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ACCEPTANCE OF CONTEMPORARY TECHNOLOGIES FOR COST MANAGEMENT OF CONSTRUCTION PROJECTS

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SUMMARY: *The construction industry has become more digital and the traditional methods of construction activities are gradually becoming outdated. In this era of digital construction, various information and communication technologies have been developed and deployed to the site for the management and control of construction activities including cost management. Irrespective of the benefits of adopting these technologies, most of them are still not readily accepted for use for construction management. This study articulated Seven (7) recent technologies driving the industry and evaluated their acceptance for cost management of construction projects. The technologies include mobile technology, Augmented/Virtual Reality (AR/VR), Building Information Modeling (BIM), Internet of Things (IoT), Autonomous Equipment (Drones and Robotics), Artificial Intelligence (AI), and Predictive Analytics (PA). Data was gathered using a restructured questionnaire and technology acceptance model analysis was performed to identify which of the technologies have higher acceptance for cost management based on the criteria of availability, affordability, frequency of use, usefulness for cost management, and acceptance in the industry. Test statistics using Spearman's correlations and Kendall's correlations for each of the technologies and Spearman's Correlations of Technology acceptance with other variables in the TAM Model were performed. The results showed that mobile technology has higher correlation values than other technologies, and therefore has a higher acceptance for cost management. Kendall's coefficient of concordance values and Spearman's correlation values for Mobile technology were all above 0.6 which indicates a high level of agreement among the raters and strong relationships between the compared TAM variables.*

KEYWORDS*: Recent Technologies, Cost Management, Construction Projects, Technology Acceptance*

REFERENCE: *Uchenna Sampson Igwe, Sarajul Fikri Mohamed, Mohd Bin Mat Dzahir Azwarie, Rex Asibuodu Ugulu, Olusegun Ajayi (2022). Acceptance of contemporary technologies for cost management of construction projects. Journal of Information Technology in Construction (ITcon), Vol. 27, pg. 864-883, DOI: 10.36680/j.itcon.2022.042*

1. INTRODUCTION

The construction industry has embraced technology like other allied industries to manage its operations for better efficiency and accuracy. Information and communication technology (ICT) adoption in the construction industry cuts across all construction operations and activities. One of the operations of the industry that determines the success of a construction project is the effective management of construction costs. Management of Construction cost is the most important function for project success (Girma and Alemu, 2018). However, the cost management practice in present-day construction is becoming more complicated due to the ever-increasing complexity, and dynamic nature of modern-day constructions. Construction projects are becoming more competitive, complicated, and difficult to handle, and conventional approaches may not be able to solve such serious issues (Vasista and Abone, 2018). Construction firms have an unusually complex, fragmented, and unique set of market relationships and approaches to deal with (Moshood *et al.*, 2020). The construction industry's project-based design, the highly complicated coordination system on projects, and the vast volume of data general contractors deal with, all highlight the need for productivity in project management (Holt, Benham, and Bigelow, 2015). All construction phases require an efficient exchange of information and collaborations among all project participants, such as project managers, consultants, engineers, site supervisors, workmen, suppliers, and subcontractors. The global advances in digital technologies gave rise to the development of different technologies to tackle construction operations, collaborations, and exchange of information, ranging from the simplest task to the most complicated. Construction planning and control, cost control and financial planning, computer-aided facilities management, and other operations all benefit from the use of information and communication technology, which gives the industry a variety of options for more effective and efficient project execution. The importance of ICT in construction project cost control cannot be overstated, but the majority of applicable ICT for cost management is still not widely adopted. Though various technologies have been deployed for use in executing construction activities including cost management, there is still an underlying gap as the problems of cost overrun are still inevitable.

Despite the fact that technology has streamlined the construction process, it has yet to achieve the efficiency gains that are necessary due to a lack of integration between applications (Holt, Benham, and Bigelow, 2015). Approximately 40 years ago, information and communication technology (ICT) was introduced into the construction industry, dramatically changing the industry's conventional paradigm into one of quicker and more advanced processes (Afolabi *et al.*, 2017). These technologies are currently being deployed for construction project delivery. However, a number of factors work against the use of these technologies in the construction industry, the most significant are budget constraints for investment, a lack of knowledge about the profitability nature of ICT investments, high costs of hiring professionals, and a lack of staff with adequate Technological skills and knowledge, as well as the cost of training professionals (Ojelabi *et al.*, 2018). These aforementioned factors lead to contracting organizations reverting to the conventional methods. Beside the factors, the main issue is users' reluctance to ICT adoption, because it is the actual ICT user who uses ICT resources to optimize work processes, and moving from a paper-based to an entirely automated system requires users to immediately embrace and use ICT (Moshood *et al.*, 2020). However, some technologies are adopted faster than others (Yapa *et al.*, 2019). While these technologies have been identified to be relevant for managing construction costs, some of these technologies are not readily adopted for this operation. This study evaluates the acceptance of these technologies by the cost managers to identify which of the technologies are readily accepted in the industry for cost management in present-day construction.

1.1 The Contemporary Technologies Relevant in Construction Industry

There are technologies relevant to every aspect of cost management. These ICT technologies aid in improving client satisfaction, reducing teamwork mistakes, and increasing project participant awareness in terms of better service delivery and requirements (Vasista and Abone, 2018). Various technologies have gained good footage in the delivery of construction activities including project cost management. Various technologies have been in existence in the industry but this research reviewed the most current in the present fourth industrial revolution (IR4.0). The fourth industrial revolution started in 2011 and gained a wider audience in 2016 according to an article written by Liao *et al.*, (2018). Hence, this research referenced the review of the technologies from 2016, capturing the key technologies that are driving the industry from the year 2016. The review identified the seven technologies that are currently being used in the industry for different construction activities. The seven technologies referenced from 2016 to 2019 include; Building Information Modelling (BIM), Augmented and Virtual Realities (AR & VR), Mobile Technology, Internet of Things (IoT), Artificial Intelligence and Machine

Learning (AI & ML), Drones and Robotics, and Predictive Analytics. The various areas of application of the identified technologies in the industry were articulated and the core benefits and application for cost management were identified as highlighted in Table 1. However, despite the applicability of these modern technologies in any industry, their acceptability in the construction industry is still subject to questioning (Ojelabi *et al.*, 2018).

Table 1 Recent technologies and their applications in Construction and the Benefits for cost management of construction projects

S/n	Technology	Applications in Construction	Core benefits for Cost Management	References
1	Building Information Modeling [BIM]	• Effective collaboration and communication among project team • Model-based Cost estimation • Project visualization at the preconstruction stage • Enhance coordination and clash detection • Cost reduction and mitigation against risk • Enhances scheduling and sequencing • Improves productivity • Safety in construction sites • Facilities management	• Applicable in cost estimating and cost planning at the design stage • Applicable in quantity measurement for valuations of variations and preparation of BOQs. • BIM enables scheduling of construction resources and their management	(Nigam *et al.*, 2016; Fadason *et al.*, 2018; Cepurnaite *et al.*, 2017; Jununkar *et al.*, 2017; Mushamalirwa, 2016; Haron *et al.*, 2017; Chu *et al.*, 2018; Kulkarni and Mhetar, 2017; Jones, 2019; Abanda *et al.*, 2018; Tahir *et al.*, 2018; Nsimire Mushamalirwa, 2016; DU, 2017; Gerbert *et al.*, 2016; Perera *et al.*, 2018; GenieBelt, 2018; Pickup, 2018; Agarwal *et al.*, 2018; Mahami *et al.*, 2019; Pistorius, 2017; Kapliński, 2018; Budiac, 2018b; J.Adwan and Al-Soufi, 2016)
2	Augmented and Virtual Realities	• Streamlines the design process • Design development and communication among project team • Defects management • Quality management • Projects scheduling • Information collection • Safety management • Logistics management • Project progress evaluation	• AR and VR are used for project inspections and monitoring. It can be used to gather cost data during project execution and to manage construction resources. • They are used for automated measurements • Very useful also for project planning and monitoring	(Ahmed, 2019; Chu *et al.*, 2018; Jones, 2019; Gerbert *et al.*, 2016; Higgins, 2019; Rhumbix, 2018; GenieBelt, 2018; Pickup, 2018; Alsafouri and Ayer, 2018; Pistorius, 2017; Zhezherov, 2018; Santos, 2018; Sharifi, 2018; Thompson, 2019; GenieBelt, 2017; Budiac, 2018b; J.Adwan and Al-Soufi, 2016)
3	Mobile Technology	• Facilitates collaboration among project teams in the office and the field. • Decision making during construction • Collection of project performance data • Cost control of projects • speeds up data retrieval and processing • Scheduling and resource allocation • Construction equipment management • Enhances safety and project inspection process	• Mobile technologies are great tools for on-site cost data collection and real-time monitoring of project costs. • It makes communication easier for on-time decisions and any remedial actions for cost control • Useful for basic cost calculations, tendering, and real-time management of construction resources	(Riddell, 2017; Liu *et al.*, 2017a; Khelifi and Hyari, 2016; Jones, 2019; Kiganda, 2017; Ishola and Babatunde, 2017; Orihuela *et al.*, 2016; BCG, 2016; Perera *et al.*, 2018; Rhumbix, 2018; GenieBelt, 2018; Pickup, 2018; Solutions and August 2019; Alsafouri and Ayer, 2018; Redden *et al.*, 2017; Yovino, 2019; JBKnowledge, 2016; Santos, 2018; Kapliński, 2018; Igwe *et al.*, 2019; Budiac, 2018; J.Adwan and Al-Soufi, 2016)

S/n	Technology	Applications in Construction	Core benefits for Cost Management	References
4	Internet of Things [IoT] and Sensors	• Smart communication • Remote site Operation • Maintenance of Machinery and Equipment • Site safety and security control • Construction workers monitoring • Project progress monitoring • Project inspection and smart evaluation • Waste management	• A connected project site enables easy and fast communication of project information, saving cost, time, and energy. • IoT is greatly used for project monitoring and control of resources • It has great applications in waste management.	(Nowotarski and Paslawski, 2017; Gerbert *et al.*, 2016; Higgins, 2019; Dave *et al.*, 2016; Agarwal *et al.*, 2018; Alsafouri and Ayer, 2018; Pistorius, 2017; Rouse, 2019; Osseiran *et al.*, 2016; Mahmud *et al.*, 2018)
5	Artificial Intelligence and Machine Learning	• Construction data management • Productivity improvement • Material and equipment management • Real-time job site monitoring • Project controls and management of construction cost • Construction safety	• AI and ML are great tools for the management of cost data [collection, processing, reporting, and documentation] • It is applicable for real-time project monitoring and management of construction resources.	(Jones, 2019; Gerbert *et al.*, 2016; Higgins, 2019; Pistorius, 2017; Rao, 2019; Rajagopal, 2017; Kapliński, 2018)
6	Drones and Robotics	• Real-time project monitoring • Project progress evaluation • Construction site operations • Productivity improvement • Project status reporting	• Drones and Robotics are useful for real-time project monitoring, evaluations, and management of construction resources.	(Jones, 2019; Higgins, 2019; Rhumbix, 2018; GenieBelt, 2018; Pickup, 2018; Alsafouri and Ayer, 2018; Pistorius, 2017; JBKnowledge, 2016; Santos, 2018; Kapliński, 2018; Budiac, 2018b)
7	Predictive Analytics	• Construction data analysis and prediction • Enhances decision-making process • Tracking and analysis of construction problems for remedial actions • Construction cost estimation	• Predictive analytics is a great tool for estimation, budgeting, and cost forecasting.	(Higgins, 2019; Rhumbix, 2018; Pistorius, 2017; Bobriakov, 2019)

1.2 Applications Of Contemporary Technologies For Construction Cost Management

The features of the identified technologies have great applications in cost management of construction projects. Project Cost Management is a management activity that deals with forecasting, planning, control, cost finding, analysis, and evaluation of the contractors and it is used to control project cost (Miri and Khaksefidi, 2015). It is the systematic process of developing, monitoring, and adjusting a budget to achieve the maximum amount of work at a given level of quality in situations where unknowns and uncertainty may cause costs to rise beyond acceptable levels (Chigara *et al.*, 2013). Specifically, cost management "identifies, collects, measures, classifies, and reports information that is useful to managers for determining the costs of products, customers, and suppliers, and other relevant objects and for planning, controlling, making continuous improvements, and decision making" (Kujala *et al.*, 2014). Most of those procedures involved in planning, forecasting, budgeting, financing, funding, managing, and monitoring costs are included in project cost management so that the project can be completed on time and within the approved budget. (Igwe, Mohamed, and Azwarie, 2020). At every stage of the cost management processes, at least one of the contemporary technologies can be useful and applicable.

Building information modelling BIM for example is applicable in cost planning, cost estimation, scheduling, and cost control (Pučko *et al.*, 2014; Ying, 2019; Kulkarni and Mhetar, 2017). Handling the project cost data by BIM approach give an opportunity to manage the construction project costs more efficiently (Pučko *et al.*, 2014). Application of BIM for cost management of construction projects helps in the elimination of unbudgeted changes on projects, cost estimation accuracy to within 3%, and up to 80% reduction in time taken to generate a cost estimate (Kulkarni and Mhetar, 2017).

The augmented and virtual realities is applicable real-time tracking of time and cost of construction projects (Zaher *et al.*, 2015). AR and VR are applicable in project planning, automated measurements, project modifications, onsite project information generation, and project team collaborations for effective communication (BigRentz Inc., 2019). AR allows teams to conduct walkthroughs of the entire project before it is executed, closely examining the details and components of the structure. This foresight can prevent schedule delays, reduce cost overruns, and identify any mistakes before they surface.

Mobile Technologies such as tablets, smartphones, and mobile intelligent hotspots are becoming increasingly important and essential tools for collaboration and bottleneck elimination in the three phases of construction: planning, designing, and construction (Kiganda, 2017). The majority of the important tools used in construction project management have been virtually translated into mobile devices such as tablets, smartphones, and other mobile devices in the form of mobile Apps. There are over 13,000 construction-related development and design smartphone apps in the market right now, according to estimates (Liu *et al.*, 2017). Most of the mobile apps are applicable in cost estimating, scheduling, budgeting, onsite data gathering, effective communication and collaborations of project participants, and monitoring of construction costs.

The Internet of Things (IoT), is a network of interconnected computing devices, mechanical and digital machinery, items, animals, and people with unique identifiers (UIDs) and the ability to transfer data without requiring human-to-human or human-to-computer interaction (Rouse, 2019). IoT is applicable in data exchange in the construction industry, effective collaborations, and cost data management. IoT has the potential to provide time and money savings and better quality in construction works (Arslan *et al.*, 2019).

When a machine duplicates human cognitive functions including problem-solving, pattern recognition, and learning, it is referred to as ***Artificial Intelligence (AI)***. ***Machine learning*** is a branch of artificial intelligence that employs statistical techniques to enable computers to "learn" from data without having to be explicitly programmed (Rao, 2019). AI and ML have been utilized in construction cost estimation, and cost modeling (Business, 2017). Some of the cost models include prediction of the life cycle cost using statistical and artificial neural network methods in conceptual product design, project cost estimation using principal component regression, web-based conventional cost estimates for construction projects using evolutionary fuzzy neural inference model and others. There is an enormous chance for AI different systems to be utilized for enhancing the effectiveness of project managers everyday job (Elrajoubi, 2019).

Drones, more accurately described in a business context as unmanned aerial vehicles (UAVs) are no longer limited to commercial activities, and they now demonstrate a wide range of business value-adding capabilities. The potential business applications are numerous, and they present organisations in the engineering and construction industries with disruptive prospects. By enabling remote sensing, actuation, and predictive capabilities, they can significantly extend human operations. These skills provide crucial benefits such as cost reduction, risk mitigation, and quality improvements, giving their adopters a competitive advantage. The various areas of applications of drones include automation of simple tasks which reduces labor costs significantly, while providing better accuracy through the use of multiple sensors on the same platform, and Real-time project cost and progress monitoring (Gregory and Laurent, 2016). Sending a drone to evaluate a job site saves time, and cost and keeps the technician on the ground rather than mounting scaffolding and managing the dangers of a construction site (Higgins, 2019). In a similar way to drones, the construction sector is integrating robots and autonomous equipment (Budiac, 2018).

Predictive analytics is the use of data, statistical algorithms, and machine learning techniques to identify the likelihood of future outcomes based on historical data. For the construction industry, the ability to capture real-time data and transform it into actionable information for forecasting has become a game-changing solution (Bobriakov, 2019). Predictive analytics is very much applicable in forcasting construction cost which is a principal component of cost management.

The use of information and communication technologies for project delivery obviously offers great benefits which cannot be overemphasized. However, one of the key determinants of ICT usage in the industry is the technology acceptance by the key players in the industry. There are many models and frameworks to explain user acceptance of new technologies but the technology acceptance model (TAM) is a popular theoretical framework (Yapa *et al.*, 2019).

1.3 Technology Acceptance Model (TAM)

TAM is a well-known model that relates to technology acceptance and usage. It was first suggested by Davis in 1986 (Tantiponganant and Laksitamas, 2014; Elshafey *et al.*, 2020). TAM has proved to be a theoretical model for explaining and predicting information technology user behavior. TAM serves as a foundation for determining how external factors affect creed, mindset, and purpose to use. Perceived importance and perceived ease of use are two cognitive views that TAM proposes. According to TAM, a user's true use of a technology system is determined by the user's behavioral intentions, attitude, perceived system utility, and perceived system simplicity, which is all directly or indirectly influenced by the user's behavioral intentions, attitude, perceived system utility, and perceived system simplicity. External influences, according to TAM, affect the intent and actual use of a product by mediating effects on perceived utility and perceived ease of use. Davis created the original technology adoption model in 1986, as shown in Figure 1 (Ma and Liu, 2011; Tantiponganant and Laksitamas, 2014).

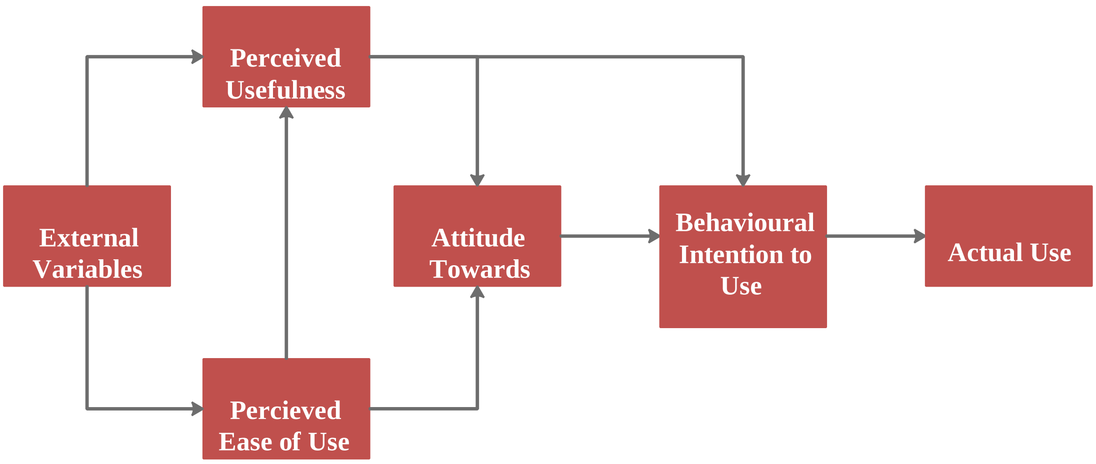


FIG. 1: Original Technology Acceptance Model (TAM)

Perceived ease of use (PEOU), perceived usefulness (PU), attitude toward using (ATU), behavioral intention to use (BI), and actual device use were all part of the original TAM (AU). The two most critical determinants of system use are PU and PEOU (Wu and Wang, 2005). TAM has received considerable attention and empirical support and has been applied to many different end-user technologies (Ma and Liu, 2011). The validated TAM is illustrated in figure 2.

FIG. 2: A validated Technology Acceptance Model

An extension of TAM by Venkatesh (2000) identified antecedents to perceived ease of use variable in the TAM model and grouped the antecedents into anchors and adjustments (Chuttur, 2009). The anchors were considered as beliefs about the technology, and the usage of the technology, whereas the adjustments were considered as beliefs that shaped direct experience with the target technology. Using this extension background, this research considered the Technology Availability (TA_v), and the Technology Affordability (TA_f) as the anchors while Frequency of Use (FU) of the technology was considered as the adjustments. Hence, the anchors and the adjustments were introduced as determinants of PEOU. Figure 3 illustrates the TAM model with the introduced antecedents.

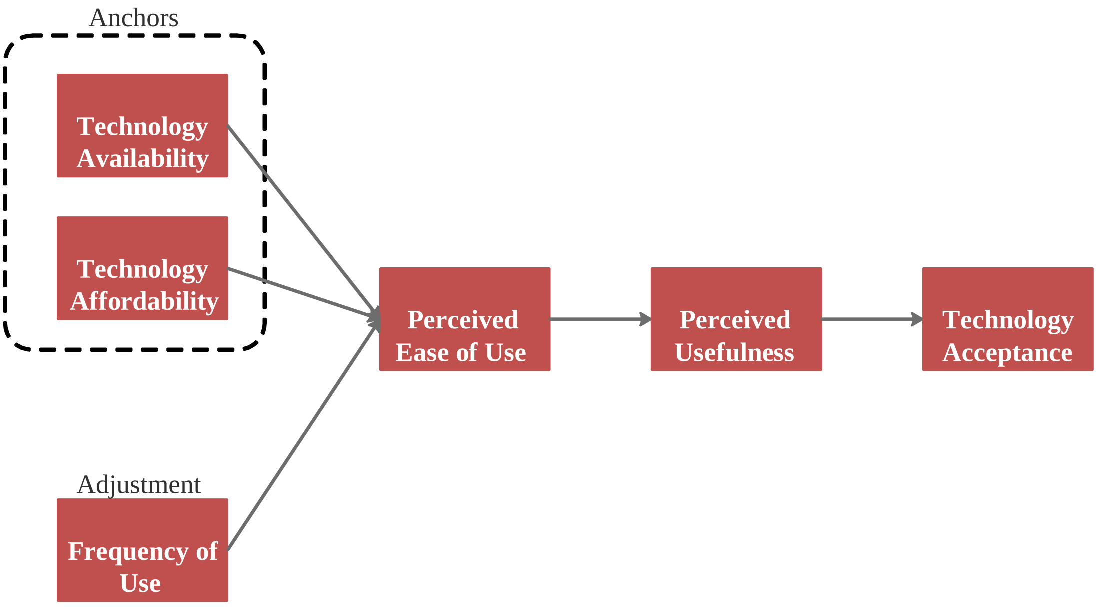


FIG. 3: TAM model with the introduced antecedents

Five relationship exist based on the model illustrated in Figure 3 which include TAv_PEOU, TAf_PEOU, TFu_PEOU, PEOU_PU, and PU_TAcpt. Hence the following five hypotheses were proposed for each of the technologies;
H1: Technology availability has a significant effect on the perceived ease of use
H2: Technology affordability has a significant effect on the perceived ease of use
H3: Technology frequency of use has a significant effect on the perceived ease of use
H4: Perceived ease of use has a significant effect on the perceived usefulness
H5: Perceived usefulness has a significant effect on technology acceptance

The technology acceptance models (TAM) have been used in construction-related researches. Elshafey *et al.*, (2020) used it to investigate the acceptance of Building Information Modeling (BIM) and Augmented Reality (AR) integration in the construction industry. Park and Park, (2020) utilized TAM to derive factors that maximize the approachability and usefulness of users through the use of a technology acceptance model in construction prior to the application of new information technology in the construction field. Also, Sorce and Issa, (2021) in their research applied the Technology Acceptance Model (TAM) to understand what factors improve the use and adoption of ICT in the US construction industry. A Scanner Technology Acceptance Model for Construction Projects was developed by Sepasgozaar *et al.*, (2017) using the TAM framework. There are other researches in the construction field that have utilized TAM. Hence, this research also employed the TAM to evaluate the acceptance of the contemporary technologies relevant in the construction with emphasis on the application for cost management of construction projects.

2. RESEARCH METHODOLOGY

Data was gathered using a Likert Scaled structured questionnaire and Quantity Surveyors were specifically the target respondents. The Quantity Surveyors were chosen because cost management of construction projects is their primary responsibility and they have the requisite knowledge on construction cost management. The questionnaire was administered online to Quantity Surveyors in Nigeria using Google Form. Nigeria was chosen for this study due to the rapid infrastructural developments recorded in the country at the time of this study. According to the National Bureau of Statistics, (2019), the Nigerian Construction sector grew by 66.99% in nominal terms (year on year) in the first quarter of 2019, an increase of 58.02% points compared to the rate recorded in the same quarter of 2018. This was also higher when compared to the rate recorded in the preceding quarter. The Google Form link was sent to the respondents through e-mails, social media platforms (WhatsApp and Facebook Messenger precisely). The data gathered using the google form was downloaded in Microsoft Excel (CSV format), coded, and entered into the Statistical Package for Social Sciences (SPSS V. 25) for analysis. A total of three hundred and forty-nine (349) responses representing 91.36% of the required 382 estimated sample size were gathered. Hence, 349 responses were used for data analysis. Their perception and acceptance of the identified technologies were evaluated in this study. The technology acceptance model (TAM) was the base for the analysis using the TAM criteria. The data gathered were tested for normality and the result showed that the data is not normally distributed, due to the number of the data used. Hence, non-parametric approach were used for the analysis. The two non-parametric statistics used included the Spearman's correlations and Kendall's coefficient of concordance. Spearman's correlations were used to evaluate the relationship between the TAM criteria for all the technologies, while Kendall's coefficient of concordance was used to check the level of agreement among the raters.

2.1 Respondent/Participants Demography

Figure 4 is the summary of the different categories of professional levels the respondents belong to, according to Nigerian professional rating and qualifications in the field of Quantity Surveying and Cost management. The majority of the respondents are fully registered professional Quantity Surveyors. 68% are fully registered professionals which comprise of the FNIQS (Fellow, Nigerian Institute of Quantity Surveyors)-12%, the MNIQS (Member, Nigerian Institute of Quantity Surveyors)-47%, the MRICS (Member, Royal Institute of Chartered Surveyors)-6%, and the MAACEi (Member, Association for the Advancement of Cost Engineers International)-3%. The remaining respondents are graduate quantity surveyors that are still in the process of getting professional membership but are currently working and practicing in different organizations.

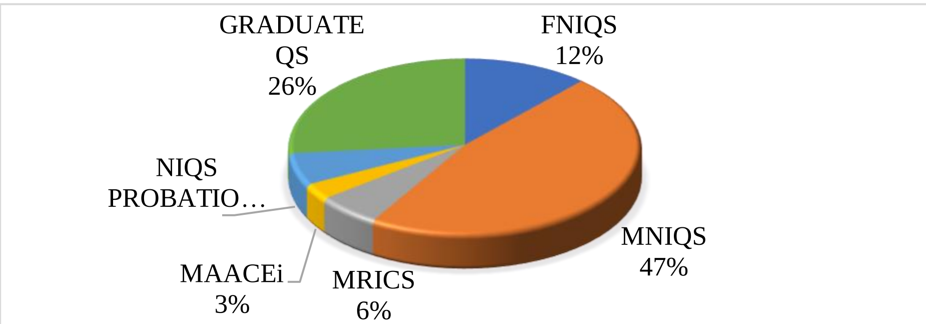


FIG. 4: Professional Qualifications of Respondents

Education was found to advance center task performance by giving people explanatory and procedural information with which they can finish their tasks effectively (Abdulrahamon *et al.*, 2018). To ensure that the responses are reliable, the educational qualification of the respondents is of paramount importance as it will be an indication that they are well informed on the subject matter. The chart in figure 2 highlights the highest educational qualifications of the respondents. The least qualification of the respondents is university first-degree certificate which only 32% has as the highest educational qualification. The larger population has a Master's Degree certificate (47%), while the remaining respondents have a doctorate (21%).

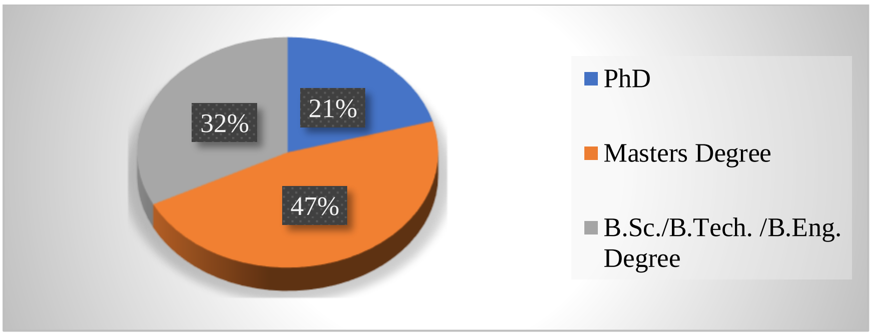


FIG. 5: Educational Qualification of Respondents

Figure 3 shows that only 27% of the respondents have professional experience of 5years and below. The remaining 73% have a professional experience above 5years, of which 24% have over 20years of professional experience. This means that the respondents have the requisite experience to give reliable information on the research area.

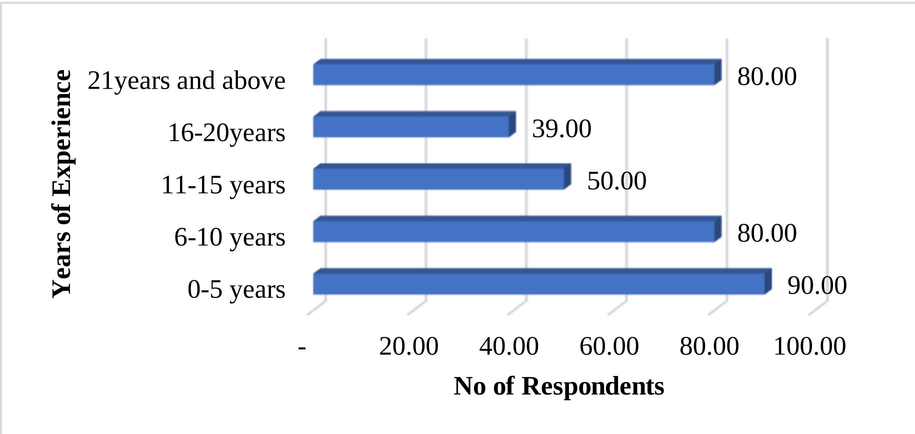
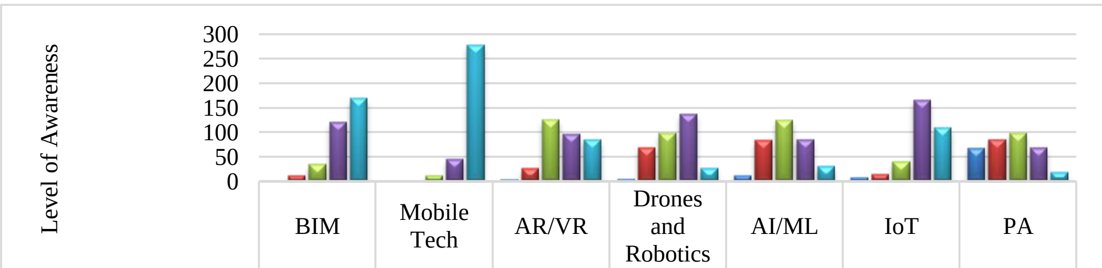


FIG. 6: Years of Professional Experience of Respondents

It is very important to ascertain the level of awareness of the respondents about the identified technologies in the construction industry. This can help to verify if the respondents have the requisite knowledge to give reliable information about the technologies. Figure 7 shows the responses of the respondents regarding their respective level of awareness of the identified technologies in the construction industry. It is obvious that a greater percentage of the respondents have at least a level of awareness for each of the identified technologies.



	BIM	Mobile Tech	AR/VR	Drones and Robotics	AI/ML	IoT	PA
Not Aware	0	0	3	5	12	8	67
Slightly Aware	12	0	26	69	84	14	85
Somewhat Aware	35	12	126	98	124	40	98
Moderately Aware	120	45	96	137	85	165	68
Extremely Aware	169	279	85	27	31	109	18

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FIG. 7: Level of Awareness of Respondents for each Contemporary Technologies

2.2 Analysis of the Identified Technologies

The reliability of the data gathered was checked and the Cronbach's alpha (α) value of 0.895 (Table 2) indicates good internal consistency. The external variables are the introduced antecedents, which their extent of influence on the validated TAM model variables was verified using Spearman's Correlations to check the strength of relationships (effect size) and Kendall's Concordance level to check the level of agreement. This research used Spearman's Correlations as the index of effect size to represent the empirical strength of a relationship between each pair of the constructs in TAM. A statistical measure of the strength of a monotonic relationship between paired data is Spearman's correlation coefficient. In a sample, it is denoted by ρ and is by design constrained as $-1 \leq \rho \leq 1$ (Pirie, 2014, Shi and Conrad, 2009). The relationships checked are as illustrated in the model in Figure 3 which include TAv_PEOU, TAf_PEOU, TFu_PEOU, PEOU_PU, and PU_TAcpt. Hence the following five hypotheses were tested for each of the technologies.

H1: Technology availability has a significant effect on the perceived ease of use

H2: Technology affordability has a significant effect on the perceived ease of use

H3: Technology frequency of use has a significant effect on the perceived ease of use

H4: Perceived ease of use has a significant effect on the perceived usefulness

H5: Perceived usefulness has a significant effect on the technology acceptance

Table 3 is the test statistic table showing Spearman's correlations and Kendall's correlations for each of the technologies. Note that PEOU is the technology ease of use (TEOU), while PU is the technology usefulness for cost control (TUCC). The Correlation is significant at the 0.01 level.

Table 2 Test statistics for Relationships between TAM variables

Cronbach's Alpha (α)	Number of items
0.895	42

The test statistics in table 3 showed that all the hypotheses were supported except for the TEOU_TUCC for Internet of Things (IoT) and Predictive Analytics with significant levels of 0.027 and 0.767 respectively which indicated that the correlations were not significant at these levels. The correlations of each pair in all the technologies show levels of effect each variable has on the paired variable. Since correlation is effect size, the following guide can be used to verbally explain the intensity of the correlation. For the absolute value of τ and ρ; *0.00-0.19 "very weak", 0.20-0.39 "weak", 0.40-0.59 "moderate", 0.60-.79 "strong", 0.80-1.0 "very strong"* (Pirie, 2014, Liu *et al.*, 2017 *and* Gie and Fenn, 2019). Based on this guide, the levels of the effects in each pair were established with Mobile Technology having the highest level of effect in each pair of the variables. The absolute values of the correlations were all greater than 0.60 which means that the effect size of the variables was all strong for each pair of the variables.

To further investigate the strength of effects of each of the TAM variables on technology acceptance, each of the variables was correlated with the acceptance of each technology. The test statistics were given in Table 4 and Table 5 for *Spearman's rho* ρ correlations and *Kendall's tau_b* τ respectively. The correlation results showed that mobile technology has higher correlation coefficients with other variables when compared to correlation values of every other technology. This is in line with the findings of Liu *et al.*, 2017 when they investigated the perceived benefits of mobile technology in New Zealand construction using Spearman's correlations. Though their investigation was centered on overall productivity in the industry, their finding showed that all the perceived benefits of using mobile technology have a positive relationship with overall productivity improvement. This is to buttress the point that mobile technology is very relevant and essential for construction management and control. The correlation coefficient of mobile technology acceptance with the affordability of the technology and the frequency of use is 0.498 and 0.564 respectively which indicates a moderate effect, which means that acceptance of mobile technology is influenced by its affordability and frequency of use, and vice versa. Other variables such as technology availability, technology ease of use, and the technology usefulness for cost control also have strong and very strong correlation values of 0.614, 0.676, and 0.853 respectively.

Table 3 Test statistics for Relationships between TAM variables

Technology	Relationship	Correlations				Remark
		Kendall's tau_b	**Sig. α**	**Spearman's rho**	**Sig. α**	
Mobile Technology	Tav_TEOU	0.850	0.000	0.865	0.000	Supported
	Taff_TEOU	0.677	0.000	0.697	0.000	Supported
	Tfu_TEOU	0.796	0.000	0.805	0.000	Supported
	TEOU_TUCC	0.768	0.000	0.784	0.000	Supported
	TUCC_Tacpt	0.829	0.000	0.853	0.000	Supported
Augmented/Virtual Reality	Tav_TEOU	0.358	0.000	0.390	0.000	Supported
	Taff_TEOU	0.311	0.000	0.335	0.000	Supported
	Tfu_TEOU	0.323	0.000	0.348	0.000	Supported
	TEOU_TUCC	0.372	0.000	0.400	0.000	Supported
	TUCC_Tacpt	0.181	0.000	0.195	0.000	Supported
Building Information Modelling (BIM)	Tav_TEOU	0.425	0.000	0.468	0.000	Supported
	Taff_TEOU	0.288	0.000	0.314	0.000	Supported
	Tfu_TEOU	0.442	0.000	0.483	0.000	Supported
	TEOU_TUCC	(0.298)	0.000	(0.321)	0.000	Supported
	TUCC_Tacpt	0.200	0.000	0.209	0.000	Supported
Internet of Things (IoT)	Tav_TEOU	0.360	0.000	0.385	0.000	Supported
	Taff_TEOU	0.226	0.000	0.245	0.000	Supported
	Tfu_TEOU	0.363	0.000	0.396	0.000	Supported
	TEOU_TUCC	0.111	0.025	0.120	0.027	Not Supported
	TUCC_Tacpt	0.203	0.000	0.224	0.000	Supported
Drones and Robotics	Tav_TEOU	0.607	0.000	0.682	0.000	Supported
	Taff_TEOU	0.489	0.000	0.537	0.000	Supported
	Tfu_TEOU	0.543	0.000	0.603	0.000	Supported
	TEOU_TUCC	0.566	0.000	0.640	0.000	Supported
	TUCC_Tacpt	0.484	0.000	0.549	0.000	Supported
Artificial Intelligence	Tav_TEOU	0.597	0.000	0.650	0.000	Supported
	Taff_TEOU	0.404	0.000	0.452	0.000	Supported
	Tfu_TEOU	0.617	0.000	0.660	0.000	Supported
	TEOU_TUCC	0.312	0.000	0.352	0.000	Supported
	TUCC_Tacpt	0.342	0.000	0.386	0.000	Supported
Predictive Analytics	Tav_TEOU	0.539	0.000	0.580	0.000	Supported
	Taff_TEOU	0.400	0.000	0.440	0.000	Supported
	Tfu_TEOU	0.462	0.000	0.512	0.000	Supported
	TEOU_TUCC	(0.011)	0.818	(0.016)	0.767	Not Supported
	TUCC_Tacpt	0.480	0.000	0.530	0.000	Supported

***. Correlation is significant at the 0.01 level (2-tailed)*

Table 4 Spearman's Correlations of Technology acceptance with other variables in TAM Model

Technology	Correlations		Tech. Availability	Tech. Ease of Use	Tech. Frequency of Use	Tech. Affordability	Tech. Usefulness for CC	Tech. Acceptance
Mobile Technology	*Spearman's rho ρ*	MTacpt	0.614	0.676	0.564	0.498	0.853	1.000
	Sig		0.000	0.000	0.000	0.000	0.000	
	R2		0.377	0.457	0.318	0.248	0.728	1.000
Augmented reality and Virtual reality (AR/VR)	*Spearman's rho ρ*	AR_VRacpt	0.441	0.336	0.131	0.293	0.195	1.000
	Sig		0.000	0.000	0.016	0.000	0.000	
	R2		0.194	0.113	0.017	0.086	0.038	1.000
Building Information Modelling (BIM)	*Spearman's rho ρ*	BIMacpt	0.425	0.392	0.35	0.174	-0.121	1.000
	Sig		.000	.000	.000	.001	.026	
	R2		0.181	0.154	0.123	0.030	0.015	1.000
Internet of Things (IoT)	*Spearman's rho ρ*	IoTacpt	0.358	0.387	0.437	0.173	0.224	1.000
	Sig		.000	.000	.000	.001	.000	
	R2		0.128	0.150	0.191	0.030	0.050	1.000
Autonomous Equipment (Drones and Robotics)	*Spearman's rho ρ*	AEacpt	0.669	0.694	0.612	0.44	0.549	1.000
	Sig		.000	.000	.000	.000	.000	
	R2		0.448	0.482	0.375	0.194	0.301	1.000
Artificial Intelligence (AI)	*Spearman's rho ρ*	AIacpt	0.119	0.235	0.151	.074	0.386	1.000
	Sig		.029	.000	.005	.175	.000	
	R2		0.014	0.055	0.023	0.005	0.149	1.000
Predictive Analytics (PA)	*Spearman's rho ρ*	PAacpt	.091	.038	-.012	-.095	0.53	1.000
	Sig		.094	.489	.825	.079	.000	
	R2		0.008	0.001	0.000	0.009	0.281	1.000

***. Correlation is significant at the 0.01 level (2-tailed)*

Kendall rank correlation is a non-parametric test that determines how closely two variables are related (Shi and Conrad, 2009). Kendall's Tau *b* is a popular statistic for describing the strength of the monotonic relationship between two variables. The values range between plus and minus one same way as Spearman's rho correlations. Mobile technology acceptance has higher dependence values on all the paired variables than other identified technologies and the level of dependence (*Kendall's tau_b τ values*) ranges from moderate to very strong (Table 5).

Table 5 Kendall's tau_b Correlations of Technology acceptance with other variables in TAM Model

Technology	Correlations		Tech. Availability	Tech. Ease of Use	Tech. Frequency of Use	Tech. Affordability	Tech. Usefulness for CC	Tech. Acceptance
Mobile Technology	*Kendall's tau_b τ*	MTacpt	0.58	0.651	0.54	0.467	0.829	1.000
	Sig		.000	.000	.000	.000	.000	
	R2		0.336	0.424	0.292	0.218	0.687	1.000
Augmented reality and Virtual reality (AR/VR)	*Kendall's tau_b τ*	AR_VRacpt	0.395	0.309	0.121	0.267	0.181	1.000
	Sig		.000	.000	.014	.000	.000	
	R2		0.156	0.095	0.015	0.071	0.033	1.000
Building Information Modelling (BIM)	*Kendall's tau_b τ*	BIMacpt	0.373	0.352	0.317	0.156	-0.113	1.000
	Sig		.000	.000	.000	.001	.024	
	R2		0.139	0.124	0.100	0.024	0.013	1.000
Internet of Things (IoT)	*Kendall's tau_b τ*	IoTacpt	0.33	0.352	0.397	0.157	0.203	1.000
	Sig		.000	.000	.000	.001	.000	
	R2		0.109	0.124	0.158	0.025	0.041	1.000
Autonomous Equipment (Drones and Robotics)	*Kendall's tau_b τ*	AEacpt	0.572	0.608	0.524	0.374	0.484	1.000
	Sig		.000	.000	.000	.000	.000	
	R2		0.327	0.370	0.275	0.140	0.234	1.000
Artificial Intelligence (AI)	*Kendall's tau_b τ*	AIacpt	0.106	0.206	0.132	.065	0.342	1.000
	Sig		.024	.000	.006	.169	.000	
	R2		0.011	0.042	0.017	0.004	0.117	1.000
Predictive Analytics (PA)	*Kendall's tau_b τ*	PAacpt	.084	.031	-.010	-.082	0.48	1.000
	Sig		.076	.503	.837	.087	.000	
	R2		0.007	0.001	0.000	0.007	0.230	1.000

3. RESEARCH FINDINGS AND DISCUSSION

The test statistics for relationships between TAM variables for each of the technologies (Table 3) showed that Kendall's coefficient of concordance values and Spearman's correlation values for Mobile technology were all above 0.6 which indicates a high level of agreement among the raters and strong relationships between the compared TAM variables. The *Kendall's tau_b* values for the compared variables TAv_PEOU, TAf_PEOU, TFu_PEOU, PEOU_PU, and PU_TAcpt were 0.850, 0.677, 0.796, 0.768, and 0.829 respectively. This indicates that a greater percentage of the respondents are in agreement regarding the relationships of the TAM variables for mobile technology. In the same vein, the *Spearman's rho ρ* values for the compared variables TAv_PEOU, TAf_PEOU, TFu_PEOU, PEOU_PU, and PU_TAcpt were 0.865, 0.697, 0.805, 0.784, and 0.853 respectively. As earlier stated, *0.60-.79* indicates a *"strong relationship",* and *0.80-1.0* indicates *a "very strong relationship"* (Pirie, 2014, Liu *et al.*, 2017 *and* Gie and Fenn, 2019). It is therefore evident that there is a strong relationship between the compared TAM variables for Mobile Technology supporting all the hypotheses. Comparing the values of *Kendall's tau_b* and *Spearman's rho ρ* for the TAM variables in each of the technologies, it is evident that the values for mobile technology were quite higher than the values for other identified technologies. The test statistics showed that in each of the technologies, there is a certain level of agreement and positive relationship between the compared TAM variables but not as high and strong as that of Mobile technology. This explains why all the hypotheses were all supported in all the identified technologies except the fourth hypothesis for Internet of Things (IoT) and Predictive Analytics. The two unsupported hypothesis is due to the significant levels.

Furthermore, *Spearman's Correlations* and *Kendall's tau_b τ Correlations* of Technology acceptance with other variables in TAM Model (Table 4 and Table 5) also indicated that the internal correlation values between technology acceptance for Mobile Technology and other TAM varaibles were all higher than the values for all other identified technologies. It can then be deduced from the values that Mobile technology has been generally rated higher than other technologies to be more readily available, easy to use, affordable, and useful for cost management compared to other technologies. This does not necessarily indicate that the potentials of other contemporary technologies for cost management were lower than that of mobile technology. The reason for the high rating for mobile technology is not only because of its capabilities for construction management operations, but due to its widely application in other spheres of life. The raters are well informed about the technology when compared to other identified technologies. Figure 7 explained that majority of the respondents were extremely aware of mobile technology than every other technologies. This explains why mobile technology has become an essential tool in the hands of all project participants, including artisans, at all project sites. The availability of mobile technology, and how it is easy to manipulate made the use more frequent. And since mobile technology is now a must-have in construction sites, several researches have been carried out on the applications of the technology for construction management and control. There are software and mobile applications available today to assist in the management of all aspects of a construction project (Jones, 2019). Budiac, (2018) reported that in September 2017, a total of 158 construction industry professionals from small to midsize (SMB) companies across North America were polled about their existing and potential technology and software use. According to the results of the study, 58% of SMB construction professionals state their company uses a smartphone or tablet-based applications at least "often.". Also unsurprising, hosted/cloud software users were more likely to depend on mobile. Also, Riddell, (2017) reported that in their survey, over 80% of construction professionals surveyed said mobile technology is a top priority, with 4 out of 5 saying they are using it. The convenience in making use of mobile technology for construction activities has drastically reduced paperwork with bulk data on record cards to a greater percentage. Cost management is a key assignment that demands accurate data management and due to the acceptability level of mobile technology in the industry, most of the cost management activities are gradually being translated into mobile apps to enhance accuracy. Liu et al., (2017) stated that Construction professionals' (CPs) workspaces are not limited to particular office locations, and since they are still on the move, mobile computing can provide them with a fast, convenient, and easy-to-carry platform for communicating pertinent on-site information to other stakeholders in different locations. Companies are becoming more aware of how mobile technology can simplify and automate the capture of information in the field and transmit the information back to company management systems, so mobile technologies are becoming more popular on the construction site (Casey Cline and Davis, 2013). Furthermore, mobile devices (such as smartphones and tablets) not only have communication and computing capabilities but also image and video recording capabilities that could be used for record-keeping and documentation. Based on this fact, construction managers should harness the potentials of mobile technology and as well make effort to also maximize the use of all other technologies for effective cost management.

4. CONCLUSION

Several technologies have been deployed to the site for the management of construction activities in the present era of digital construction. These technologies as already articulated play a vital role in enhancing the effectiveness and efficiency of operations. This article identified various contemporary technologies and their areas of applications for construction cost management. The article x-rayed these technologies to identify the top technology that is readily accepted in the industry for cost management operations. The criteria for the assessment were based on the technology acceptance model criteria which include; perceived ease of use, perceived usefulness, acceptance, and the extension criteria of availability, frequency of use, and affordability. The analyses have shown that mobile technology has gained a good acceptance level in the industry and was ranked first among the identified technologies. Mobile technology has gained applications in all construction operations including cost management of construction projects. Real-time data collection and transmission between the Jobsite and project managers in the back office is possible thanks to mobile technology. There are a plethora of construction-related mobile apps on the market right now, with features ranging from basic calculations to comprehensive architectural renderings.

Nearly 13,000 construction-related architecture and design applications are currently on the market and this figure is on the increase per day as several other applications are developed in different parts of the world, all addressing different and related construction issues at different stages. The available smartphone applications in the construction sector range from project management, calculators, safety, integrated construction cost and accounting, construction site operations, computer-aided design, 2D and 3D designs and drawings, estimating, and building information modeling (BIM). Therefore, the relevance and the applications of mobile technology in the industry for cost management cannot be over-emphasized.

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REFERENCES

Abanda, F.H., Mzyece, D., Oti, A.H. and Manjia, M.B., 2018. A Study of the Potential of Cloud/Mobile BIM for the Management of Construction Projects. *Applied System Innovation*, 1(2), p.9. Available at: http://www.mdpi.com/2571-5577/1/2/9.

Abdulrahamon, A., Toyin Adeleye, S. and Adeola, F., 2018. Impact of Educational, Professional Qualification and Years of Experience on Accountant Job Performance. *Journal of Accounting and Financial Management*, 4(1), pp.32–44.

Afolabi, A., Fagbenle, O. and Mosaku, T., 2017. IT management of building materials' planning and control processes using web-based technologies. *Advances in Intelligent Systems and Computing*, 570, pp.12–19.

Agarwal, B.R., Chandrasekaran, S. and Sridhar, M., 2018. *Imagining construction's digital future*,

Ahmed, S., 2019. A Review on Using Opportunities of Augmented Reality and Virtual Reality in Construction Project Management. *Organization, Technology, and Management in Construction: an International Journal*, 11(1), pp.1839–1852.

Alsafouri, S. and Ayer, S.K., 2018. Review of ICT Implementations for Facilitating Information Flow between Virtual Models and Construction Project Sites. *Automation in Construction*, 86(October 2017), pp.176–189. Available at: https://doi.org/10.1016/j.autcon.2017.10.005.

Arslan, V., Ulubeyli, S. and Kazaz, A., 2019. The Use of Internet of Things in the Construction Industry. *UEMK 2019 Proceedings Book*. 2019 Turkey, pp. 501–510.

BigRentz Inc., 2019, *Augmented Reality in Construction: 6 Applications in 2019* [Online]. Available at: https://www.bigrentz.com/blog/augmented-reality-construction [Accessed: 16 January 2022].

Bobriakov, I., 2019, *Top 8 Data Science Use Cases in Construction* [Online]. Available at: https://medium.com/activewizards-machine-learning-company/top-8-data-science-use-cases-in-construction-9ce8035e936f [Accessed: 27 October 2019].

Budiac, D., 2018b, *New Construction Tech Trends* [Online]. Available at: https://softwareconnect.com/construction/technology-trends-2018-report/%0D [Accessed: 20 October 2019].

Business, A., 2017, *Application of Artificial Intelligence for Cost Management in Construction Projects.* [Online]. Available at: https://ai.business/2017/03/09/applications-of-artificial-intelligence-for-cost-management-in-construction-projects/ [Accessed: 17 January 2022].

Casey Cline, R. and Davis, K.A., 2013. Using mobile technology in a construction management "hands-on" laboratory. *ASEE Annual Conference and Exposition, Conference Proceedings*. 2013 Atlanta, pp. 1–7.

Cepurnaite, J., Ustinovicius, L. and Vaisnoras, M., 2017. Modernization with BIM technology through scanning building information. *Procedia Engineering*, 208, pp.8–13. Available at: https://doi.org/10.1016/j.proeng.2017.11.014.

Chigara, B., Moyo, T. and Mudzengerere, F.H., 2013. an Analysis of Cost Management Strategies Employed By Building Contractors on Projects in Zimbabwe. *International Journal of Sustainable Construction Engineering & Technology*, 4(2), pp.2180–3242. Available at: http://penerbit.uthm.edu.my/ojs/index.php/IJSCET.

Chu, M., Matthews, J. and Love, P.E.D., 2018. Integrating mobile Building Information Modelling and Augmented Reality systems: An experimental study. *Automation in Construction*, 85(February 2017), pp.305–316. Available at: https://doi.org/10.1016/j.autcon.2017.10.032.

Chuttur, M., 2009. Overview of the Technology Acceptance Model: Origins , Developments and Future Directions. *Sprouts: Working Papers on Information Systems*, 9(37), pp.1–23.

Dave, B., Kubler, S., Främling, K. and Koskela, L., 2016. Opportunities for enhanced lean construction management using Internet of Things standards. *Automation in Construction*, 61, pp.86–97. Available at: http://dx.doi.org/10.1016/j.autcon.2015.10.009.

DU, F., 2017. Research on the Whole Process Cost Management of University Capital Construction Based on BIM. *2016 International Conference on Architectural Engineering and Civil Engineering*. 2017 pp. 511–515.

Elrajoubi, S., 2019. *Artificial Intelligence in Project Management*,

Elshafey, A. et al., 2020. Technology acceptance model for augmented reality and building information modeling integration in the construction industry. *Journal of Information Technology in Construction*, 25(August 2018), pp.161–172.

Fadason, R.T., Danladi, C.Z. and Akut, K.L., 2018. Challenges Of Building Information Modelling Implementation In Africa A Case Of Nigerian Construction Industry. *FIG Congress 2018 Embracing our smart world where the continents connect: enhancing the geospatial maturity of societies Istanbul, Turkey, May 6–11, 2018*. 2018 Istanbul, Turkey.

GenieBelt, 2017, *The present and future of VR in construction management* [Online]. Available at: https://geniebelt.com/blog/vr-in-construction-management [Accessed: 20 October 2019].

GenieBelt, 2018, *Top 10 construction technology trends for 2019* [Online]. Available at: https://geniebelt.com/blog/top-10-construction-technology-trends-for-2019 [Accessed: 11 September 2019].

Gerbert, P. et al., 2016, *Digital in Engineering and Construction; The Transformative Power of Building Information Modeling* [Online]. Available at: http://futureofconstruction.org/content/uploads/2016/09/BCG-Digital-in-Engineering-and-Construction-Mar-2016.pdf [Accessed: 15 February 2020].

Gie, T.A. and Fenn, C.J., 2019. Technology Acceptance Model and Digital Literacy of First YEar Students in a Private Institution of Higher Learning in Malaysia. *Berjaya Journal of Services & Management*, 11(January), pp.103–116.

Girma, A. and Alemu, M.G., 2018. Improving Project Cost Management Practice and Profitability of Domestic Contractors in Vadodara. *Journal of Emerging Technologies and Innovative Research (JETIR)*, 5(5).

Gregory, C. and Laurent, F., 2016. *A business approach for the use of drones in the Engineering & Construction industries*,

Haron, N.A. et al., 2017. Implementation of Building Information Modelling (BIM) in. *Pertanika Journal of Science and Technology*, 25(3), pp.661–674.

Higgins, A., 2019, *5 Major Construction Technology Trends to Watch in 2019* [Online]. Available at: https://connect.bim360.autodesk.com/construction-technology-innovation-2019 [Accessed: 11 September 2019].

Holt, E.A., Benham, J.M. and Bigelow, B.F., 2015. Emerging Technology in the Construction Industry : Perceptions from Construction Industry Professionals. *122nd ASSEE Annual Conference & Exposition*. 2015 American Society for Engineering Education, Seattle, WA.

Igwe, U.S., Fikri, M.S. and Chima Onyebuchi, O., 2019. *Recent Advances In Mobile Application For Real Time Cost Management In Construction Projects*, Universiti Teknologi Malaysia, Johor Bahru.

Igwe, U.S., Mohamed, S.F. and Azwarie, M.B.M.D., 2020. Recent Technologies in Construction; A Novel Search for Total Cost Management of Construction Projects. *IOP Conference Series: Materials Science and Engineering*, 884(1).

Ishola, A. and Babatunde, L., 2017. Impact Analysis of Information Communication Technology (ICT) in Project Evaluation and Management in Nigeria. *Canadian Social Science*, 13(7), pp.1–11.

J.Adwan, E. and Al-Soufi, A., 2016. A Review of ICT Technology In Construction. *International Journal of Managing Information Technology*, 8(3/4), pp.01–21.

JBKnowledge, 2016. *The 5th Annual Construction Technology Report*,

Jones, K., 2019, *How Technology is Disrupting the Construction Industry* [Online]. Available at: https://www.constructconnect.com/blog/construction-technology/technology-reshaping-construction-industry/%0D [Accessed: 10 March 2019].

Jununkar, S.M., Aswar, P.D.S. and Mittapalli, P.D.L., 2017. Application of Bim and Construction Process Simulation Using 5D Bim for Residential Building Project. *International Research Journal of Engineering and Technology (IRJET)*, 04(07), pp.1063–1067.

Kapliński, O., 2018. Innovative Solutions in Construction Industry . Review of 2016 – 2018 Events and Trends. *Engineering Structures and Technologies*, 10(1), pp.27–33.

Khelifi, A. and Hyari, K.H., 2016. A Mobile Device Software to Improve Construction Sites Communications " MoSIC ". *(IJACSA) International Journal of Advanced Computer Science and Applications*, 7(11), pp.51–58.

Kiganda, A., 2017, *How Mobile Technologies are Boosting Construction Site Efficiency* [Online]. Available at: https://constructionreviewonline.com/2017/02/how-mobile-technologies-are-boosting-construction-site-efficiency/ [Accessed: 8 August 2018].

Kujala, J., Brady, T. and Putila, J., 2014. Challenges of Cost Management in Complex Projects. *International Journal of Business and Management*, 9(11), pp.48–58. Available at: http://www.ccsenet.org/journal/index.php/ijbm/article/view/39454.

Kulkarni, S.B. and Mhetar, G., 2017. Cost Control Technique Using Building Information Modeling (BIM) For a Residential Building. *International Journal of Engineering Research and Technology*, 10(1), pp.324–330. Available at: https://www.ripublication.com/irph/ijert_spl17/ijertv10n1spl_62.pdf.

Liao, Y. et al., 2018. The impact of the fourth industrial revolution: A cross-country/region comparison. *Production*, 28.

Liu, T. et al., 2017. The perceived benefits of apps by construction professionals in New Zealand. *Buildings*, 7(4), pp.1–11.

Ma, Q. and Liu, L., 2011. The Technology Acceptance Model. *Advanced Topics in End User Computing, Volume 4*, 16(1), pp.59–72.

Mahami, H., Nasirzadeh, F., Hosseininaveh Ahmadabadian, A. and Nahavandi, S., 2019. Automated Progress Controlling and Monitoring Using Daily Site Images and Building Information Modelling. *Buildings*, 9(3), p.70.

Mahmud, S.H., Assan, L. and Islam, R., 2018. Potentials of Internet of Things (IoT) in Malaysian Construction Industry. *Annals of Emerging Technologies in Computing*, 2(4), pp.44–52.

Miri, M. and Khaksefidi, M., 2015. Cost Management in Construction Projects: Rework and Its Effects. *Mediterranean Journal of Social Sciences*, 6(6), pp.209–215.

Moshood, T.D. et al., 2020. Barriers and benefits of ICT adoption in the Nigerian construction industry. A comprehensive literature review. *Applied System Innovation*, 3(4), pp.1–19.

Mushamalirwa, A.-M.N., 2016. A BIM-based solution to support Earned Value Management in Construction Anne-Marie Nsimire Mushamalirwa Extended Abstract Thesis to obtain the Master of Science Degree in Civil Engineering Supervisor : Professor António Morais Aguiar da Costa Jury : , (July).

National Bureau of Statistics, 2019. *Nigerian Gross Domestic Product Report*,

Nigam, M., Dixit, A. and Sachan, K.K., 2016. BIM Vs Traditional Quantity Surveying And Its Future Mapping. *International Journal of Engineering Development and Research*, 4(2), pp.1261–1265.

Nowotarski, P. and Paslawski, J., 2017. Industry 4.0 Concept Introduction into Construction SMEs. *IOP Conference Series: Materials Science and Engineering*. 2017 IOP Publishing.

Nsimire Mushamalirwa, A.-M., 2016. *A BIM-based solution to support Earned Value Management in Construction Civil Engineering*. TECNICO LISBOA.

Ojelabi, R., Oyeyipo, O., Afolabi, A. and Amusan, L., 2018. Presence of Social Client Relationship Management within the Nigerian Construction Industry. *Buildings*, 8(4), p.60. Available at: http://www.mdpi.com/2075-5309/8/4/60.

Orihuela, P., Orihuela, J. and Pacheco, S., 2016. Information and Communications Technology in Construction: A Proposal for Production Control. *Procedia Engineering*, 164(December), pp.150–157. Available at: http://dx.doi.org/10.1016/j.proeng.2016.11.604.

Osseiran, A., Monserrat, J.F. and Marsch, P., 2016. *5G mobile and wireless communications technology*,

Park, E.S. and Park, M.S., 2020. Factors of the technology acceptance model for construction IT. *Applied Sciences (Switzerland)*, 10(22), pp.1–15.

Perera, S., Ingirige, B., Ruikar, K. and Obonyo, E., 2018. *Advances in Construction ICT and e-Business* First Edit., Routledge (Taylor & Francis Group), London New York.

Pickup, O., 2018, *Five technologies changing construction - Raconteur* [Online]. Available at: https://www.raconteur.net/business-innovation/five-technologies-changing-construction [Accessed: 11 September 2019].

Pirie, W., 2014. Spearman Rank Correlation: Introduction. In: *Wiley StatsRef: Statistics Reference Online*. p. 8.

Pistorius, C., 2017. The Impact of New Technologies on the Construction Industry. *Innovation Insight*, (4), pp.1–70.

Pučko, Z., Nataša, N. and Klanšek, U., 2014. Building Information Modeling Based Time And Cost Planning In Construction Projects. *Organization, technology and management in construction: An international journal*, 6(1), pp.958–971.

Rajagopal, A., 2017, *The Rise of AI and Machine Learning in Construction* [Online]. Available at: https://medium.com/autodesk-university/the-rise-of-ai-and-machine-learning-in-construction-219f95342f5c [Accessed: 26 October 2019].

Rao, S., 2019, *The Benefits of AI In Construction* [Online]. Available at: https://constructible.trimble.com/construction-industry/the-benefits-of-ai-in-construction [Accessed: 26 October 2019].

Redden, L., Collins, W. and Kim, J., 2017. Integration of Construction Mobile Technologies into Construction Management Curriculum: A Case Study. *Procedia Engineering*, 196, pp.535–542.

Rhumbix, 2018, *10 New Construction Technology Trends to Watch - Rhumbix* [Online]. Available at: https://rhumbix.com/10-new-construction-technology-trends-to-watch/ [Accessed: 11 September 2019].

Riddell, T., 2017, *How Mobile Technology is Transforming the Construction Industry* [Online]. Available at: https://esub.com/mobile-technology-transforming-construction-industry/ How [Accessed: 8 August 2018].

Rouse, M., 2019, *Build a WCM architecture that supports business needs ; History of IoT* [Online]. Available at: https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT [Accessed: 23 October 2019].

Santos, J.M.D., 2018, *2018 Technology and Software Trends in the Construction Industry* [Online]. Available at: https://project-management.com/2018-technology-and-software-trends-in-the-construction-industry/ [Accessed: 8 August 2018].

Sepasgozaar, S.M.E., Shirowzhan, S. and Wang, C., 2017. A Scanner Technology Acceptance Model for Construction Projects. *Procedia Engineering*, 180, pp.1237–1246.

Sharifi, S., 2018, *3 Ways Virtual Reality in Construction is Shaping the Industry* [Online]. Available at: https://connect.bim360.autodesk.com/virtual-reality-in-construction [Accessed: 10 October 2019].

Shi, R. and Conrad, S.A., 2009. Correlation and regression analysis. *Annals of Allergy, Asthma and Immunology*, 103(4 SUPPL.).

Solutions, M.C. and August, 2019, *Mobile Technology Trends for Heavy Construction* [Online]. Available at: https://mcsmag.com/mobile-technology-trends-for-heavy-construction/ Date [Accessed: 5 May 2019].

Sorce, 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, pp.227–248.

Tahir, M.M. et al., 2018. Improving cost and time control in construction using building information model (Bim): A review. *Pertanika Journal of Science and Technology*, 26(1), pp.21–36. Available at: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85041057020&partnerID=40&md5=09d00c051b08e086c97757dedf493e21.

Tantiponganant, P. and Laksitamas, P., 2014. An analysis of the technology acceptance model in understanding students' behavioral intention to use university's social media. *Proceedings - 2014 IIAI 3rd International Conference on Advanced Applied Informatics, IIAI-AAI 2014*, 12, pp.8–12.

Thompson, A., 2019, *Virtual and Augmented Reality for Construction* [Online]. Available at: https://www.buildings.com/news/industry-news/articleid/21978/title/virtual-augmented-reality-construction [Accessed: 20 October 2019].

Vasista, T.G. and Abone, A., 2018. Benefits, barriers and applications of information communication technology in construction industry: A contemporary study. *International Journal of Engineering and Technology(UAE)*, 7(Special Issue 27), pp.492–499.

Wu, J.H. and Wang, S.C., 2005. What drives mobile commerce? An empirical evaluation of the revised technology acceptance model. *Information and Management*, 42(5), pp.719–729.

Yapa, S.R., Poesche, J. and Kauranen, I., 2019. Why adoption of some Technologies is faster ? An Explanation through Sequential Coherence. *Sri Lanka Journal of Management Studies*, 1(II).

Ying, C., 2019. Application of BIM Technology in the Phase of Project Tendering and Bidding. *Scientific Workshop on Advanced in Social Sciences, Arts & Humanities (ASSAH 2019) Application*. 2019 pp. 11–14.

Yovino, J., 2019, *19 construction apps for 2019* [Online]. Available at: https://dailyreporter.com/2019/01/04/19-construction-apps-for-2019/ [Accessed: 3 March 2019].

Zaher, M., David, G. and Mohammed, M., 2015. Mobile Augmented Reality Applications for Construction Projects. *Construction Innovation; Information, Process Management*, 8, pp.1401–1416.

Zhezherov, A., 2018, *AR Solutions for Construction on the Rise — 2017 Industry Report Overview* [Online]. Available at: https://www.intellectsoft.net/blog/ar-solutions-for-construction. [Accessed: 28 August 2018].