INTERNET OF THINGS (IOT) IN CONSTRUCTION PROJECT MANAGEMENT: CURRENT TRENDS, OPPORTUNITIES AND CHALLENGES IN THE 5G ENVIRONMENT

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Abstract: I*nternet of Things (IoT) is the technology that connects billions of physical devices on a large scale to the internet for data collection, sharing and the improvement of information technology as long as computer sensors and wireless networks are available. By adding computer sensors to dumb devices is creating Artificial Intelligence that is making the devices to be effective, these efforts have culminated into real-time communication without human interactions. In the construction industry, the IoT is becoming applicable with the aid of dumb devices becoming response reliable with sensors and responding in real-time. IoT has made significant improvements in decision-making capabilities in several sectors, but little impact noticed in the construction industry subject to the unstructured nature of the process and the manner construction projects are based. The IoT platforms currently available consider not the flow of high data from distributed locations as needed in construction. As IoT advances, the application of IoT in construction projects is expected to upturn considerably especially when 5G internetworks are established. In any business organisation, also the construction industry is not left out, the objective is to render better services to their clients/customers thereby increasing profitability. This paper presented a review of the recent developments, challenges and opportunities of the IoT in Construction Project Management.*

1. INTRODUCTION

One of the effects of globalization is that business institutions have continuously expanded and this has resulted in having their projects upscale to megaprojects which are improved upon as a result of Digitalization and Information Technology (IT) [1]. This advancement has necessitated organizations to be involved in multiple projects at a time and this has led to the adoption of Project Management (PM) principles and practice in using Internet of Things (IoT) technologies in the project life cycle [2]. Project management can be referred to as the application of skills, information, techniques and tools to project activities to meet the requirements/goals of a project [3]. With the advancement of IT and IoT technologies new solutions are emerging, that provides succor to Project Managers in the practice of PM disciplines within the dynamism of the construction environments and the utilization of IoT technology to support their operations by creating some level of diffusion and improvements in the organisation [4].

IT implementation remains complex, costly, time-consuming and expensive despite considerable research at ameliorating these issues [5]. IoT technologies implementation on the other hand is a necessity to a growing organization at the same time becoming very challenging and intimidating for the adopting

organization [6]. However, IoT implementation comes with its challenges, since it is composed of a pool of smart technologies that are producing an enormous amount of Big Data which must be analyzed before it can make a meaningful contribution to decision-making processes. A clear understanding of IoT technologies aid organisations to develop proper strategies and implementation plans when adopting IoT technologies [7] The changes experienced as a result of IT evolutions will soon be insignificant in comparison with the expected evolution of IoT, the everyday networking technologies.

Project Management and IoT knowledge applications in the construction industry is of great interest and how it affects organisations in response to the influence of project-oriented organizations' performance [8]. This makes available stimulating opportunities for the construction industry to handle time and resource constraints with frequent defaults in data analysis that IoT technology represents. Present developments in the construction industry are to embrace smart technology that will enhance decision-making and productivity. Smart technology evolving to smart construction involves the augmentation of construction resources such as machinery, devices, components and people with digital technologies for transforming the construction industry. Many aspects of construction have witnessed transformation through automation, cyber-physical systems, cloud computing, cognitive computing and so on. The emergence of the IoT is gradually advancing the possibilities of smart construction in various areas of the construction industry. With the prospects that come with IoT, there is a need for proper understanding, thereby addressing the problems and obstacles in IoT implementation and its usage to aid a future where IoT will be a tool that supports effective and efficient PM in the construction industry.

This paper presents a review of areas of application in contemporary construction techniques for IoT (smart construction), which include the followings: offsite manufacturing; modelling of cyber-physical; handling, logistics; onsite assembly; control and real-time checking; safety and health; management of information and communication; energy management; waste minimisation; remote inspection which are key attributes of construction PM.

2.1 Internet of Things (IoT)

IoT is defined to be possibility connection of things applying the internet to create a platform that is used to achieve definite activities [9]. It employs internet connectivity and all the things around it to have the capability to connect and communicate with each other to perform any specific function through the network. The construction industry needs real-time information processes for effectiveness and efficiency in its projects operational deliverables, IoT has the potentials to make construction industries more effective by an increase in productivity on-site safety and operational efficiency Internet of Things (IoT) sensors/devices are in the business of collecting data in a more affordable, efficient and effective way for analysis in decision making for process improvements [8]. As IoT solutions for the construction industry become available and at the same time affect the construction business, making it to be more transparent for individual partners to comprehend and monitor each stage of the real-time development process. Figure 1 shows the representation of IoT.

Figure 1:Internet of Things [10]

Construction organizations that are adopting IoT technology can attest to the accrue benefits in efficiencies and responsiveness to the increasing demands of the industry [11]. An increase in productivity and competition are compelling reasons that should make construction companies consider the adoption of IoT technology [12]. Because data is now a critical asset for businesses towards making informed decisions. Smart construction will improve on the controls of the human resources, productivity and resources manageability. IoT tools and sensors in the construction industry can provide safety in

the working environment and the construction of the project operational cost can be reduced and control the maintenance cost of the project.

2.2 Construction Environment

Environmental concerns as it relates to the construction industry in terms of systems and products, preventative maintenance, ecological issues, social, cultural dimensions and projects management [13]. For instance, one could imagine the life cycle costs; and the impact of environmental burdens during the operation phase can be the major concerns assuming nature as the customer. Mounir Ajam the CEO of SUKAD Corp in UAE explains the effects of project environment on construction project management by assuming four different building construction projects that have the same configuration but are located differently at a varied location in a desert, mountain, crowded town or city, and on a beach area.

Based on the environment, a beach house must consider the salty water environment and should include features to resist saltwater corrosion, the mountain house should have a roof that could carry the weight of potential snow, crowded town or city should have good isolation for cold weather whereas the desert house should have good isolation for cooling [9]. However, if these four houses are built with the same standard, they would not last for a long time without significant maintenance and other issues. Failing to consider the environment in project execution would fail to meet the project objectives. Other factors for consideration in the project environment deal with culture and politics or the political situation in a given area, consider an area prone to war or civil unrest should be a major concern and should be considered [6]. This fact could be responsible to project delays and increase in cost and low quality as well, and challenges in project management.

2.2.1 IoT for Smart Buildings

Smart buildings apply small sensors and interconnected technologies to communicate information to building users and facility managers. Smart buildings currently interrelate in real-time using the information documented by the sensors to regulate the performance of the building such as fresh airflow can be adjusted based on occupancy levels. Smart buildings also give predictive competency. For instance, data on external weather conditions can be used to predict energy use during peak times, allowing the building's automated systems to regulate and improve their performance.

However, enhanced building performance seems not to be the only approach in which an IoT-enabled BMS. Smartphones can also be used to track the behaviour and preferences of building users so that the smart buildings apply small sensors and interconnected technologies to communicate information to building users and facility managers. Smart buildings currently interrelate in real-time using the information documented by the sensors to regulate the performance of the building such as fresh airflow can be adjusted based on occupancy levels of the building can build more sophisticated services and enhance user experience. End-user behavioural data from other IoT-enabled buildings can also be used at the design and development stage of a building's construction so that it can be adapted for consumption and usage patterns.

2.3 Internet of Things (IoT) and Project Management

The Internet of Things (IoT) refers to the ever-growing network of physical objects that feature an IP address for internet connectivity and the communication that occurs between these objects and other Internet-enabled devices and systems. Information Technology (IT) has contributed to the incessant changing drivers of today's markets [14]. Fundamentally with the expansion to global markets and an organization tackling more than a project at a time necessitated the realization of Project Management (PM) disciplines and the Internet of Things (IoT) technologies [15]. Project Management (PM) is the leading discipline in management that benefits enterprises through actual and operative management of change through its systematic approach of initiating, planning, executing, monitoring & controlling, Testing & Commissioning and finally Handing Over to the client project; managing various types of projects with various drivers of change and uncertainty [4]. The generic working structure of IoT system is shown in Figure 2.

Figure 2 shows a dependency of IoT on particular application parameters. IoT gateways have an important role in IoT communication as it allows connectivity between IoT servers and IoT devices related to several applications.

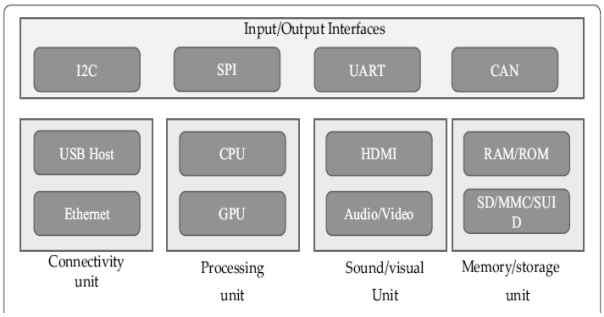

Figure 2: A Generic Function Module of IoT [16]

The method in which IoT project is changing project management is not just because anything and everything can be and will be internet-enabled [17], but also because the project management software that will be used is more interconnected and developing these IoT devices will require us, project managers, to get a better handle on research and development, which can be extremely nebulous in the internet of things. PM comprehends the project throughout its lifecycle. From project commencement to project handover, ensuring a smooth transition within the phases of the project lifecycle while being strategically aligned with the organization's objectives and goals. Even though each organization represents a unique environment and culture, the PM disciplines, and guidelines they practice are also uniquely customized; in any form, PM disciplines represent a central tool in delivering innovations to the organization.

The use of IoT technology to improve real-time decision making at an operational level is by developing a framework, in consideration of decisions, a practical approach of using sensors that are embedded in construction tools and improve the performance of operational efficiency of earthmoving equipment in construction [18]. This framework employs the IoT infrastructure to evaluate the state of health of the equipment that usually conducts the process of construction and to interconnect the same to the subtle level of the operation [19]. This is helpful in the decision-making process thereby augmenting the planning, monitoring and control as required in construction project management principles and practice [20]. When on-site, IoT can help answer questions such as the cost of unprepared downtime or interruption when a machine breaks down, why a particular machine operator uses a higher volume of fuel than average and when replacements should be made for specific parts or components at present usage levels. IoT has also contributed immensely to the rise of smart or digital buildings. Using these interconnected technologies helps to monitor a building's performance, flag up its inefficiencies and make automatic adjustments.

By checking the performance data of machinery and vehicles, the ability to maintain and repair them is improved upon. Preventative maintenance is cost-saving as it is far more expensive to fix components after they break down. Unplanned failure of equipment can also lead to downtime, extending the project timeframe. Sensors tracking indicators such as excessive vibration and temperature aid the identification of the best and actual period to service equipment through sending of cautions or warnings to connected devices so that operators can handle the underlying issue before further damage is caused. IoT can therefore prolong the life of the equipment and improve its resale value.

The 5G networks on full implementation can make an effective operation of the IoT technology in construction project management. Using current IoT applications, comparative studies show the efficient application of IoT in the construction industry becomes an intricate process that requires the constant enhancement of IoT applications for improved performance [21].

2.3.1 Current Trends

The IoT-based technology that is becoming extensively available in the construction industry is Wireless Concrete Maturity Sensors (WCMS) and it eliminates field-cured cylinders by eliminating the dependence on third-party labs for real-time information about the strength and temperature of concretes [22]. There are three major phases in construction, namely: construction, design and management (CDM) [22] and the current tool for the design phase is 5D Building Information Modeling (BIM), an intelligent 3D based with time and cost projections while the construction phase uses the offsite prefabricated and preassembled components. Similarly, the facility managers can control innovative technology for automatic detection of a fault, checking of assets and

maintenance prediction. The need for an increase in capturing of data and processing put IoT in the best position to drive smart construction [23]. In smart city construction, IoT devices or sensors are used for energy management, smart transportation, smart waste management system, smart lighting and so on [24] [17].

(i) Building Information Modelling (BIM)

The use of BIM and IoT together creates a proper understanding of the delayed or inefficient problems in the building of construction progress concerning cost and quality in construction projects of traditional steel bridges [25]; the collaborative information sharing among different levels of the project team member which is in constant change during the lifecycle of steel bridges, and it exposes the shortfall in information and communication technologies sharing [26]. BIM and IoT were used together in the steel bridge lifecycle activities to address these shortfalls which were termed smart steel bridge construction; this was later subdivided into three smart components, namely, smart steel bridge, smart construction site, and smart construction process [27]. These combinations provided an opportunity for an efficient and effective digitalization of the construction in the lifecycle of the steel bridge.

(ii) Primavera

Primavera is a project, program and portfolio management tool that is used for planning, managing and executing project work [28]. Functions of primavera include project management, scheduling, risk analysis, opportunity management, resource management, collaboration and control capabilities, information scheduling, resource allocation in construction projects, projects planning, monitoring, controlling and reporting. and incorporates with other enterprise software such as Oracle and SAP's ERP systems. It is built to handle large and small projects in diverse industries like construction, manufacturing, energy, and IT. It has been doing so for more than 30 years in projects across the globe. Primavera is an enterprise project portfolio management software.

(iii) Global Positioning System (GPS)

Global Positioning system comprised of satellites, ground control stations and client collectors and can give 3D arranges including focuses, lines and planes in a quick, precise and productive route under every single climate situation [29]. GPS satellites carry atomic clocks that provide extremely accurate time. The time information is placed in the codes broadcast by the satellite so that a receiver can continuously determine the time the signal was broadcast [30]. It has been broadly used in various fields such as geodesy, photogrammetric, marine looking over and mapping [31]. GPS enabled IoT devices to include:

(a) Location and tracking devices can be embedded or attached to everyday consumer objects such as a dog collar or school bag. This technology can also be used to track valuable assets such as cargo being shipped internationally.

(b) Accurate time stamping of transactions or movements

(c) Wearables used by employees, personnel, convicts or patients to monitor their activity.

(d) Navigational aids

(iv) Radio Frequency Identification (RFI)

It can read and write corresponding data without mechanical or optical contact with the identification system [32]. In the construction industry, IoT related devices are generally referred to as telematics, though a lot of companies are using machine-to-machine (M2M) communication technology the fact remains that lots of these organizations still consider it as their competitive advantages over the competitors, thereby hiding the information for strategic reasons. Most manufacturers of major equipment in the construction industry have embraced these concepts, in applications that manage machine hours, fuel consumption, GPS tracking and idle time which help equipment owners with preventive maintenance, securing equipment from theft and wrong use of the equipment. Other applications that measure and track information like engine load, fluid temperatures and pressures, and other operational parameters are more sophisticated and they depend more on the software that provides varying degrees of analysis of the data generated for decision making and this leads to less downtime because of accurate prediction of maintenance as at when due. Advancement in the field of IoT has improved the cyber-physical systems (CPS) applications that use computer-based rhythms to monitor and control physical things and the environment [33]. With rapid development in

IoT technology and the current transformation in construction technology, it is important to understand the current trends, future opportunities and common challenges to the implementation of IoT for smart construction.

2.3.2 IoT Opportunities

The Internet of Things (IoT) is emerging as the third wave in the development of the Internet [34]. The 1990s' Internet wave connected 1 billion users while the 2000s' mobile wave connected another 2 billion. The IoT has the potential to connect 10X as many (28 billion) "things" to the Internet by 2020, ranging from bracelets to cars. Innovations in the cost of sensors, processing power and bandwidth to connect devices are enabling ubiquitous connections right now. The rapid development and implementation of smart and IoT (Internet of Things) based technologies have allowed for various possibilities in technological advancements for different aspects of life [35]. The market size of the Internet of Things (IoT) in construction is estimated at USD 7.8 billion in 2019 and is projected to reach USD 16.8 billion by 2024, rising at a CAGR of 16.5% between 2019 and 2024. IoT in construction is widely used in remote operations, fleet management, safety management, and predictive maintenance applications. There is significant demand for IoT in construction in the emerging economies, which is one of the major opportunities for the market. However, the high initial cost of implementing IoT is one of the restraining factors in the market.

2.3.3 IoT Challenges

There are a few complications in projects management in the construction industry, some of these problems are complexity, uncertainty, fragmented supply chain, short-term thinking, and culture as a result of several stakeholders [18]. The fragmented supply chain and short-term thinking of construction companies have limited the capabilities where the short-term nature of construction projects is an obstruction to innovation. Where the culture of the construction industry is known for its reluctant practices in adaptation anticipated problems in the application of IoT in construction PM such as maintainability, scalability, safety, confidentiality and suitability [9]. A predominant problem that is common to the construction industry is the regularly fluctuating environment and disintegration among industry investors, which increases problems such as data ownership, and reluctance to long-term IT investments in project-based organisations. Considering these problems, this paper highlighted the preparedness of researchers and business owners to finance the implementation of IoT facility management rather than in the scheme and phases of smart construction. Lack of robust internet connectivity is one of the challenges, IoT needs a faster, reliable, robust internet connectivity and full implementation of 5G technology is expected to meet the needs in construction companies and other domains.

3. SUMMARY AND DISCUSSION

Despite the interesting features of IoTs (smart buildings) such as improved sustainability, security and performance, there are some challenges traceable to the technology. The most important problem is life-cycle costs. From planning to completion most construction projects for new buildings take around three to five years. However, in a rapidly changing technological environment, new technologies can have a significantly shorter life-cycle with their capacity doubling every 18 months. Therefore, systems specified in the planning process can be two or more generations old by the time occupants move in. The worksites of construction companies have been slow to accept IoT due to the disjointed nature of the industry with contractors and smaller subcontractors dividing the work.

There are also an extensive variety of sites making it more difficult to control the implementation of IoT. Smaller sites with fewer workers will have less of a need for complex sensors and software as operations can be efficiently managed by the foreman. The advantages and added value that IoT can bring to larger-scale projects are much more obvious. Any project considering the use of IoT will have to consider the expected completion time. Shorter construction projects need more immediate productivity gains than longer projects, which can justify smaller productivity gains. Smaller productivity gains over a longer project period aggregate into more substantial time/cost savings. On a more practical level, if an IoT device loses connectivity it cannot send data in real-time, losing the ability to track and provide insights into preventative maintenance.

Also, sensors can help benchmark preferred levels, they cannot always replace the benefits of physical observation. In completed buildings, poorly implemented technologies can disempower occupants, taking away control of

their environment and frustrating their user experience. With the volume and detail of data coming from IoT technology, there is a risk that the data may be managed and processed incorrectly leading to inefficiencies. As a result of digital transformation, IoT technology is shaping the construction industry on how it handles construction projects and workers. The projects manager can monitor the job site in real-time continuously by ensuring safety in the workplace, to be on track and budget. The construction industry has been reacting to a shortage of skilled labour, sustainability and as IoT advances such that intelligent devices can take up some roles, the aforementioned issues will soon become a thing of the past. A lot of developments such as robot workers and 3D printed houses are fast becoming a reality at a fast pace such that tracking these difficult is hard to keep track of it all. The following are the proposed future directions based on current issues as it relates to BIM and IoT devices integration: Service-Oriented-Architecture (SOA) and web services for BIM Building, which is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition and IoT integration.

(i) Real-time model update based on IoT device Readings
(ii) Information acquisition and control - a two-way-interaction
(iii) Ubiquitous monitoring and crowdsourcing monitoring
(iv) Integration with other cutting-edge technologies

4. CONCLUSION

The IoT technologies have great potential with continuous advancement such as verification, identification, sensing and, hardware, software and cloud platforms, communication and networks, software and algorithms, positioning, processing solutions of data, power and energy storage, security mechanisms. These technologies leverage intelligent devices, smart mobile devices, single board computers, and different types of sensors and actuators. These trends are creating awareness of the inherent advantages of IoT at a faster rate. Studies have shown that IoT has huge potential to solve decision-making, monitoring systems and improve health and safety problems in the construction industry, by minimizing construction incidents, as more organization adopts IoT technology. With the application of IoT, some occupational accidents caused by construction machines may be reduced or prevented. The IoT technology can be feasible in the improvement of construction project management performance especially in time management and cost savings.

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