in Construction*, 28, 39-69. DOI:10.36680/j.itcon.2023.003

Qin, X., Shi, Y., Lyu, K., and Mo, Y. (2020). Using a TAM-TOE model to explore factors of building information modelling (BIM) adoption in the construction industry. *Journal of Civil Engineering and Management*, 26(3), 259-277. DOI:10.3846/jcem.2020.12176

Rogers, E.M. (1995). Diffusion of innovations (4th Ed.), New York: Free Press.

Saka, A.B., and Chan, D.W. (2020). Profound barriers to building information modelling (BIM) adoption in construction small and medium-sized enterprises (SMEs). *Construction Innovation*, 20(2), 261-284. https://doi.org/10.1108/CI-09-2019-0087

Sepasgozar, S.M.E., Ghobadi, M., Shirowzhan, S., Edwards, D.J. and Delzendeh, E. (2021), Metrics development and modelling the mixed reality and digital twin adoption in the context of Industry 4.0. *Engineering, Construction and Architectural Management*, 28(5), 1355-1376. https://doi.org/10.1108/ECAM-10-2020-0880

Source, J., and Issa, R.R.A. (2021). Extended technology acceptance model (TAM) for adoption of information and communications technology (ICT) in the US construction industry. *Journal of Information Technology in Construction*, 26, 227-248. DOI:10.36680/j.itcon.2021.013

Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories.*Procedia Manufacturing*, 22, 960–967

Tornatzky, L. G., and Fleischer, M. (1990). The processes of technological innovation. Lexington, Mass.: Lexington Books.

Venkatesh, V., Morris, M., Davis, G., Davis, F.: User acceptance of information technology: towards a unified view. MIS Quarterly, 27(3), 479–501.

Wang G., Wang P., Cao D., Luo X.(2020a). Predicting behavioural resistance to BIM implementation in construction projects: An empirical study integrating technology acceptance model and equity theory. *Journal of Civil Engineering and Management*, 26(7), 651-665. DOI:10.3846/jcem.2020.12325

Xu,Y., Chong, H-Y., and Chi, M. (2022). The Impact of Contractual Flexibility on BIM-Enabled PPP Project Performance during the Construction Phase. *Journal of Infrastructure Systems*, 28(1), 1-10. doi:10.1061/(ASCE)IS.1943-555X.0000671

Young, N. W., Jones, S. A., and Bernstein, H. M. (2008). *Building information modeling (BIM)-Transforming design and construction to achieve greater industry productivity*, McGraw Hill Construction, Bedford, MA.

Zhang J., Zhang M., Ballesteros-Pérez P., and Philbin S.P. (2023). A new perspective to evaluate the antecedent path of adoption of digital technologies in major projects of construction industry: A case study in China. *Developments in the Built Environment*,14, DOI:10.1016/j.dibe.2023.100160

Zhong, B., Wu, H., Li, H., Sepasgozar, S., Luo, H. and He, L. (2019). A scientometric analysis and critical review of construction related ontology research. *Automation in Construction*, Vol. 101, pp. 17-31.

Zhou Z., Su Y., Zheng Z., and Wang Y. (2023). Analysis of the Drivers of Highway Construction Companies Adopting Smart Construction Technology. *Sustainability*, 15(1), 703; https://doi.org/10.3390/su15010703