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The Adoption of IOT in the Malaysian Construction Industry: Towards Construction 4.0

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Abstract: The construction industry is one of the most significant sectors in Malaysia, specifically in terms of its contribution to the Malaysian Gross Domestic Product (GDP) and facilitation of other industries to enhance their productivity outcome by constructing buildings and facilities for them. However, the process of constructing buildings and facilities will take a long period of time if done according to conventional practices. Due to this circumstance, the establishment of the Internet of Things (IoT) in construction development is beneficial to improve productivity levels and reduce the construction time as well as the cost. Hence, this paper intends to review the adoption of IoT in Malaysia's construction industry towards Construction 4.0. In conjunction with that, the use of IoT in terms of construction technology such as BIM, smart communication, sensor, big data, augmented reality, location services and remote operation during the construction process has made a massive impact on the monitoring of the construction process, especially in reducing the risk of construction error, defects, and avoiding construction delay. The proper adoption of IoT in the Malaysian construction industry will give a huge positive impact to the construction industry and encourage it to grow and compete with other developing countries. This paper is noteworthy to the Malaysian construction industry, especially for the key players in the construction industry to raise their awareness regarding the benefits of adopting IoT for their future projects.

Keywords: Internet of Things (IoT), Construction 4.0, Malaysian Construction Industry, digitalization, construction technology innovation

1. Introduction

Parallel to the fourth industrial revolution and technology innovation, the process of construction development has become more complex and complicated due to the improvement of innovation in building design, structure and method of construction development worldwide (Pinto & Slevin, 1987; Dossick & Neff, 2011; Hussin, Rahman, & Memon, 2013; Jabar, Ismail, Abdul Aziz, & Aziz, 2014; Tahir et al., 2018). As the fourth industrial revolution (IR 4.0) is on the horizon of the construction industry, the growth of construction technology innovation has risen exponentially. According to the nine (9) pillars of the fourth industrial revolution, the internet of things (IoT) is highlighted as one of the core elements to facilitate the industry in improving their productivity outcome (Alaloul, Liew, W.A. Zawawi, & Mohammed, 2018; Ibrahim, Esa, & Mustafa Kamal, 2019). Additionally, to successfully develop a construction project, precise information regarding the project details such as project design, structure, materials and other specifications are essential to ensure the outcome of the project is aligned with those particular items (Crotty, 2012;

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Tahir et al., 2018). Due to that, the integration of IoT and the other pillars in the fourth industrial revolution such as advanced robotics, additive manufacturing, augmented reality, simulation, system integration, cloud computing, cyber-security and big data analytics is important to optimise computerisation and digitalisation usage (Nagy, Oláh, Erdei, Máté, & Popp, 2018) by the construction players for the purpose of monitoring and controlling the whole project lifecycle (Alaloul et al., 2018; Craveiro, Duarte, Bartolo, & Bartolo, 2019) .

With high encouragement from the government and other construction agencies worldwide, IoT has become the central topic among the construction industry players, including Malaysia, especially regarding the readiness towards Construction 4.0 by using digitalization and IoT in construction industry (Z. Z. Ismail, 2018; Mahmud, Assan, & Islam, 2018; Sivakumar, Jusman, & Mohd Mastan, 2017). In IoT application, the internet connection acts directly or indirectly as a primary communication medium between humans and construction technology (Vermesan & Friess, 2014). Hence, this smart network is used to detect, control, and program the objects automatically (Vermesan & Friess, 2014). By using the IoT, the project lifecycle become more manageable, especially in monitoring and controlling the machinery, materials and labour usage, as well as the project sequence being more flexible in terms of which part needs to be done first or next or at the same time (Ahmad Latiffi, Mohd, Kasim, & Fathi, 2013; N. A. A. Ismail, Chiozzi, & Drogemuller, 2017; Tahir et al., 2018). Besides, the implementation of IoT may facilitate the construction industry to minimise the overall project time and cost by monitoring, controlling, measuring, and optimising the whole project process as well as the future forecast for the project (Tang, Shelden, Eastman, Pishdad-bozorgi, & Gao, 2019). Other than that, the IoT is also used to manage employee productivity on-site, the project's progress on-site, environmental monitoring, waste management and so on by connecting them with sensors and actuator technology through the internet, then transferring it into digital platforms. From this information, the construction players may have an indication of possible errors, the project's progress performance and the project productivity time in digital form (Mahmud et al., 2018; Tang et al., 2019).

The Malaysian government has had its attention brought to the importance of IoT application in enhancing project performance and productivity; as a direct response, various efforts have been made by the government in collaboration with the Public Works Department (PWD) and Construction Industrial Development Board (CIDB) to ensure the construction players are aware of and highly optimise IoT application in the construction industry by conducting numerous IoT workshops, seminars and training at both tertiary and professional levels (Ibrahim, Esa, et al., 2019). Additionally, the Malaysian construction industry is currently working on the application of IoT that is connected to building information modelling (BIM), augmented reality, cloud computing, and big data analytics. However, the implementation is still very much in its early stages, and needs improvement as well as requires more expertise in managing IoT implementation in Malaysia (Alaloul et al., 2018; Urie, 2019; Ibrahim et al., 2019).

Thus, this paper investigates the adoption of IoT in the Malaysian construction industry towards construction 4.0, which is essential for construction players to be aware of the importance of IoT adoption and its impact in the Malaysian construction industry. This paper covers the theoretical background of this study by exploring the importance of IoT in the construction industry including the use of IoT and the impact of IoT adoption from the perspective of its benefits and challenges. The findings of this paper will describe a general scenario of IoT adoption in Malaysia's construction industry and its impact towards achieving construction 4.0.

2. Methodology

In getting holistic and accurate data regarding the impact of the establishment of IoT in Malaysia, this study conducted an inclusive literature review in this particular area through journal articles which were limited to Scopus, Web of Science and Google Scholar due to the high impact factor and quality of the journal publications. In searching for the related articles, the researcher used a few phrases and keywords such as "internet of things", "IOT", "IOT in Malaysia", "construction technology", "industrial revolution 4.0" "Construction 4.0", "Construction 4.0" and "Internet of Things in construction industry". This research also used data gathered from digital and printed books, reports and other materials which are related to this research scope. Subsequently, all useful information and data that was gathered from the literature materials were filtered to produce a reliable outcome where the results and findings are critically reviewed and discussed in this study.

3. Theoretical Background

3.1 Internet of Things (IoT) in the Construction Industry

The significance of the Internet of Things (IoT) can be seen in almost every industry, including construction, where internet connection becomes the core medium between human and technology (Mimos, 2015; Urie, 2019). According to Mimos, (2015) the IoT is defined as the "*Intelligent interactivity between humans and things to exchange information and knowledge for new value creation*". Meanwhile, previous researchers defined it as "a technology that acts as a tool to streamline the communication between smart devices and humans through sensors, actuators, network and any other complex IoT integrated system by transferring or sharing the data into digital information which is essential to effectively monitor, measure and optimise the productivity of the industry" (Rad & Ahmada, 2017; Mahmud, Assan, & Islam, 2018; Tang, Shelden, Eastman, Pishdad-bozorgi, & Gao, 2019). The concept of IoT encompasses three main components, which consist of connected things, connectivity and infrastructure as well as analytics & apps as illustrated by Mimos in Fig. 1. As explained by Mimos, (2015) in the National Internet of Things (IoT) Strategic Roadmap of Malaysia, the concept of "connected things" refers to smart devices where the sensor is used to detect the environmental parameters and transfer the data to the cloud network. Then, data integration and processes are made to produce useful information, which can be accessed by the various parties who are in the same project through internet connectivity. Finally, the outcome from the information will transform into the relevant apps for further action and contribute to accurate decision-making for the project.

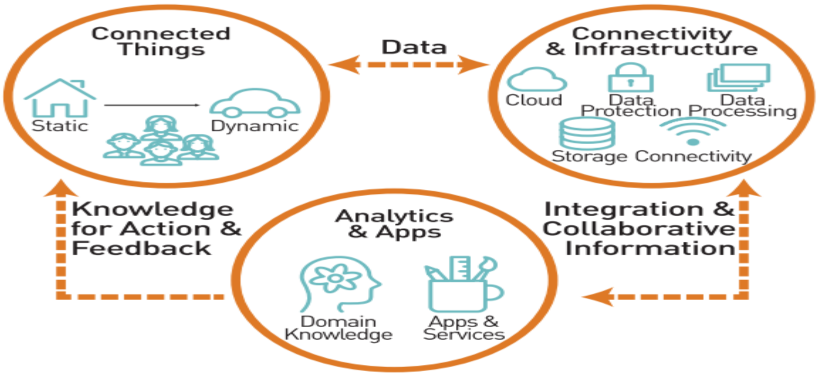

Fig. 1 - The concept of IoT (Mimos, 2015)

There are five (5) elements of control that IoT has leverage over in the construction industry, which is beneficial for the construction players in managing and controlling the construction development progress efficiently (Mahmud et al., 2018). The five (5) leverages of IoT are site monitoring, machine control, construction safety, fleet management and project management; each of these elements will be discussed below (GSM Association, 2014; Philipp Gerbert, 2016; Mahmud et al., 2018).

(i) **Site monitoring** is an essential part of the construction process to ensure the progress of the project development and the environment of the construction site is smooth, and maintain on track all the time (Project Management Institute, 2017). The site monitoring in construction is divided into two-part, which are tracking of human (track worker) and machinery (track the machinery) activities on site (Boje, Guerriero, Kubicki, & Rezgui, 2020). The used of the IoT for monitoring aspect is to facilitate the project team to keep on track and recorded the massive volume and variety of data during the whole project lifecycle automatically with the precise data, which cannot be handled manually by the project team (Kim, Lee, Oh, & Author, 2015). Additionally, through IoT, the information from the human tracking and machinery are recorded using GPS, RFID, sensor and drones. The information from these devices can be accessed via mobile, tablet and computer by the project team which is beneficial in managing the time and cost of the project in every development stages as well as enhancing the monitoring system to be more effectively and efficiently (Boje et al., 2020).

(ii) **Machine Control**, the construction industry is well-known as an industry involving lots of heavy machinery, and previously it was operated manually by the human. However, with the existence of the IoT, the construction machineries are efficiently controlled, manage, and autonomous by using the sensors and remote operation (Osunsanmi, Aigbavboa, & Oke, 2018;Slaton, Hernandez, & Akhavian, 2020). The system continuously transfer the information from the machineries to the operators via the sensor and RFID detection to control the machinery maintenance period, fuel usage, machinery temperature, equipment health and at the same time it will save the maintenance cost for the machinery as well as prolong the machineries lifespan (Mahmud et al., 2018).

(iii) **Construction Safety,** this part is the utmost importance in the construction field to ensure the safety of both site workers and project teams are at a high level during the construction process (Zhang, Cao, & Zhao, 2017; Mehata, Shankar, N, K, & P, 2019). The adoption of IoT practice in the construction industry will facilitates the project managers for easier track the workers' activity, worker's location and the site hazards more efficiently (Osunsanmi, Oke, & Aigbavboa, 2019). When the potential dangers identified, the safety alert will be sent to the construction site by the operators to prevent the workers from the accident happen inside the construction site (Zhang et al., 2017). Other than that, the adoption of IoT in this part also crucial for tracking the worker's health by recording the worker pulse rate and body temperature to make sure all the workers are in good health when they are at the construction site (Mahmud et al., 2018)(Mehata et al., 2019).

(iv) **Fleet Management,** the unpredicted weather and road traffic usually become the causes of the delay and changes in the project schedule, especially in delivery the construction materials on-time (Rane, Potdar, & Rane, 2019). Due to this problem, the IoT is used to facilitates the project manager and site supervisor to track the status of (material, vehicle and machinery), plan and coordinate on-site operation more effectively by knowing precisely the travelling route, the vehicle speed, location information and vehicle maintenance schedule (Louis & Dunston, 2018; Joshi, 2019) because it is essential to prevent the delays during the construction process and easy to update the latest changes in the project schedule (Louis & Dunston, 2018).

(v) **Project Management,** in project management, the primary key indicators for project success are time, cost, quality and the scope of the project (Ilies, Crisan, & Muresan, 2010;Project Management Institute, 2017). Previously, most of the projects are facing problems with those key indicators in completing a project within the time provided with a limited budget because they do not have efficient management at that time (Ahmad Latiffi, Fathi, & Brahim, 2014). However, with the IoT application, project management becomes more manageable by monitoring the whole project progress digitally using the visualization of the 3D model (Barati, Charehzehi, & Preece, 2013). The digitalization of 3D model assists the project management to utilise the project resources, monitor the vehicle equipment, tracking the project progress, earlier detecting the error and clash, real-time reporting, manage the project scheduling and the cost in an efficient way (Enegbuma, Aliagha, & Ali, 2014;Moreno, Olbina, & Issa, 2019; Boje et al., 2020).

Based on the above explanation, there are several IoT mechanisms that have been implemented and introduced worldwide in preparing the construction industry towards digitalisation and construction 4.0. Table 1 shows the list of IoT mechanisms that are widely put into operation in the construction industry and the corresponding function of each mechanism.

Table 1 - The IoT mechanisms and their functions in the construction industry

IoT Mechanisms	The Function
Building Information Modelling (BIM)	Building Information Modelling (BIM), is a new technology approach in the construction industry to design, analysed, construct and managed the project lifecycle by enhancing the planning, design, construction and documentation processes (Ahmad Latiffi et al., 2013). The process is commencement by developing, using and transferring the project information through digitalisation system of 3D model to visualise the real picture of the project where all the project information from various aspect are integrated (Tang et al., 2019). BIM has five main characteristics which are "visualisation, coordination, simulation, optimisation, and the ability to plot" (Alaloul et al., 2018). At the same time, BIM also is useful to enhance the project performance by identifying the project clash and error earlier before the project begin as well as improve the project team collaboration, communication and the decision making. In relation to the IoT application, the digitalization system and data integration in a cloud computing is one of the IoT components which is important to ensure the information and software are interoperability.
Smart Communication	The smart communication such as WhatsApp, telegram, skype, Facebook, zoom meeting and Instagram have given the massive impact to the industry as communication tools especially in the knowledge exchange, updating the progress and making video call as well as teleconference either on-site or off-site meeting with the project team who are at the different location. Furthermore, the use of e-tendering and e-submitting also classified as smart communication where all the tendering and project drawing submission is conducted through online (Mahmud et al., 2018).
Big Data	Big data is a platform where a large amount of project data with high volume, high variety and/or high velocity of information in different format and forms are gathered (Han & Golparvar-fard, 2016). Then, the data will efficiently manage by using a cluster commodity server (Bilal et al., 2019). Furthermore, in a project especially BIM project, there is a large amount of data storage is needed to kept numerous design data and other building information that contribute to the massive data when it reached at the operation and maintenance stage (Bilal et al., 2016). To overcome this issue, the use of big data to manage the high volume of data storage and data exchange for each of the project lifecycle into a well-organized database storage that could be utilized to optimise the construction operation (Bilal et al., 2016; Shrestha, 2013; Ismail, Bandi, & Maaz, 2018). Big data also integrated with cloud computing in term of information sharing within the project team using the internet connection as the central communication (Kasthurirangan, Agrawal, & Choundhary, 2017).

Sensor	In term of the sensor, the use of the sensor is significant to connect the IoT with the smart device like mobile, tablets and laptops or computers which from that connection, the valuable source of data are captured and transform into the information that will help the receiver to analyse the information needed (Gbadamosi, Oyedele, Mahamadu, Kusimo, & Olawale, 2019). For construction cases, the sensor also use in construction site to monitor the project progress, optimise the assets and improve the site management more efficiently, for example, sensor for construction equipment, temperature and energy sensor, and sensor for detecting the material and labour usage at the construction site as well as improve the construction safety (Zhang, Cao, & Zhao, 2017).
RFID	RFID or Radio-frequency identification is a technology based on radio waves with different frequencies which significant to identifying the objects by detecting the microchip from the RFID tag and an RFID reader (Zhang et al., 2017). There are two (2) types of RFID such as passive RFID and active RFID. The function of the RFID in the construction project is related to the managing and control the usage of construction equipment movement, materials controls, workers, maintenance and construction tools (Lu, Huang, & Li, 2011; Valero & Adán, 2016; Osunsanmi, Oke, & Aigbavboa, 2019).
Augmented Reality (AR)	Augmented Reality or well-known as AR is a virtual object which copies the real-world environment into a 3D simulation to visualise the real picture of the object or project using head google, tablet and phone. The AR can help the project team by visualising the actual image of the construction site which from this visualisation, the project team can track and monitor the construction performance as well as the clash and errors. The data from the AR provides the project team and the construction workers an information that will help them to understand the progress of the construction site as planned (Wang et al., 2013; Jiao, Zhang, Li, Wang, & Yang, 2013; Park, Lee, Kwon, & Wang, 2013; Yeh, Tsai, & Kang, 2012; Kamat et al., 2011).
Remote Operation	The intensive monitoring for the whole project progress in the construction site is significant to ensure the entire development is smooth and constructability due to the complexity of building design and its specifications (Hardin & Mccool, 2015). One of the methods that can be used to facilitate the monitoring system is by connecting the machine physically or wireless to the web where the instruction that has made will connect to the machine and the machine will operate it by itself according to the instruction given (Craveiro et al., 2019). The example of this remote operation is drone, power and energy-saving controller, environmental monitoring, security control, etc (Osunsanmi et al., 2018). Currently, drone actively used in the construction site for monitoring the progress of the development, the design, the errors and other important elements inside the construction site (Osunsanmi et al., 2018), including the construction key players in Malaysia but the price for the drone is high.
Location Services (Waze, Google Map and GPS)	In term of location services, the use of Waze, Google Map and GPS is essential to avoid delay in delivering the construction materials, to prevent road congestion and to find a shorter way to arrive at the destination as well as to find out the suitable road for heavy machinery to use for delivery a weighty or lengthy construction material (Zhai et al., 2019). The IoT also has served the updated maps using internet connection physically or wireless (Zhang et al., 2017; Mahmud et al., 2018; Zhai et al., 2019).

Sources: Author, 2020.

3.2 The Impact of IoT in the Construction Industry

3.2.1 The Benefits of IoT

Technological revolution is always moving parallel with the latest innovations to make human life easier in terms of managing their work and lifestyle. The adoption of IoT technology has provided many benefits to humans and to various industries, including the construction industry (Maskuriy, Selamat, Ali, Maresova, & Krejcar, 2019). By adopting the IoT in the construction industry, project managers and project teams are able to manage and monitor the whole project construction progress more effectively through the digitalisation system (Nagy et al., 2018).

Furthermore, in the construction industry, the IoT has provided many advantages, such as improving the availability of individual equipment through continuous monitoring, conducting preventive maintenance and repair of construction equipment to ensure the equipment can do the job smoothly and effectively as well as preventing the construction from being delayed (Almeida & Solas, 2016). The IoT will have specific apps in handling these issues by using sensors, where the operator is able to monitor the equipment based on temperature fluctuations, excessive vibrations and so on, which is useful to indicate the necessary maintenance required for that equipment (Zhang et al., 2017). Besides, the IoT is also able to manage and determine a suitable duration for each piece of equipment, whereby if the equipment is used over and above its specified duration, it will give a signal sign or switch off automatically (Zhang et al., 2017). Moreover, these sensors are also used to control the electricity, lighting and energy and fuel-saving mechanisms by detecting unmoved equipment and automatically switching off for fuel and energy-saving purposes (Zhang et al., 2017; Mahmud et al., 2018).

The benefits of IoT also enables the project team to conduct real-time inspections and report the information through real-time reporting, which is easier and faster than the previous method (Nagy et al., 2018). Besides real-time reporting, the use of digital record maintenance also facilitates the project team to record the maintenance schedule in a more organized way (Urie, 2019). Furthermore, the adoption of IoT is also useful in optimizing the use of available resources and asset management as well as reducing waste in the construction site (Nagy et al., 2018; Maskuriy et al., 2019). In addition, these benefits will help the project improve the project schedule by managing all the project equipment, material, resources, and assets in a proper way. At the same time, it also improves collaboration between the members of the project team (Gbadamosi et al., 2019).

In terms of safety, the IoT provides assistance by tracking the workers at the site, and is able to signal the workers if hazards are identified or any emergency situations occur onsite, such as an industrial accident (Zhang et al., 2017). From a health aspect, the use of health tracking for each worker enables monitoring and management of the workers' health condition through their pulse rate, which makes it easier for the project manager to manage and arrange the duties for their workers (Zhang et al., 2017). From the above, the IoT is beneficial for the construction industry as it reduces the potential risk at the construction site by identifying the hazards mentioned earlier and concerns with the workers' health condition. Overall, the adoption of IoT helps in improving the revenue of the project by reducing the cost of the project, where all the potential risks either in the pre-construction stage or construction stage are effectively managed before the project commences. This would help in saving cost and time of the project as well as enhance the construction quality (Gbadamosi et al., 2019).

3.2.2 The Challenges Faced in Implementing IoT

When it comes to new technology, low adoption rate is still a challenge due to some factors that cause construction players to be reluctant to adopt the IoT to manage their projects. The main challenge is caused by the limited number of experts who know how to operate these devices in an efficient way. This is because to be an expert, a person needs to have good knowledge and receive complete training on how to use the device (Salleh & Fung, 2014). Furthermore, it will also be an additional cost to the organization to train their employees to use these devices. The high cost of getting the devices as well as conducting regular maintenance will also become a challenge for construction players to adopt IoT (Salleh & Fung, 2014).

In operating the device, internet connection will be the main medium used to connect the IoT device with the system for data transfer into the information (Mimos, 2015). If the internet connection is low or unconnected, the interoperability of the device will be interrupted, and the information cannot be received by the operator (GSM Association, 2014). Due to that, the construction site needs to have a good internet connection to ensure the device can be operated efficiently as well as use the best device to ensure the interoperability and information are accurate (Mimos, 2015).

The lack of awareness among the construction players is another challenge in adopting the IoT (Rad & Ahmada, 2017), especially for small and medium organizations, due to limited exposure to the worldwide construction industry and technology (Ahmad Zaidi, 2017). On the other hand, they are reluctant to change because new technology is always evolving, meaning that they will have to make the necessary updates and changes accordingly, which will waste their time and incur additional cost every time the IoT devices are changed (Ibrahim, Shariff, Esa, & A.Rahman, 2019). Due to that, most of the construction players are comfortable sticking to their conventional ways, even when they are aware of the advantages of IoT in saving their time, money, and enhancing project performance (Brous, Janssen, & Herder, 2020).

Another challenge occurs when the government and organization itself cannot encourage the construction players to adopt the IoT in the construction industry (Rad & Ahmada, 2017). Government enforcement is vital to enhance the adoption of IoT in the construction industry by regulating the standards for using IoT in construction sites. This can be achieved by obliging them to use building information modelling (BIM), cloud computer, big data, sensor and remote operation as tools in operating their project.

4. IoT Adoption in The Malaysian Construction Industry (MCI)

According to the previous discussion, the IoT has provided many benefits to the industry, especially in improving productivity and project performance. In Malaysia specifically, the IoT is not yet widely used in the construction industry because it is still in its early stages of implementation, and there are a limited number of experts who are able to operate the IoT devices (Mahmud et al., 2018). However, the government has taken initiatives to improve the adoption of IoT in Malaysia by collaborating with the Public Works Department (PWD) and Construction Industry Development Board (CIDB) in conducting seminars, workshops and training for the construction players to enhance their awareness and knowledge regarding the latest technology associated with the IoT in the construction industry and devices attached with that technology (Kyritsis, 2019).

Meanwhile, according to Mahmud et al., (2018) the highest percentage of IoT devices that are currently used in the Malaysian construction industry is for smart communication, which is the use of tools that enable faster and more convenient communication such as WhatsApp, Telegram, social media (Facebook and Instagram), video call, teleconference and email. These mediums give construction players the platform to exchange information regularly according to their project's progress by sending pictures, progress details, changes and errors identified at the site. Furthermore, smart communication also helps the project team to make decisions fast and take action when it is needed.

Furthermore, the use of remotely operated devices such as drones is useful to facilitate monitoring and controlling of the construction site more effectively and efficiently (Rahimian, Seyedzadeh, Oliver, Rodriquez, & Dawood, 2020). However, getting the latest high-tech drones will be difficult for the smaller to medium construction companies due to their high price. Furthermore, they also need to have a skilled operator to operate the drone to ensure the information is accurate and precise. Currently, the implementation of drones in the Malaysian construction industry is on the rise, as many seminars and workshops have given them awareness regarding drones and the way they can help to optimize the construction progress, worker productivity, work monitoring and controlling.

Besides, the use of location services is also well-known in Malaysia as one of the tools that helps project managers and other teams to manage and control the delivery of construction resources and material using the fastest travel route (Zhai et al., 2019). It is also useful to update the project schedule based on resource availability at the specific time that requires the material to be ready on site (Zhai et al., 2019). The main location services used in Malaysia are Google Maps, Waze and GPS.

Other than that, the Malaysian construction industry has started to adopt sensor usage in construction sites. The usage of sensors is increasing, especially for detecting construction equipment and machinery usage in terms of work location, work timing, maintenance of equipment and machineries, as well as to save the fuel, power and energy of the machine. It is also important in monitoring and controlling the site for safety purposes, especially for the workers and to avoid construction hazards. Besides sensor usage, RFID is another essential step towards Construction 4.0. However, the implementation of RFID is still low because most of the construction players are comfortable with the manual practice, specifically for material tracking on site (Kasim et al., 2019).

Furthermore, in line with the global construction industry, Malaysia has improved its construction industry by implementing the Building Information Modelling (BIM) as part of the adoption of IoT. As discussed by Ibrahim, Esa, et al., (2019) in their research "Towards Construction 4.0: Empowering BIM Skill Talents in Malaysia", they found that the Malaysia government has encouraged the construction players to adopt Building Information Modelling (BIM) in construction projects by make it compulsory for public projects worth RM100 million and above. From this enforcement, the government in collaboration with MyBIM Centre has facilitated construction players by providing them with BIM training and BIM consultation through workshops and seminars. At the same time, universities also provide BIM consultation, where the centres for the study of BIM learning that is associated with the CIDB are, according to the regions and data from the MyBIM satellite Centre, located in Universiti Sains Malaysia (Northern region), Universiti Malaysia Pahang (Eastern), Universiti Teknologi Malaysia (Southern), Universiti Malaysia Perlis (UniMaP), Universiti Malaysia Sabah (UMS) and Swinburne Universiti in Sarawak. Besides that, the government also encourages the construction players to explore big data technology in the construction industry, either in operational big data or analytical big data to ensure the large data can be stored in a proper database that can be accessed by other project teams (Minister of Works, 2018). Due to that, a National BIM library and a few mandates have been established by the government as a step towards transforming the Malaysian Construction Industry into Construction 4.0 (CIDB, 2019).

5. MCI towards Construction 4.0

Construction 4.0 is a term derived from the Industrial Revolution 4.0 concept, which is to enable the industry to connect the people and machines/objects with full digitalization and the latest innovation technology (Osunsanmi et al., 2018). The Industry 4.0 is also able to merge the physical and virtual world using the IoT, simulation and virtualization (Osunsanmi et al., 2018). In the construction context, construction 4.0 requires a transformation from the conventional construction method to digitalization through an IoT mechanism called Building Information Modelling (BIM) (Klinc & Turk, 2019). BIM is an IoT mechanism that is used to develop a virtual building that can integrate with other IoT mechanisms and devices to minimize construction errors, cost and time, as well as optimize the available materials before an actual building is developed on-site. In conjunction with that, the implementation of BIM as a construction method is seen to be significant towards achieving Construction 4.0 which by implementing the BIM, will directly influence the implementation of other IoT mechanisms and devices in a project (Klinc & Turk, 2019).

To assure the successful development of the MCI towards Construction 4.0, a huge transformation needs to be done by the government and the construction industry players, especially in enhancing the implementation of IoT technology for their projects. As BIM is central to Construction 4.0 and directly influences the usage of other IoT mechanisms and devices in a project, the implementation of BIM should be mandatory to all projects, either public or private. Since Malaysia has already implemented the BIM, the government has mandated the mandatory of BIM usage for public projects worth RM100 million and above; however, it is not mandatory for private projects to use BIM as of now. As such, government needs to amend the mandate to make BIM mandatory for both public and private projects. Furthermore, the amount of project value also needs to be reviewed, because the usage of BIM in low cost projects can also facilitate the construction players to minimize and optimize the project cost, time, quality and resources. Moreover, to enhance the BIM and IoT implementation in MCI, the focus must be on intensification of awareness and knowledge as well as skill in operating BIM and the latest IoT technology devices by developing the expertise or skilled talents. With good knowledge sharing and training by experts, the number of BIM-skilled or BIM-ready talents will increase, which will serve to improve project productivity and the adoption of BIM and IoT technology. Currently, BIM awareness in Malaysia has been implemented through conducting seminars, workshops and training, yet other factors should be considered to attract the construction players in implementing BIM.

When the MCI fully incorporates BIM in construction projects, it will directly implement the associated IoT mechanisms such as the sensor, RFID, remote operation, and augmented reality. It will also improve data sharing such as big data, cloud computing and BIM library. Based on the interconnection of the IoT mechanism in a project, it will produce accurate and precise information to the construction players as well as make the development process smooth and less risky. Hence, to provide better integration in a project using BIM, a critical step forward must be taken by improving the usage of IoT on-site which is to supply a high speed internet connection around the construction site, then expand the usage of sensors and RFID for the purpose of tracking the movement of the machineries and equipment, the machineries maintenance and health, material controls, worker productivity, and detecting hazards in construction safety. Additionally, in the current situation with the Covid-19 pandemic, it is essential to track the workers' health using the current health sensor throughout the day when the workers are working on site.

In terms of the IoT mechanism of remote operation and augmented reality, the use of these technologies should also be focused on by the government and the construction players because applying them will enable more effective and efficient monitoring and controlling of the construction site. However, the cost to get good devices for these technologies are high, so the government should provide an initiative to facilitate the construction players which can be in the form of an incentive or fund to buy the technology. Alternatively, the government could introduce a rental scheme with affordable cost and reasonable time period. This initiative will attract the construction players who are unable to buy the technology to use for their project. Furthermore, towards Construction 4.0, the MCI must take a step forward and grab the opportunity to enhance the IoT adoption for all projects in Malaysia, be they small, medium or mega projects. In addition, the government should update the MCI with the current global construction technology and knowledge to ensure that our industry can measure up to and withstand global competitiveness.

6. Conclusion

Based on the discussion above, the adoption of IoT in the Malaysian construction industry is improving day by day as the technology is changing very fast. Currently, the establishment of 5G technology has become a central topic across the globe, and the new generation is aware of the existence of that improvement. The construction industry has also been exposed to the latest construction technology as the Internet of Things (IoT) is one of the core components towards Construction 4.0.

Generally, in the context of the Malaysian construction industry, the adoption of IoT is improving, but is still slow compared to other Asian countries like Singapore, China, Japan, South Korea and Hong Kong (Ansaruddin Agus, Hamzah, & Khoiry, 2019). However, with encouragement from the Malaysian government and support from the Department of Public Works (PWD) and the Construction Industry Development Board (CIDB), the adoption of IoT will have a bright future as the private and public sector are aware of the benefits of adopting the IoT. Moreover, the usage of IoT devices has also been introduced in tertiary level education institutions such as universities, polytechnics and vocational colleges to expose and train students who are studying construction and engineering to be BIM-ready and IoT-literate as they will lead the industry in the future.

From the previous discussion on IoT adoption, the Malaysian construction industry has already implemented the IoT for site monitoring, machine controlling, construction safety, fleet management and project management. These IoT adoption areas are important to ensure all the data from the construction, whether off site or on site, are accurate and sufficient for developing good project progress. The adoption of IoT devices is significant because it will facilitate humans to get accurate information and save time, cost, and reduce potential risks efficiently and effectively. However, Malaysia is still having limitation issues in providing or using the latest IoT technology devices because of their cost, as well as the limited number of experts who are able to install and operate the devices. Overall, the adoption of IoT in Malaysia is aligned with the latest global technology, but continuous improvement is needed to ensure that Malaysia's construction industry can hold it own in global competitiveness.

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