Recent Technologies in Construction; A Novel Search for Total Cost Management of Construction Projects.

Uchenna Sampson Igwe¹, ², Sarajul Fikri Mohamed¹ and Mohamed Bin Mat Dzahir Azwarie¹
¹Faculti Alambina dan Ukur, Universiti Teknologi Malaysia, 81310, Johor Bahru, Malaysia
²School of Environmental Sciences, Federal University of Technology, Owerri Imo State, Nigeria

Corresponding author: usigwe@graduate.utm.my

Abstract. There is a continuous rise in the implementation of information-driven technology in construction, especially for effective control and management of construction resources. However, the enormous opportunities that these technologies provide have not been adequately utilized for construction cost management. There are so many innovations in the current IR 4.0 era, where digitization and connected systems are the trend of activities in engineering and other allied industries. These innovations are being adopted in the construction industry, to enhance the efficiency of construction processes. The areas of the current trend include Internet of things [IoT], Augmented and Virtual Reality [AR and VR], 5D-BIM, Autonomous Equipment, Artificial Intelligence and Machine Learning, and Predictive Analytics. This paper explores the applications and benefits of these areas of new technological trends in construction project management with emphasis laid in cost management of construction projects. Eighty-one[81] recent publications in journal articles, textbooks, web pages and conference proceedings published between 2008 and 2019 were reviewed in order to articulate and reveal areas of application of the technologies in project cost management and control. The paper exposes areas of application of the current ICT trends which construction managers and project cost managers should harness.

1. Introduction
The construction industry generally has suffered low adoption of technologies in project delivery. This could be as a result of the fact that most construction projects involve long term planning and execution which could run into years. However, there is a progressive realization of the potency of information and communication technologies [ICTs] and their tangible impact on efficiency in project planning, project control and project execution. Use of ICT improves co-ordination, processes and collaboration between customer, contractor and engineer [1]. The credibility of technological advancements cannot be over emphasized as great value is generated by optimizing efficiency and productivity at every stage from planning to construction [2]. The construction industry is therefore under a significant paradigm shift looking back on the great advancement that have taken place in the history of the industry [3]. New technologies are being developed and deployed to site at a 5G speed. The great benefits in project delivery cuts across all stages of construction process. New technologies streamline construction project management processes which includes resource scheduling, tracking
performance, equipment maintenance, and collaboration between teams [4]. New technologies have enabled construction organizations to process and store their information easily and huge amount of data can be transferred quickly [5].

There are variety of applications of these new technologies in engineering, business and other allied industries. Software and applications related to project management, information or cost management are helping project teams to improve communication and resolve issues early in the process [6]. Harnessing the same opportunities provided by these current trends of technological shift is highly necessary, hence this paper presents the key areas of applications of these technologies in construction to enable construction professionals especially cost managers to adequately plunge into the full utilization of the opportunities for greater efficiency.

1.1 Overview of current construction cost management
Project cost management involves all the processes involved in planning, estimating, budgeting, financing, managing and controlling costs so that the project can be scheduled for completion within the approved budget. These processes are distinct and do overlap. On the other hand, Construction cost management deals with a broad range of functions such as estimating, scheduling, cost control, resource costing and financial control. Total cost management process spans through all construction stages as illustrated in figure 1 below. At every stage, there is cost management activity that must be implemented by cost managers/Quantity Surveyors. These cost management activities can be executed using any of the numerous available techniques and tools that have been developed for cost management process. Table 1 below articulated most of the techniques that have being in use and still being used for cost monitoring and control.
Figure 1 Cost Management activities summarized in the context of RIBA Plan of Work [Adopted from: [17]]

| Cost Management Activities/Tasks | Preliminary Cost Estimate | Design Stage Cost Plan | Tendering | Cost Control |
|----------------------------------|---------------------------|------------------------|-----------|--------------|
|                                  | • Project feasibility study | • Pre-tender cost estimate and cost plan | • Preparing costings for tender | • Pre-tender cost estimate and cost plan |
|                                  | • Preliminary cost advice  | • Advice on alternative materials and construction methods | • Preparing tender documents, such as BoQ, and Contractual documents | • Advice on alternative materials and construction methods |
|                                  | • Cost planning and budget establishment | • Advice on tendering process | • Analysis of tender cost and advice on contractor selection | • Advice on tendering process |
|                                  | • Advice on procurement methods | | | |

Table 1 Cost Management techniques currently used in the construction industry

| Cost Control Technique | Author | Remark |
|------------------------|--------|--------|
| Cost-Value Reconciliation [CVR] | [10], [9], [11], [12] | Used by contractors. CVR illustrates the company’s profitability level by bringing together the established cost and values. |
| Contract costing Variance – unit costing | [10], [13], [9], [11], [12] | The unit cost of executing an item of work is used to compare the unit cost in the tender [BoQ]. |
| Earned Value Analysis [EVM] | [14], [10], [13], [15], [9], [16], [17], [11], [12] | Earned value Analysis [EVM] is an integrated project cost and schedule control system which gives the trend variances in cost and work schedule. |
| Budgeting | [14], [13], [18], [19], [20] | Budgeting involves Collecting the cost estimates, combining them to establish an overall cost and baseline. |
| Cash Flow Forecasting | [13], [3], [21] | Cash flow forecasting involves breaking down the project budget in line with the construction program of works to establish a project cash flow. |
| Financial Reporting and Cost Reporting | [3], [21] | Cost reports provide progress information that is used to assess project performance against set |
targets.

| Work Programmes | [18], [20] | The schedule of construction works is used by contractors to checkmate the progress and cost performance of a project. |
|------------------|------------|----------------------------------------------------------------------------------------------------------------------------------|
| Inspection of Works | [18], [20] | Periodic inspections are made to check the progress of work in line with the budget. |
| Site Meetings | [18], [20], [22] | Site meetings are held to review the progress of work and compare to the predetermined cost allocated to work items. It gives the stakeholders up-to-date information on work performance. |
| Record Keeping | [18], [20] | Adequate record keeping of all activities executed gives the early signal of any unconventionality to the set standards or cost baselines. |
| Monitoring Work and Cost Performance Evaluation | | Tools for monitoring work schedules, financial budgets, work inspection, and feedbacks are used by Clients, consultants, and contractors to monitor cost performance. |
| Overall profit or Loss | [11] | Profit and loss accounts give good information on cost performance. |
| Profit or loss on each contract at valuation dates | | Valuation of work on dates of valuation gives information on the project progress and cost. |
| Reconciliation of actual Labour, Plant, and Material with the forecast | | Reconciling the actual cost of Labour/Plant/Material with the scheduled. |
| Program Evaluation and Review Technique [PERT/COST] | Leading Parameter Method | Projects are represented by sets of required activities. Cost estimates for activity are evaluated and reviewed. The major yardstick for measuring construction cost is used to check cost performance. |
| Evaluation of work carried out | [18], [20] | Work executed is evaluated against the cost. |
| Target cost, Activity-based cost, Value engineering | [15] | Cost limit is set which cannot be exceeded. Projected are costed based on the scheduled activities. Evaluating and eliminating any potential threat to cost performance. |
| Daily material & labor controlling | | Effective control of material and labor usage on site. |

These techniques used for construction cost management are implemented using applicable technologies and in recent times, there several innovations in the industry with modern technologies driving the industry. These recent technological developments are in no doubt very relevant for effective cost management of projects.

1.2 The Current technological trends in construction
There are different technologies in the present-day industrial moves whose relevance in the construction industry cannot be overemphasized. These technologies are currently reshaping the operations of the construction industry including cost management. The top ten [10] of the technologies referenced from 2016 to 2019 include; Building Information Modelling [BIM], Augmented and Virtual Realities [AR & VR], 3D Modelling, Mobile Technology, Internet of Things [IoT], Artificial Intelligence and Machine Learning [AI & ML], Drones and Robotics, Predictive
Analytics, Cyber security and Blockchain, Construction Software and data ecosystem [see table 2 below]. The applications are as highlighted in the table but not exhausted as the potentials and benefits of these technologies are not limited to those in table 2.

| S/n | Technology | Applications in Construction | Core benefits for Cost Management | References |
|-----|------------|-----------------------------|-----------------------------------|------------|
| 1   | Building Information Modeling [BIM] | • Effective collaboration and communication among project team | • Applicable in cost estimating and cost planning at the design stage | [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27] |
|     |           | • Model based Cost estimation | • Applicable in quantity measurement for valuations of variations and for preparation of BOQs. | |
|     |           | • Project visualization at the preconstruction stage | • BIM enables scheduling of construction resources and their management | |
|     |           | • Enhance coordination and clash detection | • Cost reduction and mitigation against risk | |
|     |           | • Cost reduction and mitigation against risk | • Enhances scheduling and sequencing | |
|     |           | • Enhances scheduling and sequencing | • Improves productivity | |
|     |           | • Improves productivity | • Safety in construction sites | |
|     |           | • Safety in construction sites | • Facilities management | |
|     |           | • Facilities management | | |
| 2   | Augmented and Virtual Realities | • Streamlines the design process | • 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. | [28], [13], [15], [20], [29], [4], [3], [2], [30], [24], [31], [32], [33], [34], [35], [26], [27] |
|     |           | • Design development and communication among project team | • They are used for automated measurements | |
|     |           | • Defects management | • Very useful also for project planning and monitoring | |
|     |           | • Quality management | | |
|     |           | • Projects scheduling | | |
|     |           | • Information collection | | |
|     |           | • Safety management | | |
|     |           | • Logistics management | | |
|     |           | • Project progress evaluation | | |
3D Modelling

- Project designs and collaboration with project team
- Project progress monitoring and evaluation

3D modelling has gained good attention in making real the intention of client for better understanding. This will enable the cost manger to estimate and budget more accurately.

[36], [20], [4], [2], [30], [24], [32], [25], [37], [38], [26], [27], [23]

Mobile Technology

- Facilitates collaboration among project team in the office and in 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 cost.

- 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

[39], [40], [41], [15], [42], [43], [44], [20], [21], [4], [3], [2], [45], [30], [46], [47], [48], [32], [25], [49], [26], [27]

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

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.

[50], [20], [29], [51], [22], [30], [24], [52], [53], [54]
| 6 | Artificial Intelligence and Machine Learning |
|---|---------------------------------------------|
| **•** Construction management data           |
| **•** Productivity improvement data          |
| **•** Material and equipment management data |
| **•** Real-time job site monitoring data     |
| **•** Project controls and management of    |
| construction cost data                      |
| **•** Construction safety data               |
| **•** AI and ML are great tools for          |
| management of cost data                     |
| [collection, processing, reporting and      |
| documentation]                              |
| **•** It is applicable for real-time        |
| project monitoring and management of         |
| construction resources.                     |
| [15], [20], [29], [24], [55], [56], [64],  |
| [25]                                        |

| 7 | Drones and Robotics |
|---|---------------------|
| **•** Real-time project monitoring data     |
| **•** Project progress evaluation data      |
| **•** Construction site operations data     |
| **•** Productivity improvement data         |
| **•** Project status reporting data         |
| **•** Drones and Robotics is useful for     |
| real-time project monitoring, evaluations  |
| and management of construction resources.   |
| [15], [29], [4], [3], [2], [30], [24],    |
| [48], [32], [25], [26]                     |

| 8 | Predictive Analytics |
|---|---------------------|
| **•** Construction data analysis and        |
| prediction data                            |
| **•** Enhances decision making process      |
| **•** Tracking and analysis of construction |
| problems for remedial actions              |
| **•** Construction cost estimation data     |
| **•** Predictive analytics is a great tool  |
| for estimation, budgeting and cost          |
| forecasting.                               |
| [29], [4], [24], [57]                      |

| 9 | Cyber security and Blockchain |
|---|--------------------------------|
| **•** Construction data processing and     |
| management data                           |
| **•** Security of construction information |
| transfer data                             |
| **•** Payment and project management data |
| **•** Procurement and supply chain         |
| management data                           |
| **•** Smart asset management data          |
| **•** Cost information is very sensitive   |
| and should be secured. Cyber security is   |
| therefore an important tool for this       |
| purpose.                                  |
| **•** Blockchain technology is useful for  |
| on-site payment, procurement and supply    |
| chain management.                         |
| [24], [58], [59]                          |
### 1.3 Brief recap of the identified technologies

#### 1.3.1 Building Information Modelling [BIM]

Building Information Modeling [BIM] is a 3D model-based technique that gives construction professionals the understanding and the basic tools for efficient planning, design, construction and control of projects. BIM has developed greatly with currently an expression of digital innovation in the construction industry. BIM has advanced to 5D BIM that can link individual 3D CAD components or assemblies with time schedule [4D BIM] constraints, and then with cost-related information. The advancement of BIM has linked different fields and covers all stages of project development including post construction and project maintenance. The recent innovations in BIM includes and not limited to construction data management, interoperability with other models, urban planning and infrastructure, overlaying of utilities information and post occupancy management. The construction and other allied industries and the government inclusive have realized the vast benefits of BIM and currently mandating the application in most of the operational undertakings. From the time United Kingdom government mandated BIM initiative in 2016, the modernization of the sector is greatly in process and transforming the future of the industry globally [2]. The potentials of BIM are applicable in the areas as highlighted in figure 1 below, though not exhausted.

![BIM Technology](source: LOD Planner, 2019)

#### 1.3.2 Augmented and Virtual Realities [AR and VR]

Augmented reality [AR] is one of the technology trends in construction in recent times. This technology has been in existence for years but applied in video games. The technology is recently making waves in construction, offering enormous opportunities for quality and efficient construction management. It involves using advanced camera and sensor technology, combining the physical surroundings with computer-generated information for real-time presentation. The combination of

| Construction software and data ecosystem | Construction data management and transfer | All construction cost information is processed, communicated and stored using construction software and data ecosystem. |
|-----------------------------------------|-------------------------------------------|--------------------------------------------------------------------------------------------------|
| • Applicable in all stage of construction process. |                                          |                                                                                                  |
digital and physical views using AR, enables construction teams to thrive the process more efficiently, accurately, and have overall confidence in their professional duties. AR is an enhanced version of reality created by the use of technology to overlay digital information of an artefact when viewed through a device such as tablet or smartphone camera [30]. AR can increase labour productivity, reduce costs and improve safety when used throughout the project lifecycle. For example, timelines are more likely to be met using AR wearables like DAQRI to show the workers what tasks need to be done and when they need to be completed.

AR have similar features and functionalities with virtual reality [VR], but slight difference. Figure 2 below gives the comparison between AR and VR. Virtual reality involves a detailed virtual model of a project. VR places the user directly inside the virtual environment, so that the user experiences a full immersion into the virtual space [50]. The VR is the computer-generated simulation of a three-dimensional image or environment that may be interacted within an apparently real or physical manner by a person with the use of a special digital system, which includes a helmet with a display screen inside or gloves outfitted with sensors [45]. As VR expands its reach beyond gaming and entertainment industries, one sector that’s increasingly feeling the heat is construction [52].

![Figure 2: Comparison between AR and VR](image_url)

**Figure 2** Comparison between AR and VR

**VIRTUAL REALITY**

- **VERSUS**
- **AUGMENTED REALITY**

- **EASILY ACCESSIBLE**
- Can be used in conjunction with smartphones and tablets. No additional equipment is needed

- **HEADSET IS NEEDED**
- Requires additional equipment such as a headset and controllers. Isolates the user within the virtual world

- **CREATE AN ENTIRE NEW REALITY**
- Fully immerses one into a new environment

- **BUILDS A THEORETICAL WORLD IN REAL LIFE**
- Provides a mixture of the real world and the virtual world, allowing one to interact with both

**Figure 3** Augmented Reality versus Virtual Reality

1.3.3 3D Modelling

3D Modelling involves the process of creating a mathematical representation of any object or surface in three-dimensional spaces using specialized software [54]. 3D modelling in construction, by putting all the pieces together, provides a real-view of the finished project [55]. The adoption of 3D modelling in construction has brought in numerous benefits. 3D or reality modelling, not only speeds up the design process but also enables architects and designers play around with different ideas and identify potential design problems before they become actual issues.
1.3.4 Mobile Technology
The basic tools that support teamwork and elimination of tailbacks in the three phases of construction; planning, designing, and building are practically being rooted in tablets, smartphones, and mobile intelligent hotspots [42]. Mobile technology has experienced strong growth in the construction industry and this continues to rise [46]. The “mobile era” is in full swing, and construction companies are slowly but surely making the switch [39]. The construction industry is undergoing a new and revitalized period with the aid of technology using new applications and tools [49]. Survey finding revealed that mobile technologies are commonly used by contractors and the devices that are used include smartphones, tablets, laptops, and GPS devices [45]. These mobile devices provide not only communication and computing functions but correspondingly provide image and video capturing proficiencies which could be put to use for record keeping and documentation purposes [40]. It is estimated that there may be nearly 13,000 construction-related development and design mobile apps currently in the market [40]. Figure 4 below shows that mobile technology has become an indispensable device in the running of construction business. This is a survey report of 158 construction industry professionals in September 2017, from small to midsize [SMB] businesses in North America about their present technology and software usage as well as future plans [26].

How Frequently Do Construction Businesses Rely on Mobile Apps to Run Operations?

Figure 4 How Frequent Construction Businesses Rely on Mobile Apps to Run Operations [Source: Software Connect Survey, 2017]

1.3.5 Internet of Things [IoT] and Sensors
The Internet of Things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers [UIDs] and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction [69]. IoT, also referred to as the “Internet of Everything”, according to [70], emphasizes the aspect of the Internet in which all objects [i.e. humans and machines] are uniquely addressable and communicate via a wire or wirelessly via a network. IoT technologies and standards becomes important in view of the rapid evolution and current impact that the IoT has in all sectors, including the construction sector [68]. Embedded sensors on a connected worksite create huge opportunities for collecting and managing data on safety, material performance, and operational workflow, just to name a few [46]. IoT is a technology trend that its relevance in the construction cannot be over emphasized. The technology is applicable in virtually all spheres of human endeavour. In line with the expansion of the IoT network, the construction industry should take into consideration as otherwise the construction industry will be left behind by other industries [71].
1.3.6 **Artificial Intelligence and Machine Learning**
Artificial intelligence [AI] is an aggregative term for describing when a machine mimics human cognitive functions, like problem-solving, pattern recognition, and learning while Machine learning is a field of artificial intelligence that uses statistical techniques to give computer systems the ability to "learn" from data, without being explicitly programmed [72]. The field of construction is well placed to benefit from the advent of machine learning and artificial intelligence [AI][73]. With the availability of data, AI-based applications have been finding more utility in construction.

1.3.7 **Drones and Robotics**
So many industries have been revitalized adopting the use of drones in their operations. Drone applications has no limitations in most of these industries, and the construction industry is one of those industries that the use of drones have greatly benefited in their operations. One popular use of drones in the construction process is gaining a real-time aerial view of a construction site at a significantly lower cost. Sending a drone to inspect a jobsite saves time and keeps the technician on the ground instead of climbing scaffolds and navigating the potential hazards of a working site [46]. The construction industry is adopting robots and autonomous equipment at a similar rate to drones [43].

1.3.8 **Predictive Analytics**
Prediction is one of the most fundamentals of data science. The ability to track real-time data and change it into meaningful insights for prediction has become a game-changing solution for the construction industry [74]. Predictive analytics is most popularly used for software development for construction simulation. Predictive analytics has taken under its control the analysis of vast amounts of data providing the capability to forecast. Predictive analytics, big data, drones and robotics are currently taking firm footing for better project management in the construction industry.

1.3.9 **Cyber security and Blockchain**
Blockchain technology is another of revolutionary technologies that is currently finding its full footage in the construction industry. Blockchain is a type of distributed ledger technology [DLT] which was first widely introduced almost ten years ago as the underlying technology of Bitcoin [75]. Many consultants and stakeholders in various fields have acknowledged the key potentials of blockchain technology in changing industries, business models and operating processes; such as payment settlement, accounting, administration, supply chain, customer relations, funding, etc. construction sector is not left behind in taking full advantage of this technology. Blockchain is being suggested as a way to reduce transaction costs by eliminating the need for intermediaries to build trust as a prerequisite for successfully executed agreements in construction [76].

1.3.10 **Construction software and data ecosystem**
Real-time collaboration software is currently being taken to be an indispensable element of the whole construction process. The emergence of a data ecosystem where all the innovative players of the industry will come together and share data, experience and project knowledge is closer than we might think [3]. It is never overstatement to say that this is the key way forward for construction.

1.4 **Relevance of the technologies in total cost management [TCM]**
The relevance of these technologies for total cost management of construction projects were identified in the course of this search and review [see table 3 below]. Each of the technologies is at least relevant in one or two stages of construction cost management. The applications cover all stages of construction projects spanning from project initiation [Pre-Constructions stages], to project execution [Construction Stages] to project termination and usage [Post-Construction stages].
| Technology | Application in TCM | Reference |
|------------|-------------------|-----------|
| Building Information Modelling [BIM] | Quantity take-off, cost estimation and budgeting | [78], [79], [80] |
| Augmented Reality/Virtual Reality | Project Scheduling, Information Collection, Logistics Management, And Project Progress Evaluation | [45], [30] |
| 3D Modelling | Supports Information and Communication Flows in The Production Process, Enables BIM to compile bills of quantity, to which cost estimates can be added | [44], [41] |
| Mobile Technology | Real-time communication between all stakeholders Construction data documentation Collecting performance data in the field Controlling project costs Scheduling and dispatching resources Managing equipment, including maintenance process, efficiency, costs, and uptime | [56], [62], [77] |
| Internet of Things [IoT] | Reporting real-time task status from the field Smart communication during construction Material and Equipment management Site workers management | [68], [71], [41] |
| Artificial Intelligence and Machine Learning | Construction Planning and real-time decision making Data extraction and data mining Monitoring of jobsite progress in real-time classification and measurement of quantities of work item executed | [42], [81], [32] |
| Drones and Robotics | Labor productivity and material handling Real-time site mapping, documentating, project Evaluation and progress for costing, Remote project management Improving jobsite communication and safety, along with performing highly technical tasks such as 3-D modeling and capturing on-site images from the field | [41], [3], [47], [46], [49] |
| Predictive Analytics | optimizing decision making predicting which conditions can develop in the future, given the current status Risk Management Forecasting | [49], [41], [4], [74] |
| Cybersecurity and blockchain | Data management Digital payments, self-execution of Contracts, verifiable digital Identification, workflow applications and records of procurement and inventories. | [41] |
Total cost management of construction projects covers all stages of construction, hence the great relevance of the highlighted technologies in cost management of projects. **Pre-Construction cost management** which involves project cost planning, project cost estimating and control will find such technologies like BIM, 3D Modelling, AI & ML, Construction Software and Ecosystem and Predictive Analytics are highly relevant. **Construction Stage cost management [Real-Time Cost Management]** which involves periodic budgeting, scheduling, monitoring, control, evaluation and reconciliation of actual expenditure with the budgeted will find such technologies such as BIM, AR & VR, Mobile Technology, IoT, AI & ML, Drones and Robotics, Predictive Analytics, Cybersecurity and Blockchain, and Construction Software and Ecosystem are very relevant.

Post Construction cost management which involves ensuring that the cost of running a constructed facility is within budget can find the applications of BIM, AR & VR, Drones and Robotics, and Predictive Analytics are very useful.

### Methodology

The different technologies which is currently driving all fields including construction has different unique applications in the industry. These applications cut across the different phases of construction process. This paper reviewed related literatures on these technologies, their basic applications and relevance in the construction industry, their core benefits for effective project controls, and more emphasis laid on the relevance of the technologies in total cost management [TCM] of construction projects. The articles reviewed were gathered from different sources which includes journal articles, conference proceedings, web page articles, books, and reports published between 2008 and 2019. The relevant articles were searched in different data bases including google scholar, google, Scopus, ResearchGate, Mendeley and web of science using the keywords and phrases such as current technologies in construction, relevance of ICT in construction, Applications of ICTs in construction, Internet of Things in Construction, Augmented and Virtual Reality Applications, Mobile Technologies in construction, benefits of ICTs in construction, etc. A total of 203 articles were gathered that researched on the identified technologies but for the purpose limiting the articles to those relevant to cost management, the articles gathered were screened and a total of 122 articles were removed. This method led to arriving at 81 articles that published on the identified technologies and their usefulness for cost management as well articles that published on current cost management practices in the construction industry. The data gathered were presented in tables and charts and analysed based on citation frequencies within the reference years [2008-2019].

### Results and Discussion

Figure five shows the frequency of reviewed articles within the reference years. Majority of the articles reviewed fall within 2016-2019. This indicates increase in realization of the potentials of these technologies for construction project management and control.
Figure 5 Total number of reviewed articles within the reference years

Figure 6 Citation frequency of the technologies with respect to construction cost management.

The chart in figure six shows that Mobile Technology BIM have the highest level of awareness, while IoT, AI&ML, Predictive Analytics, and Cybersecurity and blockchain is still young for full practical applications in construction. These technologies have long been well applied in manufacturing, engineering and other allied industries but the construction industry has been a slow adopter of innovations and new technologies until recent times. The great potentials of these technologies cannot be well harnessed until good attention is paid to construction innovations. The key is for the construction industry to embrace innovation in its broadest sense.
Figure 7 indicated that Mobile technology and BIM has received considerable attention from the start year of review. Summing the total number of citations from the start year shows that Mobile technology (25 citations) and BIM (24 citations) has the highest citation. The rise in the bars from 2016 indicates that these technologies are gaining full entry and reshaping the industry in the recent years when compared to previous years. The increase in the bars indicates increases in the usage of the technologies for cost management of construction projects.

4. Conclusion
It has been revealed that identified technologies is no doubt gaining footage in the construction industry and their potentials for construction cost management is being realized and utilized in the industry. The identified technologies have tendency of reshaping the approach to construction cost management going by the rise in their deployment for project execution. It is therefore, recommended that potentials of these technologies should be harnessed for better efficiency in both project performance and cost performance in order to add value to client’s investments.

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