The Internet of Things Integration in Building Information Management Towards Construction 4.0

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Abstract
In this article, the potential of the IoT and digitalisation in the building industry is highlighted, and specific IoTs applications in the industry are discussed. In addition, the challenges that developing countries experience in relation to the IOT are also discussed. The construction industry is protecting other fields in terms of the rapid adoption of newly developed technologies, and the application of these technologies in buildings is still in its infancy. In this paper, we design of an intelligent manufacturing model that is built on the IoT technology and is intended for use in urban public facilities is presented. This model can accomplish the goal of real-time management and control of personnel, equipment, machines, and infrastructure across the complete network.

Keywords: Construction Management, Building Information Management, Internet of Things, Industry 4.0.

1. Introduction

When compared to other industries, the construction industry is lagging other fields in terms of the rapid adoption of newly developed technologies [1]. A significant number of companies that are active in these spheres are persistently looking for innovative technological strategies in the hope of preserving their standing as market champions and increasing the amount of money they bring in because of their operations. On the other hand, one of the elements that contributes to the construction industry unstable productivity is a lack of investment in the advancement of technological advancement [2].

Even though having up-to-date computers, software, servers, and a dependable network are important components of digitalization in the construction industry, these are merely the beginning of what digitalization will bring about. When newly developed digital technologies are incorporated into conventional building practices, a business has the potential to become one of the most productive companies in its industry [3]. But even assuming that construction businesses are prepared to make the shift to digital, the real question is whether the individuals who work for those businesses are.

It is concerning that construction employees are typically reluctant to embrace innovation that comes with a steep learning curve affiliated with it. These professionals feel more at ease adopting a hands-on approach to their work and have little patience for laborious computer programs [4]. However, businesses still have the potential to ensure that their workers comply with these adjustments by imposing disciplinary measures on employees and providing them with additional training [5].

The slow rate of technological development and digitalization in the sector has been blamed for the widespread condemnation of the sector poor productivity. The incorporation of the IoT is an essential step that must be taken for the construction business to realize its full potential [6]. Construction 4.0, like Industry 4.0, is predicated on the idea of pervasive mechanization and seamless connectedness, both of which are made possible by the IoT [7].

Within the realm of industrial automation, there are four primary areas of emphasis that make up the industry as a whole: the planning and design of industrial automation projects, production, logistics, and customer assistance. Because of the capabilities offered by the IoTs in this respect, each of these four spheres is capable of being automated. It simplifies the process of automating machines, processes real-time data in a matter of milliseconds, and handles the most efficient use of resources at the lowest possible cost and risk [8].

IoT is still used in the construction sector, even though the construction industry is hesitant to welcome the concept of embracing IoT due to the complexity of construction projects and the high risks of failure associated with construction projects. The IoT has started to be implemented at a construction company that is concerned about the health and safety of its employees [9]. Every worker is provided with a clip-on IoTs device that, when dropped from a height of three feet or higher, will sound an alert and notify the site safety manager of the incident. After any accident on the construction site that includes a fall, the safety officer at the site needs to be notified as soon as it is practical to do so [10].

When a company observes the location of cars, as well as what they are doing and where they are, as well as the status of various other vehicles and assets, this is another example of a use case for the IoTs. The curing of concrete is one of the IoT applications that can be used in the construction industry during the fourth industrial revolution 4.0 [11]. Concrete that contains incorporated sensors allows for the observation of composites in real time. Businesses track their progress and formulate appropriate plans, which eliminates the possibility of unpredictability or delay in their operations. In the construction business, there have been some implementations of internet of things technology, but there is still a great deal more to learn.

2. Background

The model in [12, 13] talks about recent research that was published that connects the IoTs to the construction industry. Through this line of inquiry, a connection between the two disciplines is forged. In the first article, the potential of the IoT and digitalisation in the construction business is highlighted, specific IoTs applications in the industry are discussed.

In another research [14], the models and procedures that are utilized in Taiwan construction business were investigated. The acceptance of the IoTs by various stakeholders was the primary emphasis of this study. There is a lack of clarity in the discussion of how the IoTs is transforming the building industry and its sub-sectors, and there is a lack of depth in the articles that were discussed regarding the challenges that developing countries experience in relation to the IoT.

There was neither an implementation perspective nor a concentration on applications, such as site monitoring, in the article [15], which addressed the utilization of IoT in the building and construction industry. Building information modeling are just some of the fundamental ideas that are discussed in [16] review of Construction 4.0. Construction 4.0 may be summed up using the seven words that are enumerated below, according to the authors of this article. The authors also suggested redefining the terms to place a greater emphasis on the interconnectedness of the concepts they were discussing. In addition, two obstacles that need to be conquered to successfully implement IoT for smart houses. The evaluation did not explore deeply into the specifics of how initiatives related to Construction 4.0 are making use of the IoT.

The investigation that was carried out in [17] discovered a total of 26 recurrent problems that are associated with the implementation of IoT. The authors also used a questionnaire to conduct research with people currently employed in the construction business. This research was done with those individuals. The authors have compiled a list of the top five difficulties that are affiliated with putting IoT into practice in the building and construction industry. The research can only be used in the context of the construction industry in Malaysia because the article that was referenced did not go into detail about the different aspects of Construction 4.0.

Another comprehensive article on Building Information Modelling (BIM), the IoT, and Digital twins in the construction industry [18] addressed significant publications, funding agencies, conferences, significant authors, countries, and groups that generate research related to BIM. In addition, new research frontiers that have the potential to be successful have been identified. The research article that was referenced did not, however, go into detail regarding the operation of IoT or the practical applications of IoT in connection to Construction 4.0 in a few different countries.

The authors in [19] also presented an analysis of Construction 4.0. This review, on the other hand, is predominantly focused on building information modeling and offers only a few examples of how the IoTs can be integrated with BIM. A comprehensive overview of Construction 4.0, the present state of IoT applications in both developed and developing economies, and the unique challenges that each type of economy faces [20]. This is since no research has been successful in providing such a comprehensive picture. There is an immediate need to prepare a comprehensive report on the current state of the IoT in the building and construction industry. This report should examine the industry from the perspective of both the applications of IoT and the implementation of it.

3. Proposed Method

The IoTs is a network of interconnected sensors and other types of technological gadgets that share information with one another. Numerous applications of the IoT may make use of a heterogeneous assortment of instruments and apparatus. When it comes to interoperability, communication, and the equitable distribution of services among IoT devices and networks, there are some issues that can emerge. In addition, expanding already-existing networks to make room for an ever-increasing number of connected devices can be a difficult and time-consuming undertaking.

Even if all the devices in the communication infrastructure are able to communicate with one another without any problems, the next problem is going to be the amount of available bandwidth and the amount of network congestion. Since the IoTs is dependent on real-time communication, even the smallest disruptions in that area can have a significant negative impact on its delay-sensitive and mission-critical infrastructure. This can be the case even if the disruption is only temporary.

To collect information that is current and accurate from IoT devices, it is essential to have a communication infrastructure that is dependable, risk-free, and lightning-fast. The quality of the transmitted signal needs to be improved, as is the case with all different kinds of remote operations; consequently, this is one of the most essential considerations regarding construction.

It is now possible, thanks to the incorporation of IoT technology into building energy management systems (BEMS), to improve not only the operational capabilities of the building but also its structural soundness. Building information modeling (BIM) is a process that can be used to represent an intelligent structure. Figure 1 demonstrates how the IoTs can be employed in this process.

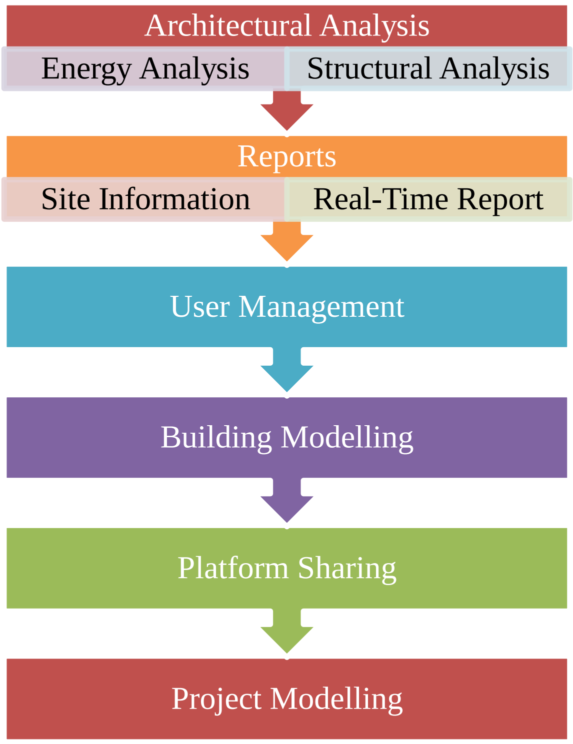

Figure 1: Proposed BIM using on IoTs

The IoTs makes feasible a simulation of the intelligent building intelligence already present in buildings. The device layer of the system is where all the system instruments and controllers are stored, and it enables communication to take place through both wired and wireless channels. This layer also houses all the system network interfaces. The wireless choices include communication protocols for a variety of field buses, whereas the wired options include a wide selection of radio frequencies and even a local area network.

The services and applications that are made feasible as a direct result of the utilization of technology that is associated with the IoTs are referred to as being on the application layer. The management and application of database systems as well as the remote monitoring and management of construction machinery are both examples of this. Another example is the remote monitoring and management of construction equipment. Alongside the expansion of the IoTs comes an accompanying rise in the number of possibilities for the development of smart structures.

Intelligent building systems have progressed from integrated wiring to multi-disciplinary integration, with most components now being networked. This evolution began with the integration of wiring. The different building components are now more connected to this development. A networked architecture was also utilized in the building surveillance and security systems to ensure the building safety.

It will have a substantial impact on how people use the building, on their lives, and even on the physical safety of the people who are inside the building if there is a problem with the safety features of the building. The equipment automation system, the security system, and the fire alert system are managed by the equipment-oriented integrated management system, which is responsible for managing a building most essential system.

When it comes to the provision of precise data, the sensing layer places a significant amount of importance on identifying components like controllers and actuators. The sensing layer is the one that oversees the implementation of functions like the automated accumulation of data and the carrying out of orders. It is entirely self-sufficient and does not require any intervention from a human being; in addition, it is designed to protect the building entryway in addition to the passageways by utilizing an alert and monitoring system.

Emission of intelligent control instructions takes place at the application layer, the highest level in the stack. It is also the level that concretely incorporates the various user requirements and is the primary driver behind the development of intelligent building systems. This level is the first level. The IoT is going to become an increasingly important component in the future of sophisticated building administration, property management, and building maintenance. The BIM functions as the beating heart and driving force behind the Internet of Things because it incorporates the fundamental data model for those applications.

3.1. IoT Technology in Construction infrastructure

The IoT is composed of several levels, the detecting layer, the network layer, and the application layer being the three that are of the utmost significance. When a building infrastructure is outfitted with technology that is connected to the IoT, it is much simpler to maintain the confidentiality of sensitive data. It possible that the user will be warned by the security component in plenty of time to prevent them from forgetting about it when the system begins to malfunction.

One of the main reasons why this is one of the most significant stages is because of this. The network layer is responsible for the completion of most of the duties involving the transmission of data and administration of the system. This layer also receives most of these responsibilities.

A connection to a network, either wired or cellular, is required for you to carry out the activities. By far the most common kind of composition that can be found is one in which a private network and the public Internet are combined. It is possible to implement the execution function in the very same sensing layer that is built on the IoT. The recognizing layer can respond when it receives a signal from a higher layer that contains an instruction and passes it down to a lower layer.

Automatic identification and administrative duties like environmental monitoring and urban planning are among the primary responsibilities of the application layer. Both local area networks (LANs) and wide area networks (WANs) serve a purpose within the framework of networked communications, and both have their own set of benefits and drawbacks.

Certain manufacturers currently have the capacity to connect their detecting products that are situated in the sensing layer immediately to the network layer. These products can be connected via a direct connection.

In this article, the design of an intelligent system that is built on the IoT and is intended for use in urban public facilities is presented. The design considers the most fundamental aspects, as well as the framework, of IoTs. Following is a mathematical expression that can be used to describe the construction of an intelligent structure model:

$$w^T S_b w = \frac{(m_1 - m_2)\phi + F}{S_b^\phi S_w^\phi} + b_{wfe}$$

$$w^T S_w w = \frac{(m_1 - m_2)\phi + F}{S_b^\phi S_w^\phi} + \alpha_{sedd}$$

where

m_1 and m_2 - IoTs factors;

ϕ - intelligent factor

F - feature space;

Sϕb - inter-diversity divergence matrix and

Sϕω - intra-class divergence matrix in F respectively;

b'ωfe' - data sample collection and

α_{sedd} - feature attribute points.

To improve the intelligent model of the building infrastructure, the IoT makes use of a constraint equation that is expressed as:

$$S(T_r) = \begin{cases} s_1 & 0 < T_r \le d_1 \\ s_1 & d_1 < T_r \le d_2 \\ s_k & d_{k-1} < T_r \le 1 \end{cases}$$

Through the wireless passive ubiquitous sensor network and communication network, the intelligent building personnel distribution data, machinery operation data, and building environment data can all be retrieved. The realization of intelligent security prevention, rapid emergency evacuation guidance, low-energy operation of construction machinery systems, and an optimally efficient construction site are all made possible because of the data provided by this, which serves as the foundation for intelligent and efficient decision-making regarding operation.

The widespread adoption of wireless passive transmission has been facilitated by developments in technology pertaining to energy harvesting as well as electronic circuits that consume an extremely insignificant quantity of power.

It is not hard to recognize the data communication characteristics of the Internet, such as its relatively high data transmission and relatively few nodes. The characteristics of the Internet are diametrically opposed to those of the data communication features of intelligent construction machinery.

$$P_f = \frac{R_n E}{n(k)} \frac{S_{sdyy}\left[p_{f_1}, p_{f_2}, ..., p_{f_i}\right]}{R_{see}}$$

where,

R_nE - average length constraint;

$n(k)$ - architectural problem interference in IoTs;

S_{sdyy} - information feature.

The building intelligent control model is referred as

$$Q_{kloo} = \left[mK_j\right] + f(x)\frac{K(x_i, x_j)}{\xi \oplus (wx + b)} + y_i$$

where

$f(x)$ - device tag of the IoTs;

ξ - introduction of slack variables;

$K(x_i, x_j)$ - Gaussian radial basis function;

y_i - resource utilization minimization principle;

w - constrained minimum;

x - optimization factor.

To make further adjustments, the formulas are given as following

$$w = \frac{1}{0.5m(m-1)}\left[\sum_{k=1}^{m} q_{ik} - 0.5\right]$$

$$T_{a_2} = \begin{cases} 0 & n = 1 \\ \dfrac{\sum_{k=1}^{n}\left(T_k T(c_k, u_i)\right)}{\sum_{k=1}^{m}(T_k)} & n > 0 \end{cases}$$

It has a low transmission frequency and a relatively low data flow, so it requires very little energy to function, and it can do so completely through the collection of ambient micro-energy. Both factors contribute to the fact that it has a low energy requirement. Because of the low frequency at which it transmits, this is actually feasible. The utilization of cloud computing and dispersed computing technology enables the optimal utilization of all available computing resources across an entire network of IoT nodes, which ultimately results in big data processing speeds that can keep up with the demands that are placed on the healthcare industry.

When a computing task is broken down into numerous subtasks that are worked on simultaneously, it is possible to make the most efficient use of the processing power available at each node. As a direct consequence of this, the total quantity of time necessary to complete the mission will be cut down by a sizeable margin.

When compared to centralized computing, parallel computing offers a significantly higher degree of accuracy in terms of the computation results. By utilizing distributed computing, it is possible to finish a broad variety of computation tasks in a short amount of time. These tasks include, but are not limited to, calculations involving summation and extremism, as well as equation solutions.

4. Results and Discussions

The administration and control of the operations and maintenance of ultra-high-rise buildings are centralized on these servers, which serve in that capacity as a platform. System integration technology makes it possible to exercise consolidated control and administration over all the building systems that are contained within extremely tall structures. This is made possible by the fact that system integration technology exists. This indicates that the appropriate technical staff for the various construction projects first needs to carry out an analysis of the constraining function and the parameter system of the construction project cost before they can even begin to construct acceptable parameters for the various construction projects.

They can even begin to construct acceptable parameters for the various construction projects, the appropriate technical staff for the various construction projects must carry out this analysis. We should be able to provide you with some educated estimates regarding the cost of carrying out this endeavor now that we have all this information. The IoT is currently being utilized in the process of developing a parameter model of engineering expenditures to forecast the prices of construction materials reasonably and accurately. This is being done to create a more accurate budget for future engineering projects.

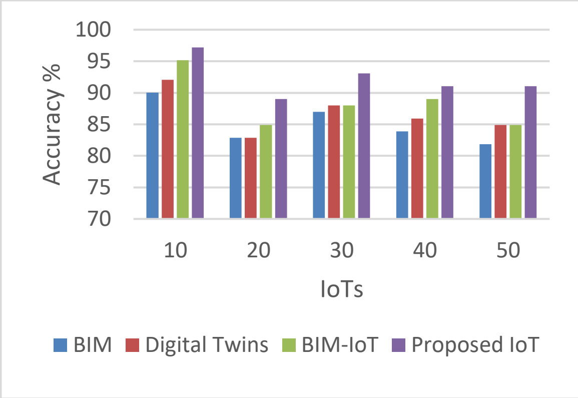

Figure 2: Data Collection Accuracy

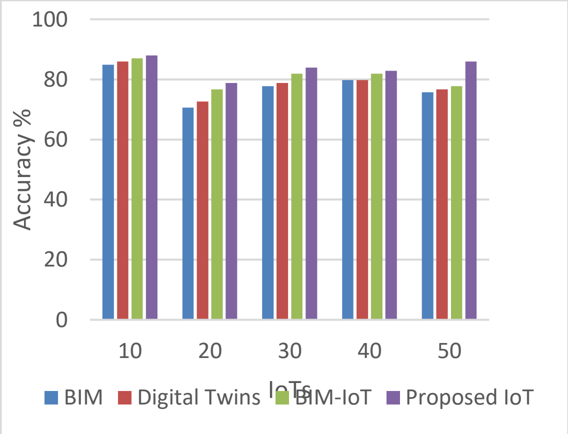

Figure 3: Data Communication Ability in terms of accuracy in %

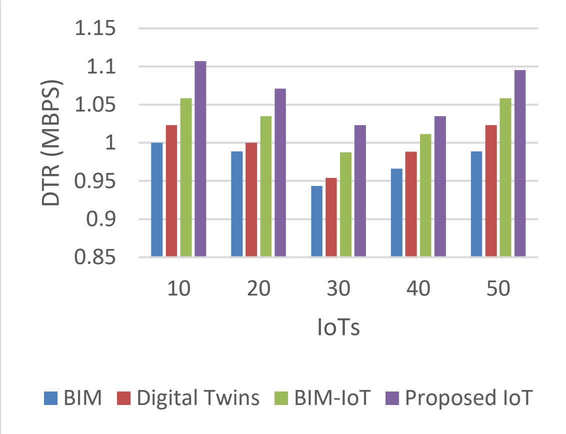

Figure 4: Data Transfer Rate

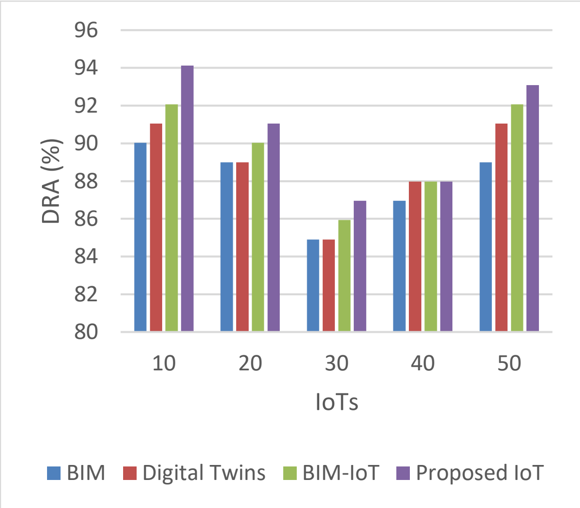

Figure 5: Data Reception Ability

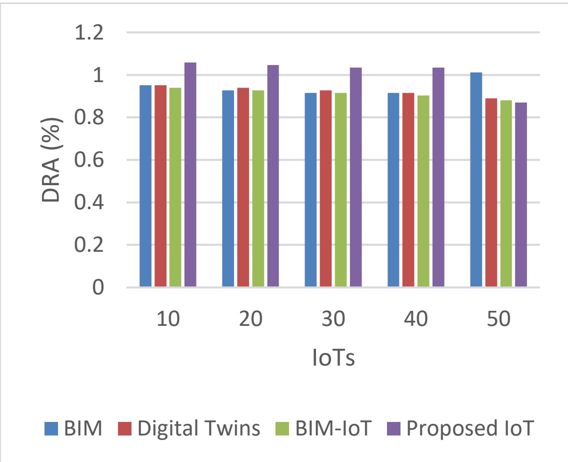

Figure 6: Delay (s)

The concept of Industry 4.0, which enables ubiquitous connectivity technologies to make decisions in real time, is the inspiration for the notion behind Construction 4.0. The Construction 4.0 is to systematize as much of the process as is humanly possible, commencing with the very first step and continuing all the way through to the very last one. The complete process of building, beginning with planning, continuing through design and administration, and ending with construction, is capable of being automated with the assistance of today technology.

The construction industry continues to rely on manual laborers, vehicles, and a method of conducting business that has not significantly changed over the course of the past half century, despite the advancements that have been made in technology. Even though IoT technologies hold a great deal of potential for facilitating continuous real-time interaction and automation in industries, the application of these technologies in buildings is still in its infancy.

Because of the capabilities offered by the IoT in this respect, each of these four spheres is capable of being automated. It simplifies the process of automating machines, processes real-time data in a matter of milliseconds, and regulates resource utilization in the most efficient and effective fashion possible, all while simultaneously lowering costs and risks. IoT is still used in the construction sector, the construction industry is hesitant to welcome the concept of embracing IoT due to the complexity of construction projects and the high risks of failure associated with construction projects.

5. Conclusions

According to the results of the model verification, the intelligent manufacturing model, this is shown by the fact that the intelligent manufacturing model was able to achieve the integration of human society and the physical system. This is a demonstration of how this is possible. The intelligent manufacturing model of the building industry using IoT technology can serve as a benchmark for future research in this field. These findings were presented in the context of the building industry. Through a wireless, passive, and pervasive sensor network and communication network, an intelligent building equipment operation data, personnel distribution data, and building environment data can all be acquired.

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