THE ADOPTION OF INTERNET OF THINGS (IOT) ON CONSTRUCTION SITE

CHONG WEN XIN

A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying

Lee Kong Chian Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

September 2021

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

Signature	:	CWX
Name	:	Chong Wen Xin
ID No.	:	16UEB06824
Date	:	26/3/2021

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"THE ADOPTION OF INTERNET OF THINGS (IOT) ON CONSTRUCTION SITE"** was prepared by **CHONG WEN XIN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

Approved by,

Signature :

Supervisor : Li Zi Qian

Date : 27 Sept 2021

Signature :

Co-Supervisor :

Date :

ACKNOWLEDGEMENTS

The successful outcome of this report required guidance and assistance from many parties.

Firstly, I would like to express my gratitude to UTAR for providing this opportunity to me to take part in this quantity surveying final year report as partial fulfilment of requirements for the degree of Bachelor of Science (Honours) Quantity Surveying.

Secondly, I am blessed to be accepted and guided by lecturer, Sr Li Zi Qian, who is also my supervisor throughout this final year report. He constantly assisted me to learn new techniques in completing the final year project and taught me how to do better in this report with countless advices and encourages.

ABSTRACT

The Internet of Things (IoT) is one of the main backbones in the fourth industrial revolution. IoT is an innovative technology and it carries huge advantages to most industries such as engineering, agriculture, medicine, etc. In recent years, the use of IoT is also penetrating into the construction industry. Due to covid-19 outbreak, construction sites have been impacted the most. The progress of the construction works has been seriously delayed, the health and safety of the construction workers on site are threatened as well as the site productivity has reached all-time low. How can the adoption of IoT mitigate the problems on the construction site? This research explores the current practices of IoT on the construction site, analyses the importance of IoT on construction site as well as evaluates the attitude of individual construction practitioners towards IoT adoption on construction site. The research method used is the quantitative method which collects data by using questionnaires. In order to design the questionnaire for data collection, a thorough literature review on the research scope has been carried out and a theoretical framework has been developed. The targeted respondents for this research are construction practitioners who work on the construction site for instance developers, consultants, contractors, sub-contractors, suppliers and specialists. A total of 300 questionnaires have been sent out, 117 questionnaires are returned and only 101 questionnaires are valid to be studied in this research. The research findings have revealed that the IoT adoption on construction sites is very low as there are only a few construction organisations that have already adopted IoT on construction sites. Overall, the construction practitioners especially those in their twenties have high agreement on the importance of the IoT on construction sites and have positive attitudes towards the IoT adoption on construction sites. This research is able to provide an insight on the current IoT adoption on the construction site and how IoT improves the construction site amidst this pandemic outbreak.

TABLE OF CONTENTS

COMMENTS ON FYP REPORTS			Error! Bookmark not defined.
DECLARATION			**2**
APPROVAL FOR SUBMISSION			**3**
ACKNOWLEDGEMENTS			**5**
ABSTRACT			**6**
TABLE OF CONTENTS			**7**
LIST OF FIGURES			**13**
LIST OF SYMBOLS / ABBREVIATIONS			**14**
CHAPTER			
1	**INTRODUCTION**		**15**
	1.1	Introduction	15
	1.2	Background	15
	1.3	Problem Statement	17
	1.4	Research Aim	20
	1.5	Research Objectives	20
	1.6	Research Methodology	20
	1.7	Research Scope and Limitation	21
	1.8	Chapter Outline	21
2	**LITERATURE REVIEW**		**22**
	2.1	Introduction	22
	2.2	Internet of Things (IoT)	22
		2.2.1 Evolution of IoT	23
	2.3	Construction Site	23
		2.3.1 The Needs of Digitalisation of Construction Site	24
	2.4	Current Practices of IoTs on Construction Site	25
		2.4.1 IoT-Based Sensor	25
		2.4.2 Drone Technology	28
		2.4.3 Cloud-based IoT Platform	30
		2.4.4 Robotics	31

	2.4.5	RFID Tagging system	32
	2.4.6	Fifth-generation Wireless System (5G)	34
2.5	Importance of IoTs on Construction Site		35
	2.5.1	Remote Inspection and Progress Report	35
	2.5.2	Locating and Tracking of Site Resources	36
	2.5.3	Monitoring and Maintenance of Machinery	37
	2.5.4	Safety and Health of Site Worker	39
	2.5.5	Security of Site	40
	2.5.6	Better Connectivity	41
2.6	Limitations of IoTs		42
	2.6.1	Security Concerns	42
	2.6.2	Privacy Concerns	43
	2.6.3	Data Storage	44
	2.6.4	Network Failure	45
	2.6.5	Fragmentation and Interoperability	46
	2.6.6	Resource Availability and Cost Consumption	47
2.7	Proposed Theoretical Framework of IoTs on Construction Site		48
3	**METHODOLOGY AND WORK PLAN**		**50**
3.1	Introduction		50
3.2	Research Definition		50
3.3	Research Philosophy		50
3.4	Research Method		52
	3.4.1	Qualitative Approach	52
	3.4.2	Quantitative Method	53
	3.4.3	Mixed Method Approach	53
3.5	Research Design		54
3.6	Justification of Adopted Research Design and Methodology		56
3.7	Research Instrument		57
	3.7.1	Questionnaire Design	57
3.8	Sample Process		58
	3.8.1	Defining the Population	59
	3.8.2	Determine Sampling Design	59
	3.8.3	Determine Sampling Size	59

		3.8.4 Executing Sampling Process	60
		3.8.5 Target Respondents	60
	3.9	Data Analysis	60
		3.9.1 Reliability Analysis	60
		3.9.2 Normality Test	60
		3.9.3 Descriptive Analysis	61
		3.9.4 Inferential Analysis	61
4	**RESULTS AND DISCUSSIONS**		**62**
	4.1	Introduction	62
	4.2	Respondents Background	62
	4.3	Reliability Analysis	63
	4.4	Normality Test	63
	4.5	IoT Adopted on construction site	64
	4.6	Importance Level of IoT on Construction Site	64
	4.7	Importance of IoT on Construction Site	70
	4.8	Limitations of IoT on Construction Site	83
	4.9	Attitude towards IoT Adoption on Construction Site	84
	4.10	Intention of Adopting IoT on the Construction Site	91
	4.11	Likeliness of Adopting IoT on construction site	92
	4.12	IoT Adopted in Construction Activities	92
	4.13	Construction Activities that will Transform with IoT Adoption on Construction Site	93
	4.14	Definition of IoT	94
	4.15	Discussion	94
		4.15.1 Current practices of IoT on Construction Site	94
		4.15.2 Importance of IoT on Construction Site	95
		4.15.3 Attitude of Individual Construction Practitioner towards IoT Adoption on Construction Site	100
5	**CONCLUSIONS AND RECOMMENDATIONS**		**102**
	5.1	Introduction	102
	5.2	Accomplishments of Research Objectives	102
	5.3	Research Contributions	104
	5.4	Research Limitations	105
	5.5	Research Recommendations	106

REFERENCES **108**

APPENDICES **123**

LIST OF TABLES

Table 2.1: Projected 5G Penetration in South East Asia by Year 2025 34

Table 3.1: Summary of Importance of IoT in Section A 58

Table 4.1: Attributes of Respondents (N=117) 63

Table 4.2: Cronbach Alpha Value of Reliability Test 63

Table 4.3: Normality Distribution Test 63

Table 4.4: Ranking of the IoT Adopted on Construction Site 64

Table 4.5: Ranking of the Importance Level of IoT on Construction Site 64

Table 4.6: Mean Ranking of the Importance Level of IoT on Construction Site 65

Table 4.7: Rejected Null Hypothesis for the Importance level of IoT on Construction Site 65

Table 4.8: Ranking of the Importance of IoT on Construction Site 70

Table 4.9: Mean Ranking for the Importance of IoT on Construction Site 71

Table 4.10: Rejected Null Hypothesis for the Importance of IoT on Construction Site 72

Table 4.11: Ranking of the Limitations of IoT on Construction Site 84

Table 4.12: Ranking of Attitude towards IoT Adoption on Construction Site 84

Table 4.13: Mean Ranking of the Attitude towards IoT on Construction Site 85

Table 4.14: Rejected Null Hypothesis for the Attitude towards IoT Adoption on Construction Site 86

Table 4.15: Scale of Intention of Adopting IoT on Construction Site 92

Table 4.16: Ranking of the Likeliness of Adopting IoT on Construction Site 92

Table 4.17: Ranking of IoT Adopted on Construction Activities 93

Table 4.18: Ranking of the Construction Activities that will Transform with IoT Adoption on Construction Site 93

Table 4.19: Ranking of Definition of IoT 94

LIST OF FIGURES

Figure 1.1: Percentage Of Companies Interested In IoT And Operational IoT Solutions In 2019 16

Figure 2.1: Evolution of IoT 23

Figure 2.2: Vibration Sensor 26

Figure 2.3: Embedded sensors 27

Figure 2.4: Concrete Curing Sensor 28

Figure 2.5: Drone 30

Figure 2.6: IoT Cloud Platform 31

Figure 2.7: Fastbrick Robotics 32

Figure 2.8: RFID Tag 33

Figure 2.9: Theoretical Framework for Adoption of IoT on Construction Site 49

Figure 3.1: Research “Onion" 52

Figure 3.2: Workflow of Research Design 56

LIST OF SYMBOLS / ABBREVIATIONS

IoT	internet of thing

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter consists of a general overview of the research. It covers the background, problem statement, research aim, research objectives, research methodology, research scope and limitations as well as the contribution of the research.

1.2 Background

It is known that the construction industry has been one of the crucial sectors contributing to the economy across the world. This statement can be represented by the spending of construction which usually shows GDP between 9% to 15% in majority of countries (Robert, 2018). It also shows that the majority of countries allocate half of the nation’s investments in built environment activities (Oesterreich and Teuteberg, 2016). Even though the construction industry is one of the main economic factors as well as highly invested, the overall performance and productivity in the construction industry are still stagnant, the construction site is the one that experiences the most serious stagnation in terms of performance and productivity.

The fourth industrial revolution involving technologies has been frequently mentioned recently and is important for the dynamic changes and complex construction industry. This revolution indicates the rise of the physical cyber system will be useful in resolving the stagnant growth of construction and reshape the construction process in the future.

Significant to the utilization of digital technology like Internet of Things (IoT) in the construction industry, the Ministry of Works (KKR) is in collaboration with various interested construction industry parties through CIDB to develop a plan called Construction Strategy Plan 4.0. It consists of 12 key technologies known as disruptive technologies and the Internet of Things is one of the key technologies. This plan is developed to assist the construction industry to get through the changes of Construction 4.0 transformation (CIDB, 2021).

Internet of Things technology is known as one of the key pillars in the fourth industrial revolution due to its innovations and huge advantages to not just the construction industry, but also to other major industries such as engineering, medicine, agriculture, etc. However, according to the Analysis Mason Business Survey 2019, the general awareness and interest to adopt IoT are still considered low across the world as observed from Figure 1.1 (Yaici, 2019).

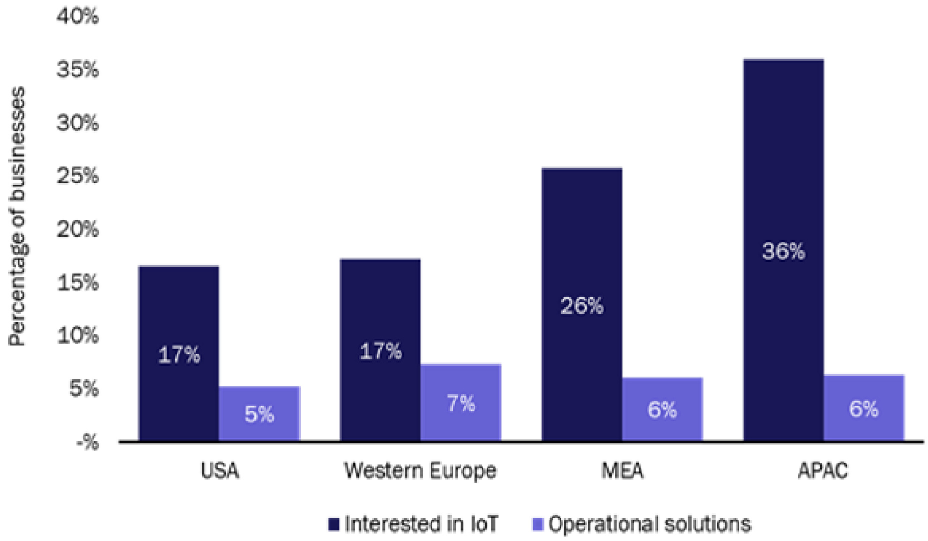


Figure 1.1: Percentage Of Companies Interested In IoT And Operational IoT Solutions In 2019
(Yaici, 2019)

Most of the past research carried out was utilising IoT technology in the construction sector. In this respect, there is also other research about how IoT can enhance the overall performance of construction management such as project management, site safety management, facility management, human resources management, equipment and materials management (Arslan, Ulubeyli and Kazaz, 2019).

As the IoT is increasingly pervading the construction industry, it is claimed that IoT will bring various benefits into the construction industry (Veras, Suresh and Renukappa, 2018). The IoT is capable of collecting a huge amount of data which can lead the construction industry in a direction with better transparency, accountability and monitoring (Attia, et al., 2018). At the same time, the implementation of IoT within the construction industry will possibly create more innovative career opportunities for people such as data analysts, computer programmers, digital technicians, etc. It is believed that all these possible innovative careers will contribute to a massive data environment for the big data driven world in the future (Bilal et al., 2016).

According to Mahmud, Assan and Islam (2018), Internet has become one of the most important network systems for every construction party in the rapid growing construction industry to ensure enhanced and real time delivery of information. As other industries have developed faster and better with utilisation of advanced digital technologies, the construction industry must carry out necessary changes like adoption of IoT due to the increasingly complicated and complex construction projects.

In the past, there has been extensive study and articles on adoption of IoT. However, they are majorly emphasizing in manufacturing industry, healthcare industry, agriculture industry, transportation industry and finance industry. The study and articles of IoT adoption in construction industry are limited. Moreover, those study and articles of IoT in construction industry are too wide and many has not investigated further into every element of construction industry thoroughly such as construction site. Hence, in this research, more attentions and efforts will be put to find out the current adoption of IoT application on construction site.

1.3 Problem Statement

The Internet of Things (IoT) has become one of the popular trends among the industries. There are several sectors which are already adopting the IoT technology and starting to practice them when carrying out daily tasks. Even though IoT technology is still considered new to the construction industry, there are more construction practitioners learning to conduct business through utilisation and adoption of the IoT application. However, the adoption of IoT on the construction site is still very low despite the IoT being capable of tackling major issues affecting the overall performance of the construction site.

Construction industry has been largely impacted due to the outbreak of Covid-19. According to the Economic Outlook 2021 of CIDB (2020), the construction industry shrank by 25.9% in the first half of 2020 and projected to contract by 11.8% in the second half of 2020. As an overview, the construction industry is expected to shrink by 18.7%. One of the main factors contributing to the shrinkage of the construction industry is the suspension of construction site operation. Construction Industry Development Board (CIDB) inspected 7,699 construction sites starting from 20 April 2020 until 14 June 2020. It showed that more than 5,000 construction sites were not operating, 295 construction sites received warning due to not adhering to the new standard operating system (SOP) during the conditional movement control order (CMCO) and other 12 construction sites were ordered to shut down (Research and Markets, 2020). The newest SOP required that all construction workers to undergo registration check-in application and temperature screening before entering the construction site. The workers at the construction site also must practice social distancing (CIDB, 2020). IoT is a new and innovative technological platform that assists in fighting with the COVID-19 pandemic. IoT is able to tackle many challenges faced by the construction industry and prevent the spread of Covid-19 during the lockdown period. This technology is effective in real time monitoring, capturing health data and collecting other important information of workers or non-workers on the construction site. It is able to keep track of who is on the site, who are working, where they are working and how they are behaving on the construction site (Singh et al., 2020).

Additionally, the construction site is considered as one of the most dangerous and unsafe industrial sites in the world. This is due to the unpredictable nature of the construction and hazardous activities on the site. Every year, there are construction workers or non-construction workers who face serious fall injuries, harms and even deaths caused by unforeseen accidents on the site. The series of unexpected accidents on construction site result in injuries to personnel, damages to equipment, machinery and plant as well as loss of production (Oladiran and Sotunbo, 2009). According to the International Labour Organization (2021) , the latest statistical data of the construction site shows a disproportionately high rate of accidents out of approximately 2.3 million accidents worldwide every year. From this statistic, it indicates that there are large groups of global construction workforce engaged in their occupation's fatalities and injuries. Currently, the safety practices at the site are mainly passive in nature instead of active, which is why the construction industry has not yielded an optimum result on site accident preventive measures. With the help of IoT, the initial passive safety system that reduces the effect of accidents on construction sites can be converted into an active safety system which prevents the accidents from occurring in the first place (Wozniak, Kukielka and Wozniak, 2013). Integration of different IoT technologies allows the interaction of humans and things on the construction site through digital platforms in managing the safety of workers, equipment and machinery during construction processes on site. The application of IoT to form an active safety system on site can be varied from monitoring the hazardous conditions around workers, tracking the health condition of workers to sending alert messages through application when any worker is injured on construction site (Gnoni et al., 2020). Overall, the IoT can improve safety management on the construction site.

The productivity of construction is another major concern which is affected by labour and capital. Labour productivity in construction can be defined as a ratio of a product output to the labour input. Labour intensive is one of the natures in the construction industry. Hence, the productivity of construction will be significantly affected by the weak growth of labour productivity. In the traditional construction site without any utilisation of advanced digital technology, it is hard to identify the exact causes of the declining labour productivity on site. However, with the development of IoT, the individual performance of the workers can be assessed and analysed via site monitoring and data collected through IoT-based devices. This is due to the fact that IoT devices are capable of recognising the activities carried out by workers such as walking, standing, sitting, running, sleeping, etc. (Forkan et al., 2019). On the other hand, capital productivity can be defined as the measure of how efficient the capitals in supplying services and goods are. The capitals in the construction industry are tools, equipment, machineries, etc. IoT devices can be embedded in the equipment and machinery to provide real time monitoring of the health condition and their aging level. These applications allow the maintenance of the equipment and machinery to be carried out regularly and when any abnormal motions are detected in them by the IoT-based devices. Indirectly, the IoT is capable of saving additional cost of maintenance, reducing wear off of equipment and machinery as well as improving the overall productivity on the construction site (Gnoni et al., 2020).

Ultimately, the number of IoT devices usage increases dramatically every year but the construction sector is still one of the least digitised sectors. It is believed that by adopting IoT on the construction site, the health and safety of site workers as well as the site productivity can be greatly improved. However, are construction practitioners aware of the IoT practices and importance on the construction site? Are construction practitioners considering adopting the IoT on construction site?

1.4 Research Aim

The aim of this research is to evaluate the adoption of IoT on construction site.

1.5 Research Objectives

In order to achieve the research aim, the following research objectives have been set up:

i) To explore the current practices of IoT application on construction site

ii) To analyse the importance of IoT application adoption on construction site

iii) To evaluate the attitude of individual construction practitioners towards IoT application adoption on construction site.

1.6 Research Methodology

The primary data in this research is obtained through quantitative approach which are by distributing questionnaires. After that, the obtained data are evaluated by using different statistical tests, including Cronbach's Alpha Coefficient Reliability Test, descriptive analysis, Friedman test and Kruskal-Wallis test.

1.7 Research Scope and Limitation

The data are collected from construction players based on different construction organisation business activities, different ages, different working experiences and different organisation sizes in order to survey the different levels of insight towards the IoT on construction sites. The samplings of this research are mainly contractor, consultant, sub-contractor, supplier and other professions involved on construction sites.

1.8 Chapter Outline

This research is prepared in five separate chapters and will be further described. Chapter 1 is the introduction which elaborates on the background of IoT in the construction industry. It also provides details of this research which are research aim, research objectives, problem statement, research scope and limitation as well as research contribution.

In Chapter 2, the literature review is prepared based on the previous relevant research papers from proper sources such as journal, thesis and conference paper. It starts with definitions and relevant study of IoT and construction sites. It continues with current practices of IoT on the construction site. Then, it discusses the importance of the IoT on the construction site. Lastly, it reviews various limitations of IoT on the construction site.

Chapter 3 explains how the research is carried out. The research design and method are defined by including all the relevant processes, data analysis and data collection in this research.

Chapter 4 emphasises on the result of the data collected through the distributed questionnaires. It mainly evaluates the collected data and compares the findings with literature review in Chapter 2.

Lastly, Chapter 5 is to summarise all the studies and findings in this research. It concludes an overview of IoT on the construction site and relates to the corresponding research objectives. This chapter ends with research limitations and recommendations to prepare for further future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents an overall review on the Internet of Things (IoT) on construction sites. It provides the definitions of IoT, evolution of IoT, background of construction site as well as the needs to digitalise the construction site. Then, this section covers the general practices of IoT on construction sites and reviews the importance of IoT on the construction site. Lastly, this chapter ends with the discussion of limitations of IoT.

2.2 Internet of Things (IoT)

The Internet of Things (IoT) is a revolution of the Internet. IoT is a system which is interconnected computing gadgets and digital tools prepared with unique identifiers (UIDs). Hence, IoT has the ability to receive or transfer data via network without needing human-to-computer or human-to-human interaction. With the ability to access information, the things or objects can now be part of a crucial component in a complex process (Fantana et al., 2013).

Generally, the Internet of Things (IoT) can be explained as a general idea of objects or things in daily life that are readable, reachable or recognisable through external information sensing devices or are manageable via the Internet. IoT can be categorised into a few categories, which are things to things, people to things or vice versa (Patel et al., 2016).

It is said that the Internet of Things is the integration of multiple processes which are sensing, identifying, networking and computing the data that allows tremendous technological inventions and value added services with customised user’s interactions with several objects (Colakovic and Hadzialic, 2018). Similarly, the Internet of Things refers to the growing network of physical objects which are able to communicate among themselves and with other internet-enabled devices over the Internet (Brous, Janssen and Herder, 2020).

2.2.1 Evolution of IoT

Even though the IoT has only gained some popularity for the recent two decades, it actually has been shaped and supported by different technologies that have been widely developed for many years.

The core technology behind IoT is the Internet which originated from a project called ARPANET initiated in 1969. The primary objective of the Internet is to develop techniques and experiences in interconnecting computers, enhance the research productivity of computers by research sharing as well as to allow the connection of designated computers to other general purpose computer stations in the public and private sector. Ever since then, the Internet had developed progressively over the years before IoT was introduced as shown in Figure 2.1 (American International Group, n.d.).

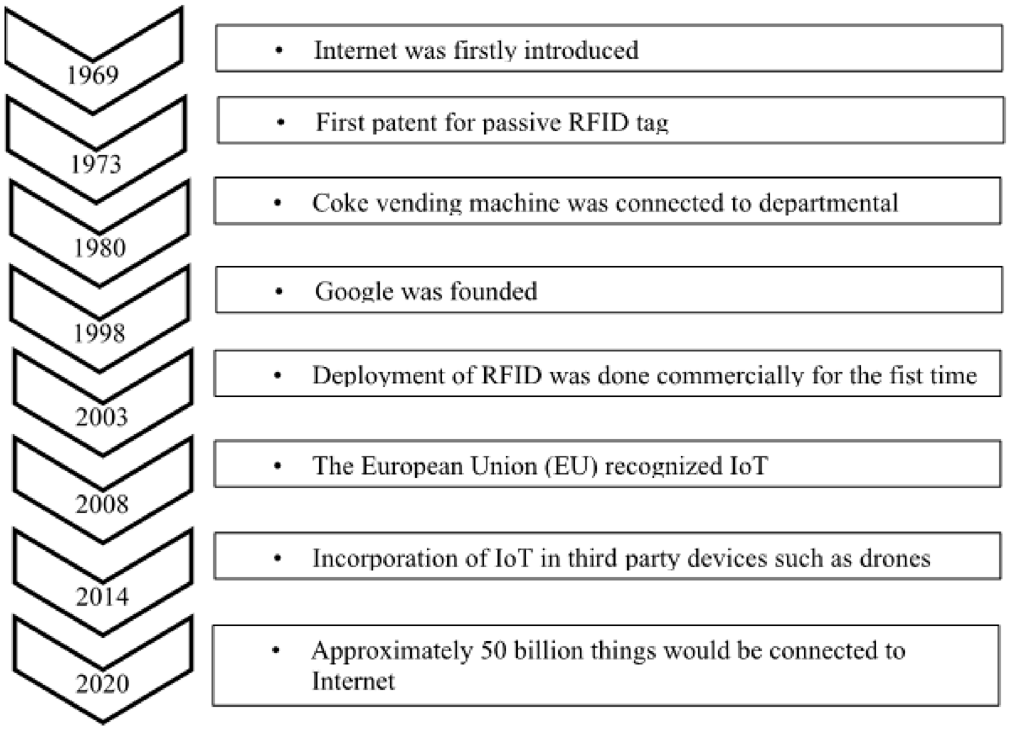


Figure 2.1: Evolution of IoT

2.3 Construction Site

The construction sector has witnessed tremendous changes and advancement of other industries over several decades. According to the industry agenda of the World Economic Forum (2016), despite the major changes and advances, the construction sector has been having the lowest productivity among other industries. When other industries are achieving nearly doubled productivity, the productivity in construction has been declining over the years. The forum also stated part of this is due to the labour skill requirements to enter the construction site is reduced. The reduced labour entry requirement can bring in a large workforce into the construction site to cope with the site worker shortage. However, this has resulted in low labour productivity. Besides, the industry agenda also stated a shortage of experienced construction professionals, for instance supervisor, project manager and engineer which further affects the productivity rate on construction sites.

In the long term, the construction site will require more highly skilled labourers and professionals to sustain the increasing complexity of on-site construction projects, for instance the famous Burj Khalifa, One World Trade Centre, High Speed 2, etc. On the other hand, the probability of safety-related issues will rise as well as a result of shortage of skilled workforces. Large scale and complex projects tend to have high safety risks and more complex operations on the site. When there is an accident on the construction site, it does not only affect the construction workforces, the public may also be affected (Triantafyllou, Sarigiannidis and Lagkas, 2018).

Hence, improving the construction site is critical as it leaves impacts on overall construction costs, performances and delays. One of the solutions to better manage the construction site is through adopting new digital applications or technologies. Despite having low productivity, construction sites are also known for lagging behind the adoption of modern technologies. These phenomena also explain the low productivity of construction. The construction site could reap the benefits from uptake of modern digital technology or termed as Construction 4.0 (UK Government, 2017).

2.3.1 The Needs of Digitalisation of Construction Site

In the 21st century, many sectors have started adopting digital technologies due to Industrial Revolution 4.0 which mainly emphasises the use of cyber-physical systems and computers in the pursuit of productivity and operational gains (Boyes et al., 2018).

Digitalisation of the construction site applying the concept of Internet of Things is still relatively new to the construction sector. A digitalised construction site is like a more connected construction site which presents interesting effects in both off-site activities and on-site activities (Triantafyllou, Sarigiannidis and Lagkas, 2018). It is an integration of information between various platforms and adopting new digital devices on site. Similarly, the digitalisation on construction sites gives smarter and more intelligent ways in assembling all the data collected from construction site with the latest digital devices to facilitate an easy analysis of collected data and make decisions promptly (Construction Products Association, 2016).

The term Construction 4.0 was firstly mentioned by Roland Berger (2016) based on the awareness of construction corporations on the digitalisation in the construction industry. It has 4 major key concepts which are connectivity, automation, digital data and digital access (Roland Berger, 2016). The concept of Construction 4.0 has evolved over the years and across different areas including industrial production and construction, digital technologies and cyber-physical systems. Internet of Things has been proven as one of the most valuable technologies in the past few years with great potential and prospects in the construction sector and will eventually transform the construction site to be more digitised (Fokaides et al., 2020).

Construction 4.0 is the trend of increasing digitalisation in the construction field by utilising Information Communication Technologies (ICT). It is seen as a force that will encourage the evolution in the construction sector as well as construction techniques and practices (Forcael et al., 2020).

In conclusion, in order for the construction sector to be more advanced and fully utilise the IoT to receive the benefits given by IoT, it is crucial to digitalise the construction site widely.

2.4 Current Practices of IoTs on Construction Site

The current practices of IoTs on construction sites are IoT-based sensor, drone technology, cloud-based IoT platform, robotics, RFID tagging system and fifth-generation wireless system (5G).

2.4.1 IoT-Based Sensor

For IoT on construction sites, sensors can be attached to things or objects on the site such as heavy machinery, construction equipment, building structures and materials. In recent years, sensors have been widely developed into various types of IoT-based sensors and applied to construction site. IoT-based sensors are one of the major breakthrough applications in solving the technical issues that exist on construction site. By introducing IoT into sensor technology, all types of data of objects or things involved on the construction site can be gathered together. There are various IoT-based sensors invented to improve the site of construction. (Zhang, Cao and Zhao, 2017).

2.4.1.1. Vibration Sensor

According to Levy (2017), vibration sensors are often used on heavy construction machinery at construction sites. This sensor can monitor the condition of the machinery remotely by collecting data from different variables to determine the performance and health of the machinery. The sensor is capable of transforming the vibrating forces into electrical signals (Du, Wang and Zhang, 2013). When there is excessive or abnormal vibration detected by the vibration sensor from the machinery, it indicates the long usage of the machinery which will potentially cause damage to the machinery and speed up the need for maintenance. Vibration sensors will give early signs of failure due to improper use, component misalignment or wear of machinery by sending alerts to the site manager. Figure 2.2 shows a type of sensor used in machinery and equipment.

Figure 2.2: Vibration Sensor

(Robotech Shop, 2021)

2.4.1.2. Embedded Sensor

Embedded sensors as shown in Figure 2.3 can provide information of the building structure state and functions. It enhances the life of the building against the extreme environmental actions and at the same time reduces further damage to the building (Abruzzese et al., 2020). The current structure state of the building can be identified by the embedded fibre optic crack sensor with the building concrete structure. This embedded sensor can quickly identify the minor opening of cracks occurring in the building structure. The principle of this detection is based on the bending loss of fibre. Two fibre optic sensors will be embedded at opposite angles of concrete (Wan and Leung, 2007). The use of embedded optic fibre sensor allows the real time structural monitoring during the execution phase at site and allows the site manager to monitor the actual condition of the building structure remotely.

Figure 2.3: Embedded sensors

(Mouser Electronics, 2021)

2.4.1.3. Concrete Curing Sensor

In Figure 2.4, it shows a concrete curing sensor which is used on construction sites to monitor the curing process of concrete. This sensor can detect the temperature, maturity and humidity in the concrete. All the data collected by the concrete curing sensor on the construction site will be transferred wirelessly to the client, contractor and engineer. It allows them to monitor the performance of the concrete and make decisions in real time throughout the whole process (Paul, Nail and Bagal, 2020).

Figure 2.4 shows the concrete curing sensor used on the construction site.

Figure 2.4: Concrete Curing Sensor

(Hilti, 2021)

2.4.2 Drone Technology

Drone technology and have been known for their enormous applications and benefits in the construction industry and built environment. Drone as shown in Figure 2.5 can also be referred to Unmanned Aerial Vehicle (UAVs) for their outstanding performance in line-of-sight-links to ground operators and their flexibility (Amorim et al., 2017). Besides, it also gains its huge attention for its high usability, low deployment cost, effective communication channel when operating as well as providing unlimited information of the surrounding environment. The major applications of drone technology include land surveying, building surveying, construction site inspection, topographic mapping, remote monitoring and progress reporting of site (Akeem, 2020).

Drone comprises aircraft components, sensors, ground control station, electronic speed controller, GPS module, receiver, camera and accelerator (Lakshmi and Ibe, 2015). The components in a drone have to be lightweight composite materials to minimize the weight and enhance the flight operations. With its lightweight feature, drones eliminate the need for construction labourers to carry out high-elevation inspections on construction site. It has reduced the potential injuries at construction sites by eliminating the dangerous inspection operations at site (Tatum and Liu, 2017).

As drone technology involves sensors, embedded software and antennas in recent years, it is considered part of IoT as it provides multiple way communication for remote control and monitoring applications through wireless connections (Luo et al., 2015). Currently, the three major sensor technologies supporting the drone are separated into three categories which are flight control, data acquisition and communication system.

Drones require a combination of GPS and inertial measurement unit to remain in flight direction and path during operation. The inertial measurement unit utilizes a magnetic compass called multi-axis magnetometers to calculate the Earth's magnetic field. This mechanism assists the drone in identifying the direction which is assumed as the magnetic North pole. The flight control system also obtains signals from a combination of tilt sensor, accelerator and gyroscopes. The flight control system is a crucial component to drone as drone needs good stability during inspection or surveillance of construction sites.

Drones are also equipped with various sensors for data acquisition in order to obtain information and data from the construction site. For applications of monitoring and surveillance, sensors such as high-resolution Red Green Blue (RGB) camera, Normalized Difference Vegetation Index (NDVI) camera for precision agriculture, Light Imaging, Detection, And Ranging (LIDAR) for synchronise mapping and localisation and ultrasonic sensor for sensing and obstacle-avoidance mechanism. The IoT sensors in all these applications will gather the signal and statistics in real time before being processed on sensor board and transferred to the base station (Lagkas et al., 2018).

Drones are controlled and managed through the use of a communication system together with a network. A drone requires technologies to carry out communication which includes WPAN (Zigbee, Bluetooth 4.0), WLAN (WAVE 802.11p, 802.11a/b/g/n/ac), LPWA (SigFox ,LoRA), and Cellular (LTE Advanced 4G, 5G, LTE, NB-IoT, LTE-M, LTE D2D) (Triantafyllou, Sarigiannidis and Lagkas, 2018). Different communication technologies have different ranges of coverage, data rate and specification of latency (Bellavista et al., 2018). It is believed that the future communication technology will leave great impacts on communication of drones and enable more applications worldwide.

Figure 2.5 shows the drone used on the construction site.

Figure 2.5: Drone

(Wikipedia, 2021)

2.4.3 Cloud-based IoT Platform

IoT is a technology that generates huge amounts of data to increase efficiency in everyday tasks. Cloud computing, on the other hand, offers a way to deliver and process the huge data as it has an infinite capacity of processing and storage power. It also offers on demand platform and web based communications for users to access the resources or data evenly (Zainea et al., 2012). Hence, a cloud-based IoT platform has the ability to manage and develop online IoT applications through the cloud. Figure 2.6 depicts various types of IoT Cloud Platform.

Every sensor or IoT-based device can connect to the cloud. On construction sites, there are many sensors and devices that will collect thousands of data and require a large amount of computational power (Mao et al., 2014). This will lead to a high amount of energy and cost. Meanwhile, IoT also has limited capacity for processing and storage power. With cloud computing, all the data collected from sensors or devices on construction sites can be delivered to the cloud. The data collected can be processed, stored, analysed with storage and computational resources of the cloud. Moreover, this platform allows different users and applications to share the sensor resources as well as enables the sensors and devices to carry out specialised processing tasks (Rao et al., 2012).

This platform allows the users to monitor and control the sensors and devices through a web browser even if they are away from the construction site (Hermerschmidt, Perez and Rumpe, 2014). It also eases the huge data flow among IoT data collection and processors while keeping the cost low with complicated data processing.

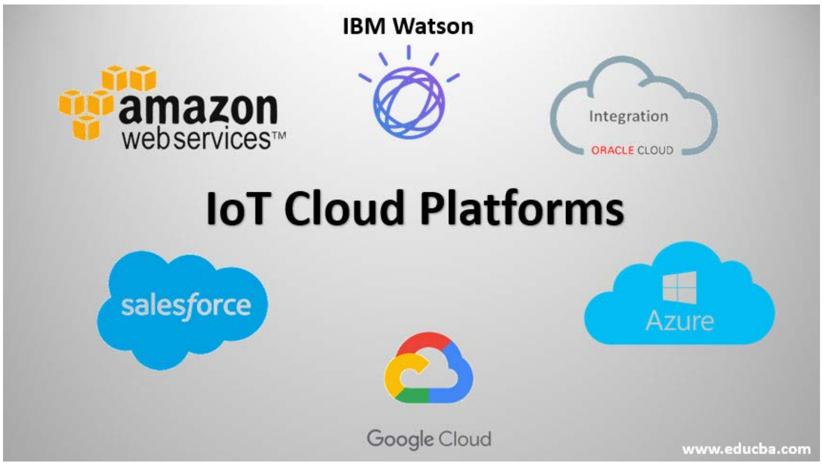


Figure 2.6: IoT Cloud Platform
(EDUCBA, 2020)

2.4.4 Robotics

Currently, the robotics level in the construction site is still quite low and is not implemented on a large scale on the construction site yet. There are two types of work for construction robotics. The first type is directly related to physical construction work for instance earthwork, reinforcement, paving, welding, coating, and assembly. The second type is related to the construction process such as planning, management, safety and quality control of the site. Robotics on construction sites concerns more on the first type of work employing IoT. (Saidi, O' Brien and Lytle, 2008).

Construction robotics on the first type of work emphasises particularly on "real works" which then produce the final products at site, for instance, concrete bricklaying, concrete polishing and paving (Bock, 2007). In Figure 2.6, it shows the famous bricklaying robotics known as Fastbrick Robotics. In the meantime, various technologies are employed in construction robotics to carry out physical works and are divided into 4 categories. The first category is traditional mechanical robotic technology which includes handling robots, single task robots, and human-robot interface. It is crucial in construction assembly works, specifically in conveying, aligning and connecting phases of construction works. The second category is the group of ICT technologies. They are used to manage and control the construction assembly works to ensure the performance throughout the process. Lastly, the third category is information or data collection through IoT (Liu, 2017).

While construction robotics is not a normal sight yet on the construction site, they are usually used for laborious and dangerous works on construction sites. Bricklaying and paving are construction activities that involve repetitive actions and can be completed by the robots. Even though bricklaying and paving are not high-risk activities on construction sites, they are however time consuming and require high labour workloads. Pritschow had proposed that a bricklaying robot can work at site to load the bricks from the prepared pallets, apply binding agent and lay the brick at the designated location and continue with mortar plastering on the laid bricks (Yu et al., 2009). Figure 2.7 shows a type of bricklaying robotics.

Figure 2.7: Fastbrick Robotics
(World Construction Today, 2021)

2.4.5 RFID Tagging system

RFID Tag system still remains as an emerging technology in the construction sector and has not been widely used on construction sites. RFID system itself is the simplest form of a pervasive sensor network which uses small radio signals for tracking and is also used for identification of various physical things or objects (Lopez et al., 2018). By integrating RFID, IoT and sensor, an

IoT-based RFID tagging system is introduced. The tag embedded with sensor can be tagged with RFID on anything or any object on the construction site for mobile tracking or monitoring purposes with the help of GPS (Global Positioning System).

RFID tag as shown in Figure 2.8 can also be referred as a transponder. The tag is defined as a mobile memory located on a microchip with detailed information of the attached item or product (Domdouzis, Kumar and Anumba, 2007). The tag can be categorized into 2 types which are active and passive. Active tag has built-in power supply and is rewritable. The features provided by active tag are more and have better noise protection. However, it is heavier, shorter battery life and higher cost compared to passive tags. It requires low signal strength and the tracking range can be up to 100 meters. It has higher memory and information storage. Generally, active tags are used on large assets which need to travel and be tracked for a long distance. On the other hand, the passive tag has no built-in power as it relies on the energy transfer from the reader device. Passive tag can only be tracked up to 5 meters but it has a longer lifespan than the active tag. It only has a microchip attached to an antenna and can be designed in many different ways such as a tag, in the middle of 2 adhesive layers, a printable label, inserted in plastic card and other unique packaging. Passive tag can be used on materials, machinery or equipment located on construction sites (Kasim, Latiffi and Fathi, 2013).

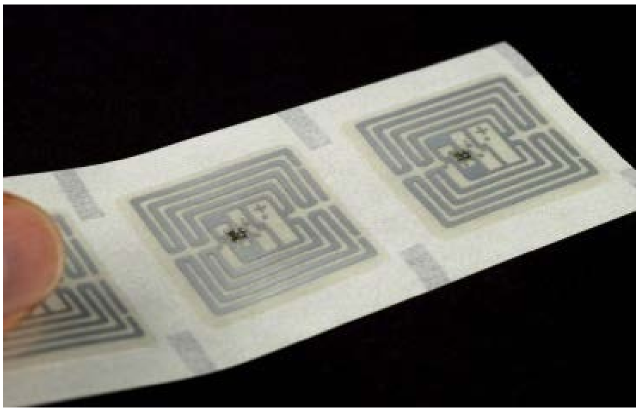


Figure 2.8: RFID Tag
(Gravic Group , 2021)

2.4.6 Fifth-generation Wireless System (5G)

Fifth-generation wireless system (5G) is on its way when IoT is also taking over the spotlight as IoT devices are anticipated to form a huge part in this 5G prototype. With the emergence of billions of IoT technologies and devices, it poses a huge challenge to the current 4G wireless system. Hence, 5G plays a crucial role and further innovation between 5G and IoT is required. Scientists, researchers and engineers are designing an IoT based system which can integrate with the 5G technology efficiently (Ejaz et al., 2016).

Internet Telecommunications Union (ITU) has a rich history and experience in designing standards for 2G, 3G and 4G. ITU is working hard on 5G technology and developing the international standards to accomplish an outstanding performance of the 5G network. IMT-2020 specifications have been set up by ITU for the 5G standard due to the growing needs of technology upgrade from the society (ITU, 2019). In Table 2.1, it shows the projection of 5G penetration in Southeast Asia by 2025.

Table 2.1: Projected 5G Penetration in South East Asia by Year 2025 (Chew et al., 2020)

No.	Country	Percentage
1	Singapore	56.89
2	Malaysia	39.81
3	Thailand	33.00
4	Indonesia	27.24
5	Brunei	17.10
6	Myanmar	16.99
7	Philippines	14.77
8	Vietnam	6.31
9	Laos	5.44
10	Cambodia	3.18

5G can be grouped into three different categories based on function which are enhanced mobile broadband service (eMbb), ultra-reliable low latency communication (URLLC) and massive machine type communication (mMTC). First of all, Embb will be largely applied in data-driven applications which require big data rates over a huge coverage area. It allows the platforms for ultra-HD video, immersive AR and VR applications. Secondly, URLLC is the second stage of 5G. It provides advanced services for mission-critical applications or communications that can transform the industry. For instance, 5G tactile internet, remote control of infrastructure and driverless vehicles on site. Thirdly, mMTC will be mainly used to assist or boost IoT devices in small areas to transmit data intermittently on applications. It is able to connect to a huge number of IoT devices with the capability of lowering the data rates, energy consumption and mobility (Chew et al., 2020).

There are few major differences between the performance of IoT when using 4G and 5G technology. IoT will perform better with 5G due to the lower latency of 5G. Latency is the delay between sending and receiving data. 5G has a latency rate of 1 millisecond while 4G is about 30 milliseconds to 50 milliseconds. When 5G is integrated with IoT on construction sites, certain operations can be carried out in real-time. Besides, 5G has a better throughput than 4G. Throughput is the ratio of data transferred in a unit time. It is predicted that the throughput of 5G is around 10 Gbps per connection while 4G is around 100 Mbps per connection. This indicates that the uploading and downloading speed of 5G is 100 times faster. Lastly, 5G can support higher user density compared with 4G. 5G is capable of supporting up to 1 million connections per kilometre square while 4G is capable of supporting up to 10 thousand connections per kilometre square. When it is adopted on the construction site, 5G is still able to run every IoT device smoothly despite having a massive number of connected devices on site (Reja and Varghese, 2019).

2.5 Importance of IoTs on Construction Site

There are several importance of IoT on construction site, they are remote inspection and progress report, locating and tracking of site resources monitoring and maintenance of machinery, safety and health of site worker, security of site and better connectivity.

2.5.1 Remote Inspection and Progress Report

Having a personnel to have physical inspection on construction sites with printed checklists and photo taking for documentation to collect as built information is seen as a traditional method (Lind, 2013). After that, the documentation produced has to be filed, compiled and distributed to the contractor manually. With the more complex and big upcoming construction projects, maintaining traditional methods to collect on site progress will become more difficult and more time consuming. Simultaneously, it will also be harder to make sure the accuracy and the of the collected as-built data due to certain site limitations.

IoT based CCTV, drones equipped with cameras, sensors and other digital devices can be used to carry out the inspection of the site remotely. Moreover, the equipped drone has various functions including taking daily pictures, site safety surveillance, visual inspection of unreachable locations and other applications on the construction sites. With the rise of IoT with drone technology, drones nowadays can also carry out real-time monitoring of buildings on construction site. Moreover, drones are also known to be used for monitoring and inspecting bridges, highway, pavement and other large-scale infrastructures to control the construction process by real time videos or images from the site. This method has reduced risk for inspectors, saved time and enhanced the quality of inspection (Anwar, Najam and Amir, 2018).

With IoT, the data collected by drones can be collected and delivered to the application of personnel easily. It allows any personnel to track the progress of the site precisely without major lag time. By using drones on site, many construction and technical issues can be identified immediately and ensure the works are being done according to plan. It allows the construction management to work more effectively on resources as well as eliminate potential delays and issues at site. Another major advantage of drones is that it provides the client the actual visibility of the site in the air. The drones can capture the progress of the site in a very short period to the client especially when the client or manager is unable to visit the site physically due to external factors. Additionally, as drones are capable of taking high resolution video or pictures from any angle, clients and managers can get a better overview of the progress at site daily, weekly or monthly (Tkac and Mesaros, 2019).

2.5.2 Locating and Tracking of Site Resources

In construction projects, locating and tracking the equipment and materials on construction sites is one of the most concerning issues. All the objects on construction sites have to be tracked and located properly to ensure their availability at the all-time (Song, Haas and Caldas, 2006).

The construction inventory such as materials always delivers to the site in bulk and has no proper identification. Improper management of the materials will cause many troubles to track available resources at the site in the future. Sensing devices like RFID tags can be attached on any construction equipment or material to help counting the available stock on the site. RFID systems can get the real-time information of the tag-attached objects. The equipment or material with RFID tags will be recorded from time to time and will be updated to management automatically. When the stocks are running low, a warning will be triggered and notify the site workers to prepare more supplies to the site (Lu et al., 2007). With the RFID system, construction resources can be managed effectively, minimise human error, reduce labour forces in managing the resources, speed up the manual identifying and counting of materials which is time-consuming. This process has eliminated the need to enter the data of materials manually.

Besides, the RFID system and GPS can record all the information of the material or equipment received on site on a tracking system. The tag can store the receiving time, the receiving location, the worker that handles the received items and update the information in the tracking system at the same time. When the material or equipment reaches the site, the RFID tag allows the update of the items in real time. By receiving the items at the proper time, site productivity can be affected. The items can be quickly placed at the right storage location to avoid missing, misplace and damage. Even if the items have gone missing, it can be traced easily by GPS for last detected location or by contacting the site worker who last handled the items through the tracking system (Goodrum, McLaren and Durfee, 2006).

2.5.3 Monitoring and Maintenance of Machinery

Various types of machinery are used on construction sites to save time and enhance efficiency. However, machinery also requires higher cost for its maintenance. Levy (2017) stated that sensors can be equipped in heavy machinery where the sensor is able to monitor the machinery and predict the maintenance session of the machinery through the data collected by sensors.

With IoT, the data collected on the condition of machinery can be transmitted to the user (Zhang, Yao and Jiang, 2014).

Hydraulic system is a system that is widely used in most heavy construction machinery operated on construction sites. Hydraulic oil contamination is the major failure reason for 70% of hydraulic systems (He et al., 2020). Wearing process occurs when metal parts in machinery come into contact with one another. It results in fall off of small metal particles from the contacted metal surfaces. These particles will then accumulate in the oil of machinery and lead to oil contamination. Under this circumstance, the independence sensors along with linear microchannels will be used. The sensors can act as inductive sensors which detect presence of the ferromagnetic and non-ferromagnetic particles in the oil. Simultaneously, the sensors can also identify 4 different types of particle pollution present in the hydraulic oil which can then be used in monitoring and diagnosing the failure in the system (Mabe, Zubia and Gorritxategi, 2017).

Vibration represents another important role and sign of the condition of the hydraulic system in machinery on site. When there is an occurrence of excessive vibration, it indicates the machinery has been overused for a long time or some faults have been detected in the machinery (Han, Jiang and Wang, 2016). Signal can be used to run analysis on possible failure or fault on the hydraulic pump in the machinery. The sensor can be very sensitive towards force, motion and vibration. Currently, the vibration of a hydraulic pump can be monitored and analysed by transforming the vibration motions into electrical signals (Du, Wang and Zhang, 2013). When the vibration has exceeded a certain value, notification will be sent to the machinery monitoring system via the internet to give a warning. Every time when the sensor detects a problem in the machinery, an appropriate analysis should be carried out and proper maintenance can be provided in time if any fault is detected before damaging the machinery.

All the sensor data will be collected and stored in the designated cloud server monitoring platform. The data is used to perform predictive analysis for the machinery in order for early maintenance and repair of the components and parts that are in fault (Lin, Luo and Zhong, 2018). This method can largely reduce and avoid unnecessary machinery downtime, component wear and other possible losses that will result in the overall construction process.

2.5.4 Safety and Health of Site Worker

The rise of IoT and other accompanying technologies such as wearable technology has given huge impacts in the safety and health of construction site workers. Research shows that the accompanying technologies including drones, wearable sensing devices, building information modelling and exoskeletons have high potential in improving the construction site worker health and safety (Nnaji, Okpala and Awolusi, 2020). Among these technologies, wearable sensing devices have been widely covered in research of site worker health and safety on site.

IoT based wearable devices for proximity detection are able to give real time warning signs to workers or operators on possible site hazards. The proximity devices can detect when a worker is caught in or between heavy objects, machinery or equipment. Next, it also monitors the condition and proximity of workers to high voltage objects or energized cable at site to ensure the safety of workers. Falling objects is another common hazard at site. Once the sensor in a wearable device detects any possible falling object within close range of the worker, alert messages or signals will be sent to workers in the form of vibration or sound (Teizer, 2015).

Health and safety of workers can be ensured by physiological monitoring. The heart rate, breathing rate, body temperature, body speed, body posture and stress level of workers can be under constant monitoring to protect them from any possible health risk during construction works at site. The physiological data collected through wearable devices will be analysed by the health system to assess the health status of workers and avoid certain hazards at site. For instance, the hazards include falling from height, slipping, tripping, dehydration, heat and cold (Gatti, Migliaccio and Schneider, 2011). It ensures the health and safety performances of workers in real time and gives quick response in any unforeseen accident.

Some hazards on construction site are invisible. On the construction site, there may be the presence of fires, smokes, explosions, toxic gases and chemicals. They can be detected with environmental sensing of wearable devices. Besides, the environmental sensor can monitor a wider range of concerns such as air quality, environment temperature, light intensity, radiation and more (Swan, 2012). All these environmental data can be checked and monitored by the workers and managers when they are performing their works in order to be alert of what is happening in their surroundings constantly to prevent possible accidents from happening in the first place (Awolusi et al., 2019).

2.5.5 Security of Site

Commonly, CCTV (Closed Circuit Television) is often set up on construction building areas or construction sites to record and monitor the environment for security purposes. However, relying only on traditional passive CCTV has many limitations such as higher storage, no network connection, no alert notifications and higher cost.

Currently, an IoT based security system is introduced at site to assist users to have a remote view of the site either day or night. Unlike traditional CCTV, an IoT based security system can perform a variety of tasks at site and give appropriate responses in real time. CCTV used in this IoT based system is active monitoring. It is connected to the internet network and can be controlled by manager or site workers remotely to capture pictures or to record videos. The suspicious personnel captured in the video or picture will be sent to the manager or site workers for identification (Sruthy, Yamuna and George, 2020). Under the help of WIFI and network connection the transmission of data like pictures and videos will be faster and reduce lag.

The system is equipped with different advanced sensors to ensure site security. These sensors can detect any motion within detecting range, door opening and glass breaking (Charadva, 2014). When sensors detect any suspicious motion on the construction site, the security alarm will be triggered immediately to give warning to the suspicious intruder. Simultaneously, the IoT based security system will send warning notifications to the manager and site workers. With the warning, necessary actions can be taken to prevent any losses of equipment, machinery, or material on the construction site (Chitnis, Deshpande and Shaligram, 2016).

2.5.6 Better Connectivity

The high speeds and intelligent networks are few of the elements that characterised the 5G technology. The 5G system provides several benefits to IoT adoption on construction sites as it has higher bandwidth, lower latency and is implemented with network slicing (Reja and Varghese).

As 5G has a higher bandwidth, it is able to achieve more data transmit rate while reducing the time of uploading and downloading. The outcome is even obvious and significant when the files are large. The drones used on construction sites are equipped with cameras which film or take full high-definition videos and images. The videos and images can be transmitted to the users in real-time or later. Besides, the robotics on construction sites can be controlled remotely through a network to carry out certain site operations. However, these processes require networks with high and wide bandwidth as they involve large files and high amounts of data. With the help of the 5G network, the IoT devices on site like drones and robotics can function without delay and without losing signal connection (Cousins, 2020).

Low latency and network slicing of 5G will largely improve the user’s experience and decision making either on-site or off-site. This is because low latency refers to shorter time between the user’s computing command on certain execution and the actual execution of the operation. In another term, it reduces the lagging time. On the other hand, network slicing which is a leading feature of 5G allows customising the data processing and connectivity based on the user’s requirements (GSM Association, n.d.). Hence, low latency and network slicing are also exceptionally important for the IoT cloud-based platform. 5G will assist the data collection of the IoT devices used on construction sites and undergo analysis over the cloud-based platform with the help of cloud computing before transmitting the data to the user’s devices in real-time. The features of 5G can support and ensure the performance of cloud computing and has the capability for real-time experience. 5G can also function on the cloud-based platform entirely and provide access to other platforms (Chew, et al., 2020).

2.6 Limitations of IoTs

The reported limitations of IoTs include security concerns, privacy concern, data storage, network failure as well as fragmentation and interoperability.

2.6.1 Security Concerns

The major concern of IoT is the security concern due to all kinds of security risks, attacks and its vulnerability (Kumar, Tiwari and Zymbler, 2019). It is essential to have reliable security in IoT because IoT devices contain personal data and information of users. However, there are several challenges in setting up undefeatable security in IoT. Firstly, it is difficult to run complex instructions due to the limitation of CPU in IoT devices. Secondly, the security algorithm designed for the IoT devices must be low power consuming due to the devices themselves required their own battery power to function. Lastly, the implementation of a designed security algorithm has to be low cost in order to cover other IoT devices simultaneously. Other than these, the security of IoT is still not strong enough as the nature of IoT is to enable the IoT devices to work under low computing level and low resources level. This has made implementing strong and complex security in the IoT system a big challenge (Hameed and Alomary, 2019).

Andrea, Chrysostomou and Hadjichristofi (2015) identified the attacks in IoT into four main groups. They are physical attack, software attack, network attack and encryption attack. The physical attack occurs when the attacker appears physically and is within contact with the IoT devices. This type of attack involved the hardware elements of IoT such as the node. For instance, node tempering that damage or replace the entire node in IoT devices and malicious node injection that install a new functioning node in the communication node to help the attacker to access to personal information in IoT devices as attacker can control the data flow between the nodes (Soni, 2019).

Next, a network attack occurs when an attacker gains access into the network of IoT and damages a particular device by manipulation. As an IoT system is a combination of different networks, there are huge amounts of data transfer between different IoT devices. A few examples of network attacks are camouflage, routing attacks, replication attacks and eavesdropping (Babar et al., 2011). Moreover, software attacks are another major security threat in IoT systems. They occur when there are bugs in the IoT application which allow the attacker to gain access into the IoT devices and initiate and attack. According to Ge, et al. (2017), the software attacks include worms, viruses, spyware and DoS attacks. All of these attacks are to gain access, obtain personal data, disturb the system and inject malicious software into the system (Oh and Kim, 2017). Lastly, there is an encryption attack. As IoT is connected with various things through communication channels, encryption algorithms are created to protect the communication. The encryption attacks occur when an attacker reaches the encryption structure and breaks the encryption in IoT devices to make an attack. This attack contains different factors which are side channel attacks, cryptanalysis attack and MITM attack (Soni, 2019).

2.6.2 Privacy Concerns

As everything is connected with the internet in the IoT, privacy on the other hand will become a serious concern. It is important to ensure the users feel comfortable and secure when using any IoT devices. Additionally, it is the right of users to know who will use their data and decide the amount of personal information they are willing to share on the internet with others. (Vikas, 2015) Another issue is that different types of objects communicating have various privacy policies in the IoT system. Hence, every IoT device before transmitting any data must verify their respective privacy policies to protect the privacy of users (Kumar, Tiwari and Zymbler, 2019).

There are several privacy threats in IoT. Firstly, it is the personal identification of the users. From the aspect of privacy, personal identification represents the ability to identify and distinguish a particular person. Additionally, it can also be explained as revealing one identity regarding any personal data of that person such as real name, valid address and other personal information. Once the identity of a user is identified, the privacy violating actions might be carried out by any person on the user. Thus, the identification of users is one of the major privacy threats. With the wide adoption of IoT, other identification threats and related risks will largely increase in future (Seliem, Elgazzar and Khalil, 2018).

Every technology comes with its own advantages and disadvantages. Radio frequency identifier (RFID) is one of the widely used recognising and identifying technology people use in their daily activities. When the RFID is connected to the internet, it can be recognised, monitored and tracked in real time when necessary. Pateriya and Sharma (2011) claimed that the tag in RFID is vulnerable and is subject to spoofing, spying and service attacks. Any unauthorized person may be able to access the vulnerable RFID tag without proper consent from the owner.

Tracking of users is another privacy threat in IoT systems. Tracking of users is based on the identification of users. The tracking turns into a threat when the data collected is used on tracking the user. The most common tracking of users is through location. After identifying a user, the history of binding location can be used in tracking the user. This can be done through applications or services that require the sharing of the user's location. Hence, the user may be tracked by others without the user's proper consent or knowledge. There are multiple available techniques which likely affect the tracking of users. One of the most common tracking techniques is Global Positioning System (GPS) (Warrior, McHenry and McGee, 2003).

2.6.3 Data Storage

The rapid growth of IoT involves generation of huge amounts of data as well as collection of substantial different data bulk. This can be explained as IoT contains various types of digital devices such as sensors, RFID, GPS devices, etc. and as a result, millions of things and people connected to the internet create tremendous amounts of heterogeneous data through the increasing use of digital devices. Under these circumstances, high processing speed and large storage are required. The wide applications of IoT devices have generated a high volume of unstinted data in the IoT ecosystem. The amount of data generated may be doubled in a few months with an accelerated speed (Alshaer, 2018). There is a possible risk that data flood may come due to the digital IoT devices. Unsolved data storage problems will eventually affect the data protection. Once the data storage is damaged, it is very difficult to retrieve or backup all the historical data stored previously. It is crucial and urgent to collect, store, process and retrieve these data for the users. (Papalkar, Nerkar and Dhote, 2017)

Besides, the data collected by IoT can be in different forms such as video, audio, images, raw data etc. They are collected from different sources, from software applications, social networks, humans and digital devices. When it is gathered and appended, it requires more storage capacity. Simultaneously, there is no standard criteria on the secure distribution of IoT devices to the main data centre. This is due to an unsynchronized data transfer process and hence making a disproportionate to the data centre (Gil et al., 2019).

2.6.4 Network Failure

Due to the tremendous increase of devices in IoT and also heterogeneity data, network performance is getting more attention than before. It is expected that billions more IoT devices will be connected to the global network in the future. It is shown that network failure is one of the critical issues in the functionality of an IoT system (Rahim et al., 2021).

As IoT devices are working in a dense network environment as massive amounts of IoT devices are connected to the same network and create traffic. The traffic is often caused by the heterogeneity of data from connected devices and applications. The connected devices which are under the same network will compete for limited radio and network resources. Hence, it is crucial to reduce the network traffic generated by IoT as it will impact overall network services and network resources (Srinidhi, Kumar and Venugopal, 2019). Additionally, IoT is not able to function properly when there is a lack of stable internet or network availability especially in remote areas. It is impossible to obtain the necessary information or messages during emergency cases under an unstable network or during network failure (Pateriya and Sharma, 2011). Without a well-designed system, the IoT will be sensitive to single point failure which may eventually damage the whole system.

Other types of faults like failures of node, network link, communication and protocol conversion will also affect the IoT network. These failures are caused by malfunctioning software and applications installed in the IoT devices. The failure of nodes and links are the most serious among all network failures. The network failures of IoT can occur at local network level, internet level, device level, controller level, gateway level, remote storage and computing level. These network failures are caused by the breakdown or malfunctioning of the system. Once the network failure occurs, the entire IoT network will not be able to operate or to serve the purpose of users. Hence, the IoT system must be designed in a fault tolerant form to prevent any major disaster that will eventually affect the users (Sastry and Bhupathi, 2020).

2.6.5 Fragmentation and Interoperability

The IoT in the current world is filled with more than thousands of digital devices from different inventors and serves different purposes. Each of the invented devices are designed to perform their tasks on a proprietary ecosystem. The proprietary system requires support from various separate tools, gateways and applications. This condition results in unbelievable fragmentation which will leave a great impact on the development of IoT systems in many sectors (Aly, et al., 2019).

Additionally, the latest trend in collaboration of internet, communications and autonomous entities are the initial phase of development of IoT. This trend allows the delivery of various and diverse services and applications. However, this trend is a factor that led to the fragmentation of IoT in the industry because of the challenges in integrating all the diverse technologies of different IoT objects. The diverse technologies then induce the issues of interoperability (Aly et al., 2018). Interoperability is important to the users for its feasibility across different products and services. The term of interoperability means that the devices shall be able to communicate, share information and carry out tasks in a closely synchronized way. Besides, they have to perform the tasks while not compromising any security standards and performance of the connected devices overall (Jindal, Jamar and Churi, 2018). With the overwhelming progress of IoT, more technologies incorporating into the IoT system will pose more difficulties and challenges when designing hardware and software that can establish communication flexibly with others. It also limits the possibility to reuse the existing data, software works, programming interfaces of application and firmware. If an IoT device is poorly planned, there may be negative impact for devices to connect to the networking resources. At the same time, the users may face security threats and different bugs in new services or applications (Zaldivar, Tawalbeh and Muheidat, 2020).

Hence, when designing a software or hardware of IoT devices to be used on the construction site, it is crucial to ensure that the devices are compatible with other cooperating devices due to the fragmentation. Testing for the compatibility of devices has to be conducted thoroughly which is time consuming and costly. It is crucial to ensure the compatibility of devices because one improper planned device will ripple several other devices and cause certain emergency incidents (Chen et al., 2018).

2.6.6 Resource Availability and Cost Consumption

Another key limitation of IoT is the constrained resources. The constrained resources of IoT can be categorized into physical resources and virtual resources. The physical resources are the energy, processing, memory, network bandwidth, etc. On the other hand, the virtual resources are algorithms and protocols used in storage, processing, encryption and data fusion (Zahoor and Mir, 2018).

Among all the resources, the energy resource is treated as one of the valuable resources in the IoT network. This is due to the connected devices used in IoT applications requiring batteries to operate. Furthermore, the data transmission is carried out from time to time and requires support from different accompanying technologies such as gateways, network adapters etc. This data transmission involves high consumption of energy (Aloufi, et al., 2019).

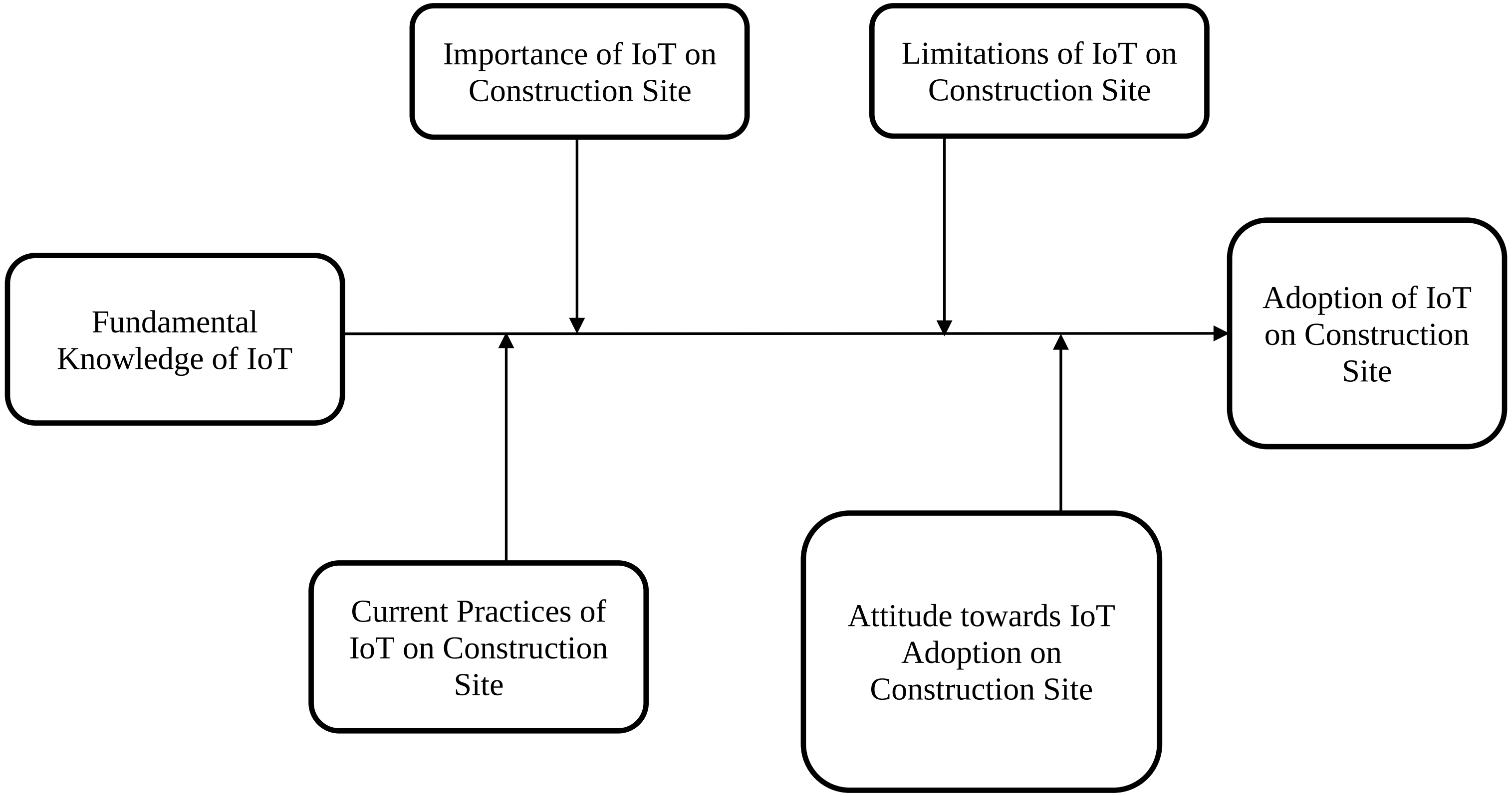
Besides, the capability of IoT in processing and networking is highly dependent on the available energy resource. An IoT node can be defined as a sensor or actuator that are heavily constrained by nature, which are limited available energy and usage of CPU. In several applications, when the nodes are located in remote areas and the battery of nodes are draining out, it is very challenging to replace the battery in a short time to resume the services (Sarwesh, Shet and Chandrasekaran, 2017).

Although IoT devices can provide various services to users, they are often limited by available resources like energy, storage capability and processing power. It is proven that in order to enhance the overall performance of IoT, the IoT resources availability must be allocated efficiently and optimally. However, the allocation of optimal resources in IoT is a critical and difficult task due the heterogeneous and distributed nature of IoT (Angelakis et al., 2016).

2.7 Proposed Theoretical Framework of IoTs on Construction Site

To summarise the literature review of this research, a theoretical framework is set up as shown in Figure 2.9. It is proposed that the fundamental knowledge of IoT, current practices of IoT on construction site, importance of IoT on the construction site, limitations of IoT on construction site and the attitude of individual construction practitioner on IoT adoption on construction site will have impacts on the adoption of IoT by construction practitioners. The knowledge and attitude of construction practitioners will also influence the adoption of IoT on construction sites.

As an outcome, a theoretical framework of evaluating the adoption of IoT on the construction site is developed.



i

Figure 2.9: Theoretical Framework for Adoption of IoT on Construction Site

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

In this chapter, it elaborates on the definition, nature and philosophy of this research. Moreover, it discusses the research method and research design provided with the justification of adopted research design and method. This chapter ends with the timeline and milestone of this research.

3.2 Research Definition

Research could be known as obtaining answers to definite questions through systematic search. It involves using the empirical evidence as well as logical reflection and arguments on social comprehension. The process of research focuses on exploring facts, proposing theories and enhancing understanding. It eventually draws a conclusion and publishes to the public which is subjected to critical review (Oxford Reference, 2021).

Additionally, research can also be known as the formation of new knowledge. It consists of combination and analysis of existing research and leads to brand new outcomes (Western Sydney University, 2021).

3.3 Research Philosophy

Philosophy of research could be referred to as a system of values and assumptions in respect to the development of knowledge. Knowledge is developed when creating new theories through human motivation or addressing certain problems in a particular field which lead to new knowledge development (Saunders, Lewis and Thornhill,2015).

During every stage of a research, several types of hypotheses will be made consciously or unconsciously. These hypotheses include ontological assumptions when one encounters the nature of reality, epistemological assumptions when one comes to the acceptable knowledge of human and axiological assumptions when one refers to the role of ethics as well as values (Burrell and Morgan, 2019).

Saunders, Lewis and Thornhill (2015) listed five major philosophies in research which are positivism, critical realism, interpretivism, postmodernism followed by pragmatism as shown in Figure 3.1.

Firstly, positivism relates to the knowledge and scientific facts that are unambiguous, accurate and not influenced by interpretation of human. It helps a researcher to develop hypotheses through existing theories which can be confirmed and tested.

In contrast, critical realism relates to the explanation of observation and experience as it emphasises on reality (Fleetwood, 2005). It views reality as independent and external, but it is inaccessible purely through knowledge and observation. It also involves experiencing what is the underlying reality of the observation.

Thirdly, interpretivism is similar to critical realism which is a critique of positivism. However, interpretivism highlights that humans cannot be analysed in the same measure as physical phenomena because humans create different meanings. It mainly focuses on creating richer interpretations and understandings of contexts.

On the other hand, postmodernism highlights the role of language and power relations. It emphasises on movement, change and fluidity. There is no definite way to determine language as it is inadequate and partial in nature. It encourages the undertaking of detailed investigation of phenomena and shapes the knowledge during the process of research.

Lastly, pragmatism states a concept is only applicable when they support a course of action. It takes into consideration theories, ideas, hypotheses and findings of research in a practical consequence of certain contexts. As a result, research will start with an issue or a problem and lead to a practical solution that improves future practice.

Figure 3.1 shows the well-known research onion.

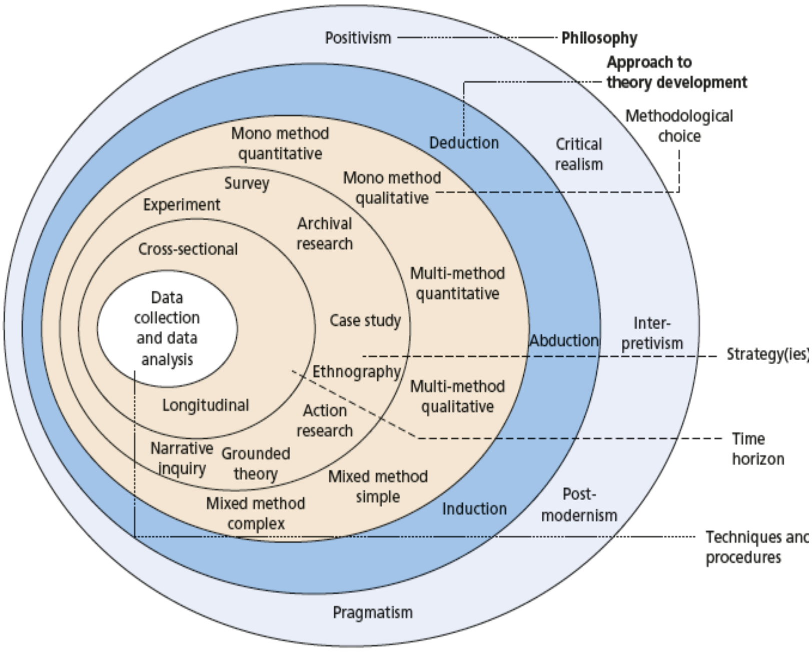


Figure 3.1: Research “Onion"

(Saunders, Lewis and Thornhill, 2015)

3.4 Research Method

According to the pragmatism of research philosophy, there is no fixed type of method suggested to be adopted in the research. Pragmatism acknowledges that there are multiple measures to interpret the world as well as undertake research. However, the research method used to accomplish this research must be able to collect reliable, justifiable and relevant data for the research (Kelemen and Rumens, 2008).

A research method is a plan to cover wide assumptions with in-depth methods of data collection, study and interpretation. A suitable research method should be selected to analyse the research topic, address the research problem and fulfil the research objectives. There are three common research methods that would be considered which are qualitative, quantitative and mixed method.

3.4.1 Qualitative Approach

The aim of the qualitative approach is to obtain detailed and complete description from the participants. It examines the statements and meanings expressed by the participants. Then, the relationships between the statements and meanings will also be studied in order to create a theoretical framework. This approach is non-standardised, the design of this approach will unfold and alter during the conduction of research. The data obtained through this approach is rich, harder to be standardized and more time consuming. The data collected is in the form of pictures, words or objects. For instance, the data can be collected using in-depth interviews, diary entries or other data gathering instruments (Saunders, Lewis and Thornhill, 2015).

3.4.2 Quantitative Method

The aim of the quantitative approach is to categorise attributes and features, analyse them to build a statistical model. It studies the relationship between the variables obtained from the participants. Then, the relationships between the variables will be measured in numeric form and analysed with various statistical techniques. This approach is standardized, every aspect of this approach is properly designed before collecting data. The data obtained through this approach is generalised, more efficient and lacks contextual detail. The data collected is in the form of statistics and numbers. For instance, the data of this approach can be collected by using questionnaires or surveys (Saunders, Lewis and Thornhill, 2015).

3.4.3 Mixed Method Approach

Mixed method research can be defined as a design with methods of inquiry together with philosophical assumptions. It is a combination of quantitative research and qualitative research that can be arranged in simple or concurrent form to more complex or sequential form. It emphasises on both the process of design and the outcome of the design. The data obtained through this approach is fuller and richer than other approaches. The data collected can be the form of words or numbers. Multiple ways can be used to carry out mixed method approach including interviews, questionnaires and others (Saunders, Lewis and Thornhill, 2015).

3.5 Research Design

Research design could be described as a structure or procedure of investigation in order to acquire answers to the research problems. The structure of research design consists of the outline of the outcomes of research hypotheses and impacts on the final data analysis (Kerlinger and Lee, 2000).

Hence, the research design was created in a way that was able to state the research problem, achieve the research aim and answer the research objectives. This research was carried out as an exploratory research design. It was designed in a way to explore for better insights and understandings on the adoption of IoT on construction site to acquire a specific definition to the problems on construction site. The purposes of an exploratory research are identifying problems, obtaining different perspectives and developing formulation of the identified problem (Saunders, Lewis and Thornhill, 2015).

Prior to research design, it was crucial to identify a relevant research topic and research question. In this research, the Covid-19 outbreak impacts on construction site, high accident death and injury rate on construction site and low productivity of construction site led to this research study. Therefore, this research studied mainly on the IoT on construction site which was a new and innovative trend in the construction sector.

The conduct of literature review was then carried out. It was to enable the researchers to have an in-depth understanding and knowledge on the selected research topic. Literature review summarises a large group of previous researches and studies relevant to the selected research topic. Its purpose was to highlight the importance of current research and create differentiation between previous research and current proposed research (Creswell and Creswell, 2018)

The literature review of this research outlined the current IoT practices on construction site, benefits of IoT implementation on construction site and the limitations of IoT. In the meantime, literature review helped researchers to better explore and pinpoint the problem in the research. Reviewing the relevant literature has identified the adoption of IoT on construction site.

In order to minimise the gap of research, research aim and objectives were derived based on the research questions and problems. In order to address research problems and minimise the gaps, the aim of this research was to investigate the adoption of IoT on construction site.

To gather desired data, several methods could be used. In this research, to collect primary data, the quantitative method was selected to evaluate the adoption of IoT on construction site and its relevant concerns. Meanwhile, secondary data was obtained through studying and reviewing conference papers, journal articles, organization reports and books to support the data collected.

Upon collecting the desired data, data analysis had to be conducted to assist researchers to manage the data obtained, study the overall pattern, apply statistical techniques and develop conclusions. There were several types of data analysis used which are narrative analysis, descriptive statistics and inferential statistics. Data analysis was able to analyse the obtained results of data and show the direction of the research by summarising all the obtained data in a proper approach (Saunders, Lewis and Thornhill, 2015).

Next, the conclusion developed must be logical in the research findings. It should have a direct link with the research aim, objectives and findings. Based on these linkages, recommendations of the research could be formulated.

This research is utterly important as it is the complete procedure in evaluating the adoption of IoT on construction site.

Figure 3.2 shows the workflow of research design of this research from first stage until last stage.

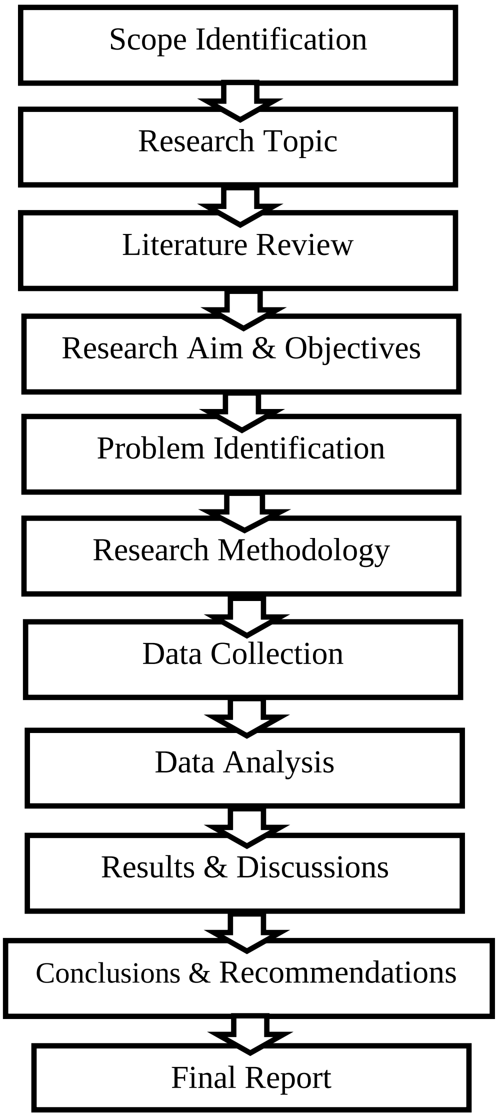


Figure 3.2: Workflow of Research Design

3.6 Justification of Adopted Research Design and Methodology

A research design will be affected by the research philosophy. It is because a research philosophy is a framework which acts as a guidance on how research should be conducted (Collis and Hussey, 2014). With pragmatism as the principle of this research, the research design involves remarkable decision making on establishing the objectives, formulating the problems, and selecting the most suitable methodology of a research. Hence, the literature review is carried out to reduce the knowledge gap and to refine the objectives of research. At the same time, the problems of the research are revealed and the crucial problems are identified in order to enhance the relevance of the research outcomes (Morgan, 2007). As a result, the research is conducted as shown in Figure 3.2.

The approach of theory development of the research is abduction. It is the first stage of the inquiry where the hypothesis of this research is built on the observation on reality of the targeted respondents (Flach and Kakas, 2000).

The methodological choice of the research is mono method quantitative. In considering investigating the adoption of IoT application on construction site, a questionnaire survey is adopted as the strategy to collect data and results. This method can provide a better understanding of the research problem and achieving the research objectives in a relatively short time. The time horizon of this research is cross-sectional where it is only carried out at a specific given time instead of over an extended time.

3.7 Research Instrument

In this research, the responses of respondents were collected through questionnaires which were distributed in the form of Google form. They were distributed through social media applications such as Facebook, Twitter, LinkedIn, WhatsApp and Email. The questionnaire mainly collected responses from construction profession working on construction site to gather their understanding, attitude and adoption towards IoT on the construction site

3.7.1 Questionnaire Design

The questionnaire in this research was designed into four different categories. The questionnaire was derived from the theoretical framework proposed in Chapter 2 (Figure 2.9). The designed questionnaire consisted of two main sections to assess the adoption of IoT on construction site.

In the first part of Section A, it investigated the fundamental knowledge of the respondent towards IoT by emphasising the definitions of IoT. Then, the importance of six different IoT extracted from the literature review which were IoT-based sensor, drone technology, cloud-based IoT platform, robotics, RFID tagging system and 5G network were listed to be evaluated by the respondents. 24 statements related to the importance of IoT were prepared in the third part. Table 3.1 showed the summary of statements regarding the IoT. Whereas the last part focused on the attitude and perception of the respondents if IoT was adopted in their respective organisations.

Table 3.1: Summary of Importance of IoT in Section A

IoT Knowledge	Statement
General IoT	Statement 1-5
IoT-Based Senso	Statement 6-9
Drone Technology	Statement 10-12
Cloud-Based IoT Platform	Statement 13-15
Robotics	Statement 16-18
RFID Tagging System	Statement 19-21
5G Network	Statement 22-24

In the first part of Section B, a question was set up to evaluate the level of intention of respondents in adopting IoT on the construction site. The respondents were tested on their opinions on IoT adoption using likert scale. 10 statements were designed to assess the respondents' attitude towards IoT adoption. Another question was designed to investigate the current level of IoT adoption on the respondents' construction site. Nine construction activities were set up to analyse the willingness of respondents' organisations in adopting IoT and how IoT would transform the construction activities. The last part of Section B was to reveal the limitations of IoT and the concern of respondents when adopting IoT on construction site.

3.8 Sample Process

Sampling is an alternative to select a general subset of the population which is also called sample. The sampling can make the study more precise and specific. In general, sampling is the process of choosing a sample from the population (Showkat and Parveen, 2017).

3.8.1 Defining the Population

Before proceeding into the sample, the population of the study should be defined. The population studied could be defined according to their age, geographical boundaries, sex and other attributes such as occupation, type of organisation, size of company and working experience. Then, the observation would be made on the samples collected from the defined population.

The population of contractors, quantity surveyors and suppliers could be extracted through data provided by official websites available online. The number and grade of registered contractors and suppliers could be obtained through CIDB while the number of registered consultants could be obtained through BQSM. Moreover, the population of accredited architects and engineers also could be gathered through BAM and BEM respectively.

3.8.2 Determine Sampling Design

There are two categories of sampling design which are probability sampling and non-probability sampling. Probability sampling indicates that every sample has an equal chance of being selected. This sampling method provides that the sample is the generalisation of a population. The nature of non-probability is the opposite of probability sampling. This sampling method usually involves non-randomization and judgement causing not all samples have equal chance of being selected (Showkat and Parveen, 2017).

Non-probability sampling consists of convenience sampling, purposive sampling, quota sampling and judgement sampling. In this study, convenience sampling was used. This method of sampling enabled the researcher to select the participants as per their own convenience. The participants selected were readily available or accessible for the researcher. The questionnaires in this study were distributed mainly to previous colleagues, surrounding individuals and other connections who work on construction site.

3.8.3 Determine Sampling Size

The sampling size was determined according to the central limit theorem (CLT). It stated its sample distribution was almost similar to normal distribution when the sample size increased without considering the population distribution. When the sample size is equal to or exceeded 30, the CLT could be used (Ganti, 2021).

3.8.4 Executing Sampling Process

After receiving all the responses from the respondents, descriptive and inferential statistical tests were carried out to access and analyse the results to produce inferences of the population.

3.8.5 Target Respondents

The target respondents of this research were the professionals mainly working on construction site or visiting construction sites regularly in Malaysia. These professions came from different working backgrounds mainly working on construction sites including contractor, consultant, supplier, sub-contractor and specialist. Besides, they had different age groups, working experience and experience in using IoT.

3.9 Data Analysis

In order to ensure the consistency of the questions designed in the questionnaire, this research carried out Cronbach's Alpha to test the reliability. Moreover, descriptive analysis and inferential analysis were adopted when carrying out the analysis.

3.9.1 Reliability Analysis

All matrix questions in Section A and Section B adopted this reliability test. This reliability test is an assessment tool to produce solid and well - constructed results. The type of reliability used in this research was internal consistency reliability which was to examine the degree of non-identical items that study the same construct will produce similar results (Phelan and Wren, 2005). The alpha coefficient range from zero to one. Any alpha coefficient value higher than 0.7 stipulates that the data are reliable.

3.9.2 Normality Test

Prior to any statistical test, an assessment on the normality of data should be identified to decide on the appropriate parametric and non-parametric testing for data analysis. Two of the most used methods to test the normality of continuous data are Kolmogorov–Smirnov test and Shapiro–Wilk test. Kolmogorov–Smirnov test is more suitable for larger sample size larger than 50 samples while Shapiro–Wilk test is more suitable for smaller sample size either less than 50 samples up to 2000 samples (Laerd Statistics, 2020). The null hypothesis of the normality test is that the data are normally distributed. If the p-value in the test is lesser than 0.05, the null hypothesis is rejected.

3.9.3 Descriptive Analysis

Descriptive analysis assists in summarising and describing the data efficiently. It summarises the large amounts of data in a simple form. Basically, it is shown with simple graphics analysis to form the quantitative data virtually (Laerd Statistics, 2020).

Median is a useful statistical method to measure the centre of the collected data. It is sorted in ascending or descending order before identifying the middle value from the collected data. It is more suitable to be used for data that is skewed. Unlike mean, median is less influenced by outliers which makes it opposed to the mean sometimes (Ganti, 2021).

3.9.4 Inferential Analysis

Freidman test and Kruskal-Wallis test were used to analyse the data collected in Chapter 4. Firstly, the Friedman test was one of the non-parametric tests. It was used to test for the dissimilarity between three groups or more (Schenkelberg, 2020.) Next, the Kruskal-Wallis test was another non-parametric test. This test had a multiple pairwise-comparison function which was able to compute multiple testing between different groups. It showed which pairs of groups led to the significance different from the output (STHDA, n.d.).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the result collected from the survey. The results are analysed and inferred to show the results of generalisation. Section 4.2 presents the background of the respondents while Section 4.3 and Section 4.4 presents reliability analysis and normality test respectively. Section 4.5 to Section 4.14 reports the results of the data. Lastly, the discussion for the results is summarised in Section 4.15.

4.2 Respondents Background

A total of 300 questionnaires were distributed and 117 responses were collected. The attributes of the respondents are summarised and presented in Table 4.1.

The highest respondents are from construction company. Most of the respondents aged between below 25 to 30 years old at 29.1% and 29.1% of respondents have 0 to 5 years of working experience in the construction industry. It also shows that 56.4% of the respondents are from large organisations and 43.6% of respondents are from small and medium organisations.

The size of company of the respondents are grouped as small and medium organisation and also large organisation. The small and medium organisation is firm that has sales turnover lower than RM20 million or consists of full-time workers lesser than 75. While large organisation has sales turnover higher than RM 20 million or full-time workers more than 75 (SME Corp. Malaysia, 2021).

Table 4.1: Attributes of Respondents (N=117)

General	Categories	Frequency	Percentage (%)
Organisation Business Activities	Consultancy Company	32	27.4
	Construction Company	36	30.8
	Supplier/ Sub-contractor/ Specialist Company	33	28.2
	Development Company	16	13.7
Age	Below 25	34	29.1
	26-30	34	29.1
	31-40	31	26.5
	Above 40	18	15.4
Working Experience	0-2 years	34	29.1
	3-5 years	34	29.1
	6-10 years	31	26.5
	11-20 years	18	15.4
Size of Organisation	Small and Medium	51	43.6
	Large	66	56.4

4.3 Reliability Analysis

Table 4.2 presents the result of reliability analysis on two sections of the questionnaire. It is shown that the Cronbach Alpha Value for the two sections is higher than 0.7 which indicates the two sections have consistent results.

Table 4.2: Cronbach Alpha Value of Reliability Test

Section	Cronbach Alpha Value
Section A: Fundamental Knowledge of IoT	0.948
Section B: Adoption of IoT	0.949

4.4 Normality Test

Table 4.3 presents the result of the Shapiro-Wilk test on the dependent list. The Sig. (p) shows that all the data collected in Section A and Section B of questionnaires are lower than 0.05 which is non-normally distributed.

Table 4.3: Normality Distribution Test

Section	Sig.
Section A: Fundamental Knowledge of IoT	0.000
Section B: Adoption of IoT	0.000

4.5 IoT Adopted on construction site

Table 4.4 presents the ranking of the adoption of IoT on construction site by the respondents. Majority of the respondents are not adopting robotics, cloud-based IoT platform, RFID tagging system, drone technology and 5G network on construction site. The percentages are 88.1%, 79.2%, 70.3%. 68.3%, 58.4% and 53.5 respectively.

Table 4.4: Ranking of the IoT Adopted on Construction Site

Statements	Median	Median Frequency	Percentage (%)
Robotics	1	89	88.1
Cloud-based IoT Platform	1	80	79.2
IoT-based Sensor	1	71	70.3
RFID Tagging System	1	69	68.3
Drone Technology	1	59	58.4
5G Network	1	54	53.5

Note: 0= No Idea, 1= Not Adopting, 2= Will Be Adopting, 3= Adopting Less Than 1 Year, 4= Already Adopted More Than 1 Year

4.6 Importance Level of IoT on Construction Site

Table 4.5 presents the ranking of the importance level of the IoT on construction site by the respondents. The respondents have agreed that drone technology is much important at 30.7%, IoT-based sensor and RFID tagging system are important at 22.8% and 21.8%. Robotics is rated by the respondents as slightly important on construction site at 35.6%. While more than half of the respondents have agreed that the cloud-based IoT platform and 5G network is not important at 52.5% and 50.5% respectively.

Table 4.5: Ranking of the Importance Level of IoT on Construction Site

Statements	Median	Median Frequency	Percentage (%)
Drone Technology	3	31	30.7
IoT-based Sensor	2	23	22.8
RFID Tagging System	2	22	21.8
Robotics	1	36	35.6
Cloud-based IoT Platform	0	53	52.5
5G Network	0	51	50.5

Note: 0= Not Important, 1= Slightly Important, 2= Important, 3= Much Important, 4= Very Much Important

The mean ranking of the importance level of IoT on construction site are presented in Table 4.6. The Friedman test has listed out the mean rank of the importance level of IoT and the results are statistically significant.

Table 4.6: Mean Ranking of the Importance Level of IoT on Construction Site

Statements	Mean Rank	Chi-Square	Asymp. Sig.
Drone Technology	5.31	203.987	0.000
RFID Tagging System	3.91		
IoT-based Sensor	3.55		
Robotics	3.20		
5G Network	3.64		
Cloud-based IoT Platform	2.39		

According to the table 4.6, the highest ranking of importance level of IoT on the construction site by the respondents is drone technology (5.31), then followed by RFID Tagging System (3.91), IoT-based Sensor (3.55), Robotics (3.20), 5G Network (3.64) and lastly cloud-based IoT platform (2.39).

Post hoc tests are conducted on the importance level of IoT on construction site with the attributes of the respondents. Table 4.7 presents the rejected null hypothesis which are statistically significant with $p<0.05$.

Table 4.7: Rejected Null Hypothesis for the Importance level of IoT on Construction Site

Null Hypothesis	Sig.
The perception on the importance of ‘IoT-based sensor’ is same between contractor and supplier/sub-contractor/specialist.	0.015
The perception of ‘IoT-based Sensor’ is same between consultant and supplier/sub-contractor/specialist.	0.000
The perception on the importance of ‘drone technology’ is same between contractor and supplier/sub-contractor/specialist.	0.036
The perception on the importance of ‘drone technology’ is same between consultant and supplier/sub-contractor/specialist.	0.000
The perception on the importance of ‘cloud-based IoT platform’ is same between consultant and supplier/sub-contractor/specialist.	0.000
The perception on the importance of ‘cloud-based IoT platform’ is same between contractor and consultant.	0.011
The perception on the importance of ‘5G network’ is same between consultant and supplier/sub-contractor/specialist.	0.018

Table 4.7 (Continued)

The perception on the importance of 'IoT-based sensor' is same between respondents below 25 and respondents between 31-40.	0.006
The perception on the importance of 'IoT-based sensor' is same between respondents between 26-30 and respondents between 31-40.	0.000
The perception on the importance of 'Drone technology' is same between respondents below 25 and respondents between 31-40.	0.006
The perception on the importance of 'Drone technology' is same between respondents between 26-30 and respondents between 31-40.	0.000
The perception on the importance of 'cloud-based IoT platform' is same between respondents below 25 and respondents between 31-40.	0.000
The perception on the importance of 'cloud-based IoT platform' is same between respondents between 26-30 and respondents between 31-40.	0.000
The perception on the importance of 'RFID tagging system' is same between respondents between 26-30 and respondents between 31-40.	0.000
The perception on the importance of '5G network' is same between respondents below 25 and respondents between 31-40.	0.000
The perception on the importance of 'IoT-based sensor' is same between respondents with 0-2 years and respondents with 6-10 years.	0.027
The perception on the importance of 'IoT-based sensor' is same between respondents with 3-5 years and respondents with 6-10 years.	0.000
The perception on the importance of Drone technology' is same between respondents with 0-2 years and respondents with 6-10 years.	0.048
The perception on the importance of 'Drone technology' is same between respondents with 3-5 years and respondents with 6-10 years.	0.000
The perception on the importance of 'cloud-based IoT platform' is same between respondents with 0-2 years and respondents with 6-10 years.	0.000
The perception on the importance of 'cloud-based IoT platform' is same between respondents with 3-5 years and respondents with 6-10 years.	0.000
The perception on the importance of 'RFID tagging system' is same between respondents with 3-5 years and respondents with 6-10 years.	0.012
The perception on the importance of '5G network' is same between respondents with 0-2 years and respondents with 6-10 years.	0.002
The perception on the importance of 'IoT-based sensor' is same between respondents in large organisation and respondents in small and medium organisation.	0.000

The perception on the importance of 'drone technology' is same between respondents in large organisation and respondents in small and medium organisation.	0.000
The perception on the importance of 'cloud-based IoT platform' is same between respondents in large organisation and respondents in small and medium organisation.	0.000
The perception on the importance of 'RFID tagging system' is same between respondents in large organisation and respondents in small and medium organisation.	0.000
The perception on the importance of '5G network' is same between respondents in large organisation and respondents in small and medium organisation.	0.005

The results of the post hoc test for the importance level of IoT on construction site reported in Table 4.7 are summarised below.

a) The respondents working for construction company perceived

i. higher importance of IoT-based sensor (mean rank= 52.17) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.41).

ii. higher importance of drone technology (mean rank= 52.96) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.11).

b) The respondents working for consultancy company perceived

i. higher importance of IoT-based sensor (mean rank= 69.89) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.41).

ii. higher importance of drone technology (mean rank= 66.22) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.11).

iii. higher importance of cloud-based IoT platform (mean rank= 69.56) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.91).

iv. higher importance of cloud-based IoT platform (mean rank= 69.56) than the respondents working for contractor company (mean rank=49.25).

v. higher importance of 5G network (mean rank= 63.58) than the respondents working for supplier/sub-contractor/specialist company (mean rank=43.73).

c) The respondents aged below 25 years old perceived

i. higher importance of IoT-based sensor (mean rank= 55.65) than the respondents aged 31 – 40 years old (mean rank=32.78).
ii. higher importance of drone technology (mean rank= 55.00) than the respondents aged 31 – 40 years old (mean rank=32.41).
iii. higher importance of cloud-based IoT platform (mean rank= 59.81) than the respondents aged 31 – 40 years old (mean rank=30.56).
iv. higher importance of 5G network (mean rank= 63.46) than the respondents aged 31 – 40 years old (mean rank=36.46).

d) The respondents aged 26-30 years old perceived

i. higher importance of IoT-based sensor (mean rank= 64.98) than the respondents aged 31 – 40 years old (mean rank=32.78).
ii. higher importance of drone technology (mean rank= 66.03) than the respondents aged 31 – 40 years old (mean rank=32.41).
iii. higher importance of cloud-based IoT platform (mean rank= 62.98) than the respondents aged 31 – 40 years old (mean rank=30.56).
iv. higher importance of RFID tagging system (mean rank= 63.76) than the respondents aged 31 – 40 years old (mean rank=35.84).

e) The respondents with 0-2 years working experience perceived

i. higher importance of IoT-based sensor (mean rank= 54.62) than the respondents with 6-10 years working experience (mean rank=34.91).
ii. higher importance of drone technology (mean rank= 54.16) than the respondents with 6-10 years working experience (mean rank=35.87).
iii. higher importance of cloud-based IoT platform (mean rank= 59.21) than the respondents with 6-10 years working experience (mean rank=33.57).

iv. higher importance of 5G network (mean rank= 61.32) than the respondents with 6-10 years working experience (mean rank=38.16).

f) The respondents with 3-5 years working experience perceived

i. higher importance of IoT-based sensor (mean rank= 63.85) than the respondents with 6-10 years working experience (mean rank=34.91).
ii. higher importance of drone technology (mean rank= 63.33) than the respondents with 6-10 years working experience (mean rank=35.87).
iii. higher importance of cloud-based IoT platform (mean rank= 60.50) than the respondents with 6-10 years working experience (mean rank=33.57).
iv. higher importance of RFID tagging system (mean rank= 60.77) than the respondents with 6-10 years working experience (mean rank=39.24).

g) The respondents working for large organisation perceived

i. higher importance of IoT-based sensor (mean rank= 65.86) than the respondents working for small and medium organisation (mean rank=35.23).
ii. higher importance of drone technology (mean rank= 63.97) than the respondents working for small and medium organisation (mean rank=37.23).
iii. higher importance of cloud-based IoT platform (mean rank= 61.30) than the respondents working for small and medium organisation (mean rank=40.07).
iv. higher importance of RFID tagging system (mean rank= 63.16) than the respondents working for small and medium organisation (mean rank=38.09).
v. higher importance of 5G network (mean rank= 58.27) than the respondents working for small and medium organisation (mean rank=43.29).

4.7 Importance of IoT on Construction Site

Table 4.8 presents the ranking of the importance of IoT on construction site by the respondents. More than half of the respondents have ranked top for the robotics carries out repetitive works efficiently (64.4%), then followed by drone technology carries out remote monitoring and surveillance (60.4%), drone technology carries out high-elevation inspection (59.4%) and robotics carries out dangerous and high risk works (51.5%).

Table 4.8: Ranking of the Importance of IoT on Construction Site

Importance of IoT	Median	Median Frequency	Percentage (%)
Robotics carries out repetitive works efficiently	3	65	64.4
Drone technology carries out remote monitoring and surveillance	3	61	60.4
Drone technology carries out high-elevation inspection	3	60	59.4
Robotics carries out dangerous and high risk works	3	52	51.5
5G provides better and more stable connectivity.	3	46	45.5
Robotics saves cost and time	3	45	44.6
RFID tagging system tracks materials and equipment	3	44	43.6
IoT is important in remote Inspection and progress report	3	41	40.6
IoT-based sensor ensures safety of workers	3	40	39.6
RFID tagging system provides identification of objects	3	39	38.6
Drone technology obtains real-time information	3	38	37.6
IoT-based sensor collects and gathers the relevant data	3	38	37.6
IoT is important in locating and tracking of site resources	3	37	36.6
IoT is important for safety and health of site workers	3	35	34.7
5G allows faster transmission of huge data and big files.	3	33	32.7
IoT-based sensor improves performance of equipment	2	49	48.5
IoT-based sensor monitors site conditions	2	47	46.5
Cloud-based IoT platform manages huge data generated by IoT devices	2	45	44.6
5G supports higher IoT user density.	2	44	43.6
Cloud-based IoT platform provides infinite storage for data	2	43	42.6

Table 4.8 (Continued)

IoT is important in monitoring and maintenance of machinery	2	41	40.6
Cloud-based IoT platform analyses data generated by IoT devices	2	38	37.6
IoT is important for security of site	2	37	36.6
RFID tagging system allows better planning of project schedules	2	36	35.6

Note: 0= Strongly Disagree, 1= Disagree, 2= Neutral, 3= Agree, 4= Strongly Agree

The mean ranking of the importance of IoT on construction site is presented in Table 4.9. The Friedman test has listed out the mean rank and the results are statistically significant.

Table 4.9: Mean Ranking for the Importance of IoT on Construction Site

Importance of IoT	Mean Rank	Chi-Square	Asymp. Sig.
Robotics carries out dangerous and high risk works	19.31	904.788	0.000
Drone technology carries out high-elevation inspection	18.79		
Robotics carries out repetitive works efficiently	18.43		
Drone technology carries out remote monitoring and surveillance	17.82		
IoT is important for safety and health of site workers	15.50		
IoT-based sensor ensures safety of workers	15.20		
RFID tagging system provides identification of objects	15.08		
IoT is important in remote Inspection and progress report	14.73		
RFID tagging system tracks materials and equipment	13.77		
Drone technology obtains real-time information	13.67		
5G allows faster transmission of huge data and big files.	13.53		
IoT-based sensor collects and gathers the relevant data	13.13		
IoT is important in locating and tracking of site resources	13.10		

Table 4.9 (Continued)

5G provides better and more stable connectivity.	12.36
Robotics saves cost and time	12.10
IoT-based sensor monitors site conditions	10.56
5G supports higher IoT user density.	9.67
IoT is important in monitoring and maintenance of machinery	9.16
RFID tagging system allows better planning of project schedules	8.97
Cloud-based IoT platform manages huge data generated by IoT devices	7.94
IoT is important for security of site	7.56
Cloud-based IoT platform provides infinite storage for data	7.14
IoT-based sensor improves performance of equipment	6.47
Cloud-based IoT platform analyses data generated by IoT devices	6.00

According to the Table 4.9, the five highest mean ranking of the importance of IoT are robotics carries out dangerous and high risk works (19.31), drone technology carries out high-elevation inspection (18.79), robotics carries out repetitive works efficiently (18.43), drone technology carries out remote monitoring and surveillance (17.82) and IoT is important for safety and health of site workers (15.50).

Post hoc tests are conducted on the level of agreement towards the statements with the entire attributes of the respondents. Table 4.10 presents the rejected null hypothesis which are statistically significant with $p<0.05$.

Table 4.10: Rejected Null Hypothesis for the Importance of IoT on Construction Site

Null Hypothesis	Sig.
The agreement of 'IoT is important in remote inspection and progress report' is same between contractor and supplier/sub-contractor/specialist.	0.006
The agreement of 'IoT is important in remote inspection and progress report' is same between contractor and consultant.	0.001
The agreement of 'IoT is important in locating and tracking of site resources' is same between consultant and supplier/sub-contractor/specialist.	0.050

Table 4.10 (Continued)

The agreement of 'IoT-based sensor collects and gathers the relevant data' is same between contractor and supplier/sub-contractor/specialist.	0.002
The agreement of 'IoT-based sensor collects and gathers the relevant data' is same between consultant and supplier/sub-contractor/specialist.	0.000
The agreement of 'IoT-based sensor ensures safety of workers' is same between contractor and supplier/sub-contractor/specialist.	0.019
The agreement of 'IoT-based sensor ensures safety of workers' is same between consultant and supplier/sub-contractor/specialist.	0.017
The agreement of 'Cloud-based IoT platform manages huge data generated by IoT devices' is same between contractor and supplier/sub-contractor/specialist.	0.000
The agreement of 'Cloud-based IoT platform manages huge data generated by IoT devices' is same between consultant and supplier/sub-contractor/specialist.	0.000
The agreement of 'Cloud-based IoT platform provides infinite storage for data' is same between contractor and supplier/sub-contractor/specialist.	0.001
The agreement of 'Cloud-based IoT platform provides infinite storage for data' is same between consultant and supplier/sub-contractor/specialist.	0.000
The agreement of 'Cloud-based IoT platform analyses data generated by IoT devices' is same between contractor and supplier/sub-contractor/specialist.	0.000
The agreement of 'Cloud-based IoT platform analyses data generated by IoT devices' is same between consultant and supplier/sub-contractor/specialist.	0.000
The agreement of 'Robotics carries out repetitive works efficiently' is same between contractor and supplier/sub-contractor/specialist.	0.031
The agreement of 'Robotics carries out repetitive works efficiently' is same between consultant and supplier/sub-contractor/specialist.	0.001
The agreement of '5G provides better and more stable connectivity' is same between consultant and supplier/sub-contractor/specialist.	0.000
The agreement of '5G provides better and more stable connectivity' is same between contractor and consultant.	0.006
The agreement of '5G allows faster transmission of huge data and big files' is same between consultant and supplier/sub-contractor/specialist.	0.000
The agreement of '5G allows faster transmission of huge data and big files' is same between contractor and consultant.	0.002
The agreement of '5G supports higher IoT user density' is same between consultant and supplier/sub-contractor/specialist.	0.001

Table 4.10 (Continued)

The agreement of ‘IoT is important in remote Inspection and progress report.’ is same between respondents between 26-30 and respondents between 31-40.	0.044
The agreement of ‘IoT is important for safety and health of site workers.’ is same between respondents between 26-30 and respondents between 31-40.	0.000
The agreement of ‘IoT-based sensor collects and gathers the relevant data.’ is same between respondents between 26-30 and respondents between 31-40.	0.042
The agreement of ‘IoT-based sensor ensures safety of workers.’ is same between respondents between 26-30 and respondents between 31-40.	0.047
The agreement of ‘Cloud-based IoT platform manages huge data generated by IoT devices.’ is same between respondents below 25 and respondents between 31-40.	0.031
The agreement of ‘Cloud-based IoT platform manages huge data generated by IoT devices.’ is same between respondents between 26-30 and respondents between 31-40.	0.001
The agreement of ‘Cloud-based IoT platform provides infinite storage for data.’ is same between respondents below 25 and respondents between 31-40.	0.038
The agreement of ‘Cloud-based IoT platform provides infinite storage for data.’ is same between respondents between 26-30 and respondents between 31-40.	0.005
The agreement of ‘Cloud-based IoT platform analyses data generated by IoT devices.’ is same between respondents between 26-30 and respondents between 31-40.	0.009
The agreement of ‘Robotics carries out dangerous and high risk works.’ is same between respondents below 25 and respondents between 31-40.	0.032
The agreement of ‘RFID tagging system tracks materials and equipment.’ is same between respondents between 26-30 and respondents between 31-40.	0.045
The agreement of ‘RFID tagging system provides identification of objects.’ is same between respondents between 26-30 and respondents between 31-40.	0.001
The agreement of ‘5G provides better and more stable connectivity.’ is same between respondents below 25 and respondents between 31-40.	0.000
The agreement of ‘5G provides better and more stable connectivity.’ is same between respondents between 26-30 and respondents between 31-40.	0.000
The agreement of ‘5G allows faster transmission of huge data and big files.’ is same between respondents below 25 and respondents between 31-40.	0.002
The agreement of ‘5G allows faster transmission of huge data and big files.’ is same between respondents between 26-30 and respondents between 31-40.	0.000

Table 4.10 (Continued)

The agreement of ‘5G supports higher IoT user density.’ is same between respondents below 25 and respondents between 26-30.	0.040
The agreement of ‘5G supports higher IoT user density.’ is same between respondents between 26-30 and respondents between 31-40.	0.000
The agreement of ‘IoT is important in remote Inspection and progress report.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.023
The agreement of ‘IoT is important in monitoring and maintenance of machinery.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.039
The agreement of ‘IoT is important for safety and health of site workers.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.001
The agreement of ‘IoT-based sensor collects and gathers the relevant data.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.014
The agreement of ‘Cloud-based IoT platform manages huge data generated by IoT devices.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.004
The agreement of ‘Cloud-based IoT platform provides infinite storage for data.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.031
The agreement of ‘Cloud-based IoT platform analyses data generated by IoT devices.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.014
The agreement of ‘RFID tagging system provides identification of objects.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.048
The agreement of ‘5G provides better and more stable connectivity.’ is same between respondents with 0-2 years and respondents with 6-10 years.	0.010
The agreement of ‘5G provides better and more stable connectivity.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.003
The agreement of ‘5G allows faster transmission of huge data and big files.’ is same between respondents with 0-2 years and respondents with 6-10 years.	0.031
The agreement of ‘5G allows faster transmission of huge data and big files.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.000
The agreement of ‘5G supports higher IoT user density.’ is same between respondents with 3-5 years and respondents with 6-10 years.	0.000
The agreement of ‘IoT is important in remote Inspection and progress report.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.000

Table 4.10 (Continued)

The agreement of ‘IoT is important in locating and tracking of site resources.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.000
The agreement of ‘IoT is important in monitoring and maintenance of machinery.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.025
The agreement of ‘IoT is important for safety and health of site workers.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.002
The agreement of ‘IoT is important for security of site.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.045
The agreement of ‘IoT-based sensor collects and gathers the relevant data.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.002
The agreement of ‘IoT-based sensor monitors site conditions.’ is same between respondents in large organisation and respondents in small and medium organisation.	0.041
The agreement of ‘Drone technology carries out high-elevation inspection.’ is same between respondents in large organisation and respondents in small and medium organisation	0.016
The agreement of ‘Cloud-based IoT platform manages huge data generated by IoT devices.’ is same between respondents in large organisation and respondents in small and medium organisation	0.001
The agreement of ‘Cloud-based IoT platform provides infinite storage for data.’ is same between respondents in large organisation and respondents in small and medium organisation	0.002
The agreement of ‘Cloud-based IoT platform analyses data generated by IoT devices.’ is same between respondents in large organisation and respondents in small and medium organisation	0.001
The agreement of ‘Robotics carries out repetitive works efficiently.’ is same between respondents in large organisation and respondents in small and medium organisation	0.039
The agreement of ‘RFID tagging system tracks materials and equipment.’ is same between respondents in large organisation and respondents in small and medium organisation	0.000
The agreement of ‘RFID tagging system provides identification of objects.’ is same between respondents in large organisation and respondents in small and medium organisation	0.000
The agreement of ‘5G provides better and more stable connectivity.’ is same between respondents in large organisation and respondents in small and medium organisation	0.000

Table 4.10 (Continued)

The agreement of '5G allows faster transmission of huge data and big files.' is same between respondents in large organisation and respondents in small and medium organisation	0.000
The agreement of '5G supports higher IoT user density.' is same between respondents in large organisation and respondents in small and medium organisation	0.000

a) The respondents working for construction company are

i. more agreed on IoT is important in remote inspection and progress report (mean rank= 56.71) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.68).

ii. more agreed on IoT-based sensor collects and gathers the relevant data (mean rank= 56.01) than the respondents working for supplier/sub-contractor/specialist company (mean rank=32.08).

iii. more agreed on IoT-based sensor ensures safety of workers (mean rank= 57.22) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.38).

iv. more agreed on Cloud-based IoT platform manages huge data generated by IoT devices (mean rank= 57.28) than the respondents working for supplier/sub-contractor/specialist company (mean rank=28.30).

v. more agreed on Cloud-based IoT platform provides infinite storage for data (mean rank= 54.03) than the respondents working for supplier/sub-contractor/specialist company (mean rank=28.92).

vi. more agreed on Cloud-based IoT platform analyses data generated by IoT devices (mean rank= 57.75) than the respondents working for supplier/sub-contractor/specialist company (mean rank=30.41).

vii. more agreed on Robotics carries out repetitive works efficiently (mean rank= 54.18) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.58).

viii. more agreed on 5G provides better and more stable connectivity (mean rank= 47.06) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.95).

ix. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 47.72) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.09).

b) The respondents working for consultancy company perceived

i. more agreed on IoT is important in remote inspection and progress report (mean rank= 61.41) than the respondents working for supplier/sub-contractor/specialist company (mean rank=34.68).

ii. more agreed on IoT-based sensor collects and gathers the relevant data (mean rank= 64.88) than the respondents working for supplier/sub-contractor/specialist company (mean rank=32.08).

iii. more agreed on IoT-based sensor ensures safety of workers (mean rank= 58.05) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.38).

iv. more agreed on Cloud-based IoT platform manages huge data generated by IoT devices (mean rank= 57.28) than the respondents working for supplier/sub-contractor/specialist company (mean rank=28.30).

v. more agreed on Cloud-based IoT platform provides infinite storage for data (mean rank= 70.36) than the respondents working for supplier/sub-contractor/specialist company (mean rank=28.92).

vi. more agreed on Cloud-based IoT platform analyses data generated by IoT devices (mean rank= 64.64) than the respondents working for supplier/sub-contractor/specialist company (mean rank=30.41).

vii. more agreed on Robotics carries out repetitive works efficiently (mean rank= 61.27) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.58).

viii. more agreed on 5G provides better and more stable connectivity (mean rank= 68.89) than the construction company (mean rank=37.95).

ix. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 72.12) than the construction company (mean rank=34.09).

x. more agreed on 5G supports higher IoT user density (mean rank= 65.58) than the respondents working for supplier/sub-contractor/specialist company (mean rank=40.12).

c) The respondents aged below 25 are

i. more agreed on Cloud-based IoT platform manages huge data generated by IoT devices (mean rank= 55.03) than the respondents aged 31 – 40 years old (mean rank=36.41).

ii. more agreed on Cloud-based IoT platform provides infinite storage for data (mean rank= 55.75) than the respondents aged 31 – 40 years old (mean rank=37.65).

iii. more agreed on Robotics carries out dangerous and high risk works (mean rank= 57.22) than the respondents aged 31 – 40 years old (mean rank=39.71).

iv. more agreed on 5G provides better and more stable connectivity (mean rank= 59.29) than the respondents aged 31 – 40 years old (mean rank=32.94).

v. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 55.24) than the respondents aged 31 – 40 years old (mean rank=30.82).

vi. more agreed on 5G supports higher IoT user density (mean rank= 49.01) than the respondents aged 31 – 40 years old (mean rank=37.06).

d) The respondents aged 26-30 years old are

i. more agreed on IoT is important in remote inspection and progress report (mean rank= 58.29) than the respondents aged 31 – 40 years old (mean rank=40.18).

ii. more agreed on IoT is important for safety and health of site workers (mean rank= 65.02) than the respondents aged 31 – 40 years old (mean rank=37.07).

iii. more agreed on IoT-based sensor collects and gathers the relevant data (mean rank= 57.59) than the respondents aged 31 – 40 years old (mean rank=39.41).

iv. more agreed on IoT-based sensor ensures safety of workers (mean rank= 59.91) than the respondents aged 31 – 40 years old (mean rank=41.79).

v. more agreed on Cloud-based IoT platform manages huge data generated by IoT devices (mean rank= 61.88) than the respondents aged 31 – 40 years old (mean rank=36.41).

vi. more agreed on Cloud-based IoT platform provides infinite storage for data (mean rank= 59.86) than the respondents aged 31 – 40 years old (mean rank=37.65).

vii. more agreed on Cloud-based IoT platform analyses data generated by IoT devices (mean rank= 59.50) than the respondents aged 31 – 40 years old (mean rank=38.60).

viii. more agreed on RFID tagging system tracks materials and equipment (mean rank= 60.80) than the respondents aged 31 – 40 years old (mean rank=42.93).

ix. more agreed on RFID tagging system provides identification of objects (mean rank= 64.68) than the respondents aged 31 – 40 years old (mean rank=39.69).

x. more agreed on 5G provides better and more stable connectivity (mean rank= 61.06) than the respondents aged 31 – 40 years old (mean rank=32.94).

xi. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 67.42) than the respondents aged 31 – 40 years old (mean rank=30.82).

xii. more agreed on 5G supports higher IoT user density (mean rank= 67.41) than the respondents aged 31 – 40 years old (mean rank=37.06).

e) The respondents with 0-2 years working experience are

i. more agreed on 5G provides better and more stable connectivity (mean rank= 57.34) than the respondents with 6-10 years working experience (mean rank=36.38).

ii. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 54.41) than the respondents with 6-10 years working experience (mean rank=35.29).

f) The respondents with 3-5 years working experience perceived

i. more agreed on IoT is important in remote inspection and progress report (mean rank= 60.60) than the respondents with 6-10 years working experience (mean rank=40.51).
ii. more agreed on IoT is important in monitoring and maintenance of machinery (mean rank= 58.45) than the respondents with 6-10 years working experience (mean rank=40.04).
iii. more agreed on IoT is important for safety and health of site workers (mean rank= 64.02) than the respondents with 6-10 years working experience (mean rank=38.99).
iv. more agreed on IoT-based sensor collects and gathers the relevant data (mean rank= 59.20) than the respondents with 6-10 years working experience (mean rank=38.63).
v. more agreed on Cloud-based IoT platform manages huge data generated by IoT devices (mean rank= 61.14) than the respondents with 6-10 years working experience (mean rank=38.50).
vi. more agreed on Cloud-based IoT platform provides infinite storage for data (mean rank= 58.68) than the respondents with 6-10 years working experience (mean rank=39.97).
vii. more agreed on Cloud-based IoT platform analyses data generated by IoT devices (mean rank= 59.23) than the respondents with 6-10 years working experience (mean rank=39.09).
viii. more agreed on RFID tagging system provides identification of objects (mean rank= 62.15) than the respondents with 6-10 years working experience (mean rank=44.07).
ix. more agreed on 5G provides better and more stable connectivity (mean rank= 59.53) than the respondents with 6-10 years working experience (mean rank=36.38).

x. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 63.67) than the respondents with 6-10 years working experience (mean rank=35.29).

xi. more agreed on 5G supports higher IoT user density (mean rank= 66.41) than the respondents with 6-10 years working experience (mean rank=38.03).

g) The respondents working for large organisation are

i. more agreed on IoT is important in remote inspection and progress report (mean rank= 60.63) than the respondents working for small and medium organisation (mean rank=40.79).

ii. more agreed on IoT is important in locating and tracking of site resources (mean rank= 60.33) than the respondents working for small and medium organisation (mean rank=41.10).

iii. more agreed on IoT is important in monitoring and maintenance of machinery (mean rank= 57.02) than the respondents working for small and medium organisation (mean rank=44.61).

iv. more agreed on IoT is important for safety and health of site workers (mean rank= 59.43) than the respondents working for small and medium organisation (mean rank=42.05).

v. more agreed on IoT is important for security of site. (mean rank= 56.34) than the respondents working for small and medium organisation (mean rank=45.34).

vi. more agreed on IoT-based sensor collects and gathers the relevant data (mean rank= 59.09) than the respondents working for small and medium organisation (mean rank=42.42).

vii. more agreed on IoT-based sensor monitors site conditions (mean rank= 56.40) than the respondents working for small and medium organisation (mean rank=45.27).

viii. more agreed on Drone technology carries out high-elevation inspection (mean rank= 56.88) than the respondents working for small and medium organisation (mean rank=44.76).

ix. more agreed on Cloud-based IoT platform manages huge data generated by IoT devices (mean rank= 60.02) than the respondents working for small and medium organisation (mean rank=41.13).

x. more agreed on Cloud-based IoT platform provides infinite storage for data (mean rank= 59.38) than the respondents working for small and medium organisation (mean rank=42.11).

xi. more agreed on Cloud-based IoT platform analyses data generated by IoT devices (mean rank= 59.34) than the respondents working for small and medium organisation (mean rank=42.15).

xii. more agreed on Robotics carries out repetitive works efficiently (mean rank= 55.90) than the respondents working for small and medium organisation (mean rank=45.80).

xiii. more agreed on RFID tagging system tracks materials and equipment (mean rank= 61.38) than the respondents working for small and medium organisation (mean rank=39.98).

xiv. more agreed on RFID tagging system provides identification of objects (mean rank= 63.07) than the respondents working for small and medium organisation (mean rank=38.19).

xv. more agreed on 5G provides better and more stable connectivity (mean rank= 61.98) than the respondents working for small and medium organisation (mean rank=39.35).

xvi. more agreed on 5G allows faster transmission of huge data and big files (mean rank= 64.44) than the respondents working for small and medium organisation (mean rank=36.73).

xvii. more agreed on 5G supports higher IoT user density (mean rank= 63.92) than the respondents working for small and medium organisation (mean rank=37.29).

4.8 Limitations of IoT on Construction Site

Table 4.11 presents the ranking of the limitations of IoT on construction site by the respondents. 38.6% of the respondents are very much concerned about the resource availability and cost consumption of adopting IoT on construction site.

Table 4.11: Ranking of the Limitations of IoT on Construction Site

Statements	Median	Median Frequency	Percentage (%)
Resource Availability and Cost Consumption	4	39	38.6
Network Failure	3	41	40.6
Data Storage and Data Analysis	3	39	38.6
Security Concerns	3	34	33.7
Privacy Concerns	2	41	40.6
System Fragmentation and Interoperability	2	36	35.6

Note: 0= No Concern, 1= Slight Concern, 2= Neutral, 3= Concern, 4= Very Much Concern

4.9 Attitude towards IoT Adoption on Construction Site

Table 4.12 presents the ranking of the attitude towards adopting IoT on construction site by the respondents. The respondents are agreed and strongly agreed for I feel more confident when the data collected is reliable (15.8%). Then, the respondents are neutral for I will recommend others to use IoT devices (66.3%), I feel using IoT devices is helpful to my tasks (56.4%), I am willing to initiate culture of IoT in my organization (53.5%), I prefer using IoT devices than traditional devices (49.5), I have the intention to use IoT devices (37.6%) and I am willing to undergo IoT workshop training on my own cost (34.7%). However, 31.7% of respondents slightly disagree on I am willing to learn IoT during my personal time.

.

Table 4.12: Ranking of Attitude towards IoT Adoption on Construction Site

Statements	Median	Median Frequency	Percentage (%)
I feel more confident when the data collected is reliable.	3	16	15.8
I will recommend others to use IoT devices.	2	67	66.3
I feel using IoT devices is helpful to my tasks.	2	57	56.4
I am willing to initiate culture of IoT in my organisation.	2	54	53.5
I prefer using IoT devices than traditional devices.	2	50	49.5
I have the intention to use IoT devices.	2	38	37.6

Table 4.12 (Continued)

I am willing to undergo IoT workshop training on my own cost.	2	35	34.7
I am willing to learn IoT during my personal time.	1	32	31.7

Note: 0= Strongly Disagree, 1= Slightly Disagree, 2= Neutral, 3= Slightly Agree, 4= Strongly Agree

The mean ranking of the attitude towards IoT on construction site are presented in Table 4.13. The Friedman test has listed out the mean rank and the results are statistically significant.

Table 4.13: Mean Ranking of the Attitude towards IoT on Construction Site

Statements	Mean Rank	Chi-Square	Asymp. Sig.
I feel more confident when the data collected is reliable.	7.60	395.837	0.000
I have the intention to use IoT devices.	6.93		
I am willing to initiate culture of IoT in my organisation.	6.05		
I will recommend others to use IoT devices.	5.99		
I prefer using IoT devices than traditional devices.	5.81		
I feel using IoT devices is helpful to my tasks.	5.57		
I am willing to undergo IoT workshop training on my own cost.	3.21		
I am willing to learn IoT during my personal time.	2.48		

According to the Table 4.14, the top three mean ranking of attitude towards IoT adoption on the construction site by the respondents are I feel more confident when the data collected is reliable (7.60), I have the intention to use IoT devices (6.93) and I am willing to initiate culture of IoT in my organisation (6.05).

Post hoc tests are conducted on the attitude towards IoT on construction site with the entire attributes of the respondents. Table 4.14 presents the rejected null hypothesis which are statistically significant with $p<0.05$.

Table 4.14: Rejected Null Hypothesis for the Attitude towards IoT Adoption on Construction Site

Null Hypothesis	Sig.
The agreement of 'I have the intention to use IoT devices.' is same between contractor and supplier/sub-contractor/specialist.	0.037
The agreement of 'I prefer using IoT devices than traditional devices.' is same between contractor and supplier/sub-contractor/specialist.	0.039
The agreement of 'I prefer using IoT devices than traditional devices.' is same between consultant and supplier/sub-contractor/specialist.	0.006
The agreement of 'I foresee I will have more opportunities to use IoT devices.' is same between contractor and supplier/sub-contractor/specialist.	0.005
The agreement of 'I foresee I will have more opportunities to use IoT devices.' is same between consultant and supplier/sub-contractor/specialist.	0.007
The agreement of 'I am willing to undergo IoT workshop training on my own cost.' is same between consultant and supplier/sub-contractor/specialist.	0.018
The agreement of 'I am willing to learn IoT during my personal time.' is same between consultant and supplier/sub-contractor/specialist.	0.002
The agreement of 'I have the intention to use IoT devices.' is same between respondents below 25 and respondents between 31-40.	0.030
The agreement of 'I prefer using IoT devices than traditional devices.' is same between respondents below 25 and respondents between 31-40.	0.001
The agreement of 'I prefer using IoT devices than traditional devices.' is same between respondents between 26-30 and respondents between 31-40.	0.010
The agreement of 'I feel more confident when the data collected is reliable.' is same between respondents below 25 and respondents between 31-40.	0.007
The agreement of 'I foresee I will have more opportunities to use IoT devices.' is same between respondents below 25 and respondents between 31-40.	0.009
The agreement of 'I will recommend others to use IoT devices.' is same between respondents below 25 and respondents between 31-40.	0.010
The agreement of 'I feel using IoT devices is helpful to my tasks.' is same between respondents below 25 and respondents between 31-40.	0.042
The agreement of 'I am willing to undergo IoT workshop training on my own cost.' is same between respondents below 25 and respondents between 31-40.	0.012

Table 4.14 (Continued)

The agreement of 'I have the intention to use IoT devices.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.020
The agreement of 'I have the intention to use IoT devices.' is same between respondents with 3-5 years and respondents with 6-10 years.	0.024
The agreement of 'I prefer using IoT devices than traditional devices.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.001
The agreement of 'I prefer using IoT devices than traditional devices.' is same between respondents with 3-5 years and respondents with 6-10 years.	0.004
The agreement of 'I feel more confident when the data collected is reliable.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.015
The agreement of 'I foresee i will have more opportunities to use IoT devices.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.019
The agreement of 'I will recommend others to use IoT devices.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.012
The agreement of 'I feel using IoT devices is helpful to my tasks.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.042
The agreement of 'I am willing to undergo IoT workshop training on my own cost.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.028
The agreement of 'I am willing to initiate culture of IoT in my organisation.' is same between respondents with 0-2 years and respondents with 6-10 years.	0.037
The agreement of 'I have the intention to use IoT devices.' is same between respondents in large organisation and respondents in small and medium organisation.	0.003
The agreement of 'I prefer using IoT devices than traditional devices.' is same between respondents in large organisation and respondents in small and medium organisation.	0.005
The agreement of 'I feel more confident when the data collected is reliable.' is same between respondents in large organisation and respondents in small and medium organisation.	0.013
The agreement of 'I foresee i will have more opportunities to use IoT devices.' is same between respondents in large organisation and respondents in small and medium organisation.	0.000
The agreement of 'I will recommend others to use IoT devices.' is same between respondents in large organisation and respondents in small and medium organisation.	0.007
The agreement of 'I feel using IoT devices is helpful to my	0.010

Table 4.14 (Continued)

tasks.' is same between respondents in large organisation and respondents in small and medium organisation.	
The agreement of 'I am willing to undergo IoT workshop training on my own cost.' is same between respondents in large organisation and respondents in small and medium organisation.	0.002
The agreement of 'I am willing to learn IoT during my personal time.' is same between respondents in large organisation and respondents in small and medium organisation.	0.000

a) The respondents working for construction company are

i. more agreed on I have the intention to use IoT devices (mean rank= 58.07) than the respondents working for supplier/sub-contractor/specialist company (mean rank=39.55).

ii. more agreed on 'I prefer using IoT devices than traditional devices (mean rank= 55.43) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.59).

iii. more agreed on 'I foresee I will have more opportunities to use IoT devices (mean rank= 58.07) than the respondents working for supplier/sub-contractor/specialist company (mean rank=36.42).

b) The respondents working for consultancy company perceived

i. more agreed on 'I prefer using IoT devices than traditional devices (mean rank= 59.84) than the respondents working for supplier/sub-contractor/specialist company (mean rank=37.59).

ii. more agreed on 'I foresee I will have more opportunities to use IoT devices (mean rank= 58.08) than the respondents working for supplier/sub-contractor/specialist company (mean rank=36.42).

iii. more agreed on 'I am willing to undergo IoT workshop training on my own cost (mean rank= 59.59) than the respondents working for supplier/sub-contractor/specialist company (mean rank=38.79).

iv. more agreed on 'I am willing to undergo IoT workshop training on my own cost (mean rank= 63.55) than the respondents working for supplier/sub-contractor/specialist company (mean rank=38.32).

c) The respondents aged below 25 are

i. more agreed on I have the intention to use IoT devices (mean rank= 59.28) than the respondents aged 31 – 40 years old (mean rank=40.15).

ii. more agreed on I prefer using IoT devices than traditional devices (mean rank= 60.93) than the respondents aged 31 – 40 years old (mean rank=35.63).

iii. more agreed on I feel more confident when the data collected is reliable (mean rank= 60.19) than the respondents aged 31 – 40 years old (mean rank=38.53).

iv. more agreed on I foresee I will have more opportunities to use IoT devices (mean rank= 59.76) than the respondents aged 31 – 40 years old (mean rank=39.01).

v. more agreed on I will recommend others to use IoT devices (mean rank= 60.68) than the respondents aged 31 – 40 years old (mean rank=41.96).

vi. more agreed on I feel using IoT devices is helpful to my tasks (mean rank= 58.41) than the respondents aged 31 – 40 years old (mean rank=41.19).

vii. more agreed on I am willing to undergo IoT workshop training on my own cost (mean rank= 62.97) than the respondents aged 31 – 40 years old (mean rank=41.79).

d) The respondents aged 26-30 years old are

i. more agreed on I prefer using IoT devices than traditional devices (mean rank= 56.61) than the respondents aged 31 – 40 years old (mean rank=35.63).

e) The respondents with 0-2 years working experience are

i. more agreed on I have the intention to use IoT devices (mean rank= 57.79) than the respondents with 6-10 years working experience (mean rank=37.84).

ii. more agreed on I prefer using IoT devices than traditional devices (mean rank= 59.62) than the respondents with 6-10 years working experience (mean rank=35.37).

iii. more agreed on I feel more confident when the data collected is reliable (mean rank= 58.60) than the respondents with 6-10 years working experience (mean rank=38.41).

iv. more agreed on I foresee I will have more opportunities to use IoT devices (mean rank= 58.65) than the respondents with 0-2 years working experience (mean rank=39.35).

v. more agreed on I will recommend others to use IoT devices (mean rank= 59.15) than the respondents with 6-10 years working experience (mean rank=40.78).

vi. more agreed on I feel using IoT devices is helpful to my tasks (mean rank= 56.99) than the respondents with 6-10 years working experience (mean rank=39.76).

vii. more agreed on I am willing to undergo IoT workshop training on my own cost (mean rank= 61.15) than the respondents with 6-10 years working experience old (mean rank=41.79).

viii. more agreed on I am willing to initiate culture of IoT in my organisation (mean rank= 59.15) than the respondents with 6-10 years working experience old (mean rank=41.34).

f) The respondents with 3-5 years working experience perceived

i. more agreed on I have the intention to use IoT devices (mean rank= 57.56) than the respondents with 6-10 years working experience (mean rank=40.15).

ii. more agreed on I prefer using IoT devices than traditional devices (mean rank= 58.23) than the respondents with 6-10 years working experience (mean rank=35.37).

g) The respondents working for large organisation are

i. more agreed on I have the intention to use IoT devices (mean rank= 59.18) than the respondents working for small and medium organisation (mean rank=42.32).
ii. more agreed on I prefer using IoT devices than traditional devices (mean rank= 58.31) than the respondents working for small and medium organisation (mean rank=43.24).
iii. more agreed on I feel more confident when the data collected is reliable (mean rank= 57.63) than the respondents working for small and medium organisation (mean rank=43.97).
iv. more agreed on I foresee i will have more opportunities to use IoT devices (mean rank= 60.69) than the respondents working for small and medium organisation (mean rank=40.71).
v. more agreed on I will recommend others to use IoT devices (mean rank= 57.38) than the respondents working for small and medium organisation (mean rank=44.32).
vi. more agreed on I feel using IoT devices is helpful to my tasks (mean rank= 57.52) than the respondents working for small and medium organisation (mean rank=44.08).
vii. more agreed on I am willing to undergo IoT workshop training on my own cost (mean rank= 59.60) than the respondents working for small and medium organisation (mean rank=41.88).
viii. more agreed on I am willing to learn IoT during my personal time (mean rank= 64.13) than the respondents working for small and medium organisation (mean rank=37.06).

4.10 Intention of Adopting IoT on the Construction Site

Table 4.15 presents the scale of intention of adopting IoT on construction site by the respondents. More than half of the respondents have the intention of adopting IoT on construction site. While 19.8% of respondents have no intention to adopt IoT on construction site and 14.9% of respondents remain neutral.

Table 4.15: Scale of Intention of Adopting IoT on Construction Site

Scale of Intention	Frequency	Percentage (%)	Rank
Fair Intention	26	25.7	1
Very Much Intention	22	21.8	2
No Intention	20	19.8	3
Much Intention	18	17.8	4
Neutral	15	14.9	5

4.11 Likeliness of Adopting IoT on construction site

Table 4.16 presents the ranking of the likeliness of adopting IoT on construction site by the respondents. Nearly half of the respondents are somewhat likely to adopt drone technology and RFID tagging system on construction site at 43.6% and 42.6% respectively. The respondents are not likely to adopt IoT-based sensor and robotics at 27.7% and 25.7% respectively. While more than half of the respondents never consider adopting cloud-based IoT platform at 54.5% and some of the respondents never consider adopting 5G network at 21.8%.

Table 4.16: Ranking of the Likeliness of Adopting IoT on Construction Site

Statements	Median	Median Frequency	Percentage (%)
Drone Technology	3	44	43.6
RFID Tagging System	3	43	42.6
IoT-based Sensor	2	28	27.7
Robotics	2	26	25.7
Cloud-based IoT Platform	1	55	54.5
5G Network	1	22	21.8

Note: 0= No Idea, 1= Never Consider, 2= Not Likely, 3= Somewhat Likely, 4= Very Likely

4.12 IoT Adopted in Construction Activities

Table 4.17 presents the ranking of the IoT adopted in construction activities. Most of the construction activities in the respondents' organisations are not adopting any IoT currently. The two construction activities in some of the respondents' organisations will be adopting IoT which are site inspection and site progress monitoring at 34.7% both.

Table 4.17: Ranking of IoT Adopted on Construction Activities

Statements	Median	Median Frequency	Percentage (%)
Site inspection	2	35	34.7
Site progress monitoring	2	35	34.7
Design	1	84	83.2
Site security and safety	1	80	79.2
Site maintenance work	1	79	78.2
Site construction work	1	67	66.3
Site logistic	1	63	62.4
Site quantity taking off	1	61	60.4
Site resource management (labour, equipment, material)	1	58	57.4

Note: 0= No Idea, 1= Not Adopting, 2= Will Be Adopting, 3= Adopting Less Than 1 Year, 4= Already Adopted More Than 1 Year

4.13 Construction Activities that will Transform with IoT Adoption on Construction Site

Table 4.18 presents the ranking of the construction activities that will transform with IoT adoption by the respondents. More than half of the respondents slightly agree that site quantity taking off and site inspection will undergo transformation at 55.4% and 51.5%. Nearly half of the respondents slightly agree the site progress monitoring, site construction work and site logistics will be transformed 49.5%. 49.5% and 45.5% respectively. Meanwhile, 37.6% of the respondents also slightly agree that IoT will transform site resource management. While some of the respondents are neutral towards site security and safety, site maintenance work and design will undergo transformation at 37.6%. 34.7% and 26.7% respectively.

Table 4.18: Ranking of the Construction Activities that will Transform with IoT Adoption on Construction Site

Statements	Median	Median Frequency	Percentage (%)
Site Quantity Taking Off	3	56	55.4
Site Inspection	3	52	51.5
Site Progress Monitoring	3	50	49.5
Site Construction Work	3	50	49.5
Site Logistic	3	46	45.5
Site Resource Management (Labour, Equipment, Material)	3	38	37.6
Site Security and Safety	2	38	37.6

Table 4.18(Continued)

Site Maintenance Work	2	35	34.7
Design	2	27	26.7

Note: 0= Strongly Disagree, 1= Slightly Disagree, 2= Neutral, 3= Slightly Agree, 4= Strongly Agree

4.14 Definition of IoT

Table 4.19 presents the definition of IoT rated by the respondents. Most of the respondents have chosen the growing network of physical objects which are able to communicate among themselves and with other internet-enabled devices over the Internet best describe the IoT at 33.7% which is also the most complete definition of IoT.

Table 4.19: Ranking of Definition of IoT

Definition	Frequency	Percentage	Rank
The growing network of physical objects which are able to communicate among themselves and with other internet-enabled devices over the Internet.	34	33.7	1
The integration of multiple processes which are sensing, identifying, networking and computing the data.	26	25.7	2
The general idea of devices in daily life that are manageable via the Internet.	25	24.8	3
The communication between anything from anywhere at any time through digital applications.	16	15.8	4

4.15 Discussion

4.15.1 Current practices of IoT on Construction Site

a) IoT Adopted on Construction Site

From Table 4.4, IoT is not actively practiced and adopted on the construction site for the majority of the respondents. The six IoT technologies are all rated as not adopted by more than 50% of respondents.

According to Ibrahim, Esa and Rahman (2021), the Malaysian construction industry has begun to adopt sensors on the construction site. Hence, the adoption of IoT-based sensors on site is relatively low. Besides, it also suggested RFID to be implemented on construction but the implementation of RFID will be lower than sensor. However, from the results of Table 4.4 is concurred with the arguments made by Ibrahim, Esa and

Rahman as the overall IoT currently adopted on Malaysian construction site is very low for IoT-based sensor and RFID tagging system.

Moreover, Malaysia is ranked top three (3) in the Drone Readiness Index and also in Biggest Market Size in Asean (New Straits Times, 2021). It reveals that the adoption of drones in Malaysia is mainly in other industries instead of the construction industry as the result shows most of the respondents have not adopted drone technology by their organisations on construction site.

b) IoT Adopted in Construction activities

More than half of the organisation of the respondents are not adopting IoT in most of the construction activities from Table 4.17.

Only 34.7% of the organisation of respondents will be adopting IoT in site inspection and site progress monitoring. According to Scarlet Tech (2021), IoT is able to ensure the construction projects running on schedule amidst the Covid-19 pandemic. Other than that, employers, surveyors and inspectors are slowly embracing the use of IoT to carry out virtual site inspection to prevent possible delay. Even working from off-site, the employers, surveyor and inspectors are able to monitor the construction works remotely to prepare necessary documents such as interim valuation (Mazhandu, 2020).

It is believed after the Covid-19 outbreak is contained, IoT will gradually get more attention and be applied in more construction project activities (Scarlet Tech, 2021).

4.15.2 Importance of IoT on Construction Site

a) Importance Level of IoT on the Construction Site Perceived by the Respondents

The respondents perceived that drone technology is the most important IoT on construction site followed by IoT-based sensor and RFID tagging system in Table 4.5.

According to the statistics compiled from 400,000 job sites in 180 countries in 2018 by Drone Deploy, there was a 239% increase in drone technology adoption in the construction industry. Meanwhile, there was also a 100% increase in drone adoption for the surveying industry (The Asean Post, 2019). The statistics have proven that drone technology is becoming one of the most important IoT on construction site. Meanwhile, The Association for Unmanned Vehicle Systems International (AUVSI) also stated that the construction industry accounted for the largest growth of drone use (Sanson, 2019).

Despite the low adoption of IoT-based sensor and RFID tagging system on Malaysian construction site, Ibrahim, Esa and Rahman (2021) agreed that the usage of sensor and RFID are increasing which will also make these two IoT devices gradually become more important on the construction site in the future.

On the other hand, cloud-based IoT platform and 5G network are perceived as least important by more than half of the respondents. This result may be caused by the underlying security concern and privacy concern which can be observed in Table 4.11. The security concern of the cloud-based IoT platform is that the process of refining and retrieving the data collected from IoT and kept in the platform is lacking cloud computing information. The user or owner of the IoT do not have insight of the physical location of their own data (Abdulkareem, et al., 2021). Besides, as massive IoT devices such as sensor and drone are transmitting data which involves sensitive and personal information in the 5G network, it poses security and privacy challenges to the 5G network as more efforts and costs will be needed for protection from illegal cyber breaches (Humayun, et al., 2021).

b) Relationship between the Importance Level of IoT on Construction Site and the Attributes of the Respondents

Based on the result in Table 4.12, the drone technology and IoT-based sensor shows significant differences.

The respondents working for construction company and consultancy company perceived that drone technology and IoT-based sensor are more important than those respondents working for supplier, sub-contractor and specialist companies. According to Drone Deploy user data, the drone technology mainly benefits the project managers, superintendents and technology managers from construction company (Drone Deploy, 2018).

Moreover, Royal Institution Chartered Surveyors (2019) also agreed that drone technology and sensors will play a pivotal role to surveyors in the future in completing their tasks.

Meanwhile, the respondents aged below 25 years old and aged between 26 to 30 years old perceived drone technology, IoT-based sensor, cloud-based IoT platform, RFID tagging system and 5G network are more important than the respondents aged 31 to 40 years old. It shows that the technological IoT solutions are more appealing to the Generation Z youth aged between 16 to 24 years old in 2021 as they tend to be more tech savvy than the older generation (Turner, 2015). Hence, the younger respondents have agreed a higher importance level on most of the IoT on construction site compared with the older respondents.

The respondents working for large organisation are perceived that drone technology, IoT-based sensor, RFID tagging system, cloud-based IoT platform and 5G network are more important than respondents working for small and medium organisation. According to Rad and Ahmada (2017), the awareness on IoT is low among construction players in small and medium organisation as they have limited exposure to the latest technology in construction industry compare with large organisation (Ahmad Zaidi, 2017) Hence, the respondents from small and medium organisation have a lower agreement on the importance level of IoT on site.

c) Importance of IoT on Construction Site

More than half of the respondents have agreed that robotics carries out repetitive work efficiently and robotics carries out dangerous and high-risk work as shown in Table 4.8.

The Malaysian construction site is known for its labour-intensive nature, low productivity problems and high accident rates as discussed in the problem statement of Chapter 1. However, robotics has been proven to be very effective in improving productivity, quality while minimising labour cost. Moreover, it is argued that robotics is able to minimise injuries and accident rate of construction workers as well as relying less on construction workers to carry out dangerous tasks on the construction site (Delgado etc., 2019)

Additionally, the ABB Construction Industry Survey May 2021 reveals that the robotics is getting more important to construction business and the demand will increase rapidly by 2030. This is due to the efficiency of robotics in carrying out construction works which can solve the future construction skill crisis and construction job recruitment on site. Besides, robotics can improve the health and safety on construction site as it replaces the construction workers to carry out dangerous construction tasks (ABB, 2021).

Meanwhile, more than half of the respondents have also agreed that drone technology carries out remote monitoring and surveillance and drone technology carries out high-elevation inspection in Table 4.8. The Association for Unmanned Vehicle Systems International (2019) also mentioned that the use of drone in construction has made the site safer with remote inspection as well as making it possible to access those areas that are unable to be accessed by foot such as enormous skyscrapers (Sanson, 2019). Moreover, the result is also in line with the study carried out by The Oregon Department of Transportation (2018) which reported the drones are mainly used for monitoring and inspecting purposes. It also claimed that the drone is deployed to inspect tall buildings and tall structures.

d) Relationship between the Importance of IoT on Construction Site and The Attributes of the Respondents

Majority of the respondents working for the construction company (contractor) are more agreed on “Robotics carries out repetitive works efficiently.” than the respondents working for supplier, sub-contractor and specialist companies. This is due to the robotics not only carrying out construction works efficiently, but also accurately (Cropp, 2021). The robotics is not subject to any fatigue like humans, tiredness after carrying out long repetitive works and is able to produce consistent work quality which leads to higher efficiency of the construction site. With these features, the robotics helps the construction company to produce good quality of construction, minimise operation cost and improve the overall performance of the construction company (Carra, el al., 2018)

The respondents working for construction company (contractor) are more agreed on “IoT-based sensor ensures safety of workers.” than the respondents working for supplier, sub-contractor and specialist company. This result is in line with the Dodge Data & Analytics’ Safety Management Construction Report which stated that IoT sensors such as wearables sensor devices improve the safety on site (Triax, n.d.). The construction company (contractor) emphasises on the site safety more than supplier, sub-contractor and specialist company because the construction company has the main responsibility to maintain the overall site safety from time to time under The Occupational Safety and Health Act (OSHA) Clause 15 in Malaysia.

Meanwhile, the respondents working for construction company and consultancy company are also more agreed on “IoT is important in remote inspection and progress report.” than the respondents working for supplier, sub-contractor and specialist company. Firstly, the respondents working for construction company (contractor) agreed on the statement because it is the contractual responsibility of the contractor to carry out construction inspection and report the construction progress to the client or a third party (LetsBuild, 2019). With IoT on construction site, it enables the contractor to monitor and record the construction progress on site at any time and allow them to make responses or decisions in real time when any construction issue is detected on the site. On the other hand, it is also the contractual responsibility of the consultancy company to assess the site progress in order to evaluate the progress claim, prepare relevant reports to the client and to ensure there is no delay in the construction progress. Hence, the respondents working for consultancy company agreed on the statement because IoT can help them to carry out site inspection remotely and effectively without having to worry about the accessibility of the site or unpredictable weather.

The majority of the respondents working in large organisation are more agreed on most of the importance of IoT in the questionnaire which are IoT is important in remote inspection and progress report, IoT is important in locating and tracking of site resources, IoT is important in monitoring and maintenance of machinery, IoT is important for safety and health of site workers and IoT is important for security of site than small and medium organisation. There are several studies show the high tendency of IoT acceptance in large companies. According to Deloitte (2015), it reveals that the companies that emphasise and invest in IoT are generally large enterprises with leading role in their own industries and in society. Additionally, most of the large companies have better knowledge and resources to adopt IoT than smaller companies. It shows that the size of company plays an important role in IoT (Carcary, et al., 2014) Nonetheless, Jones and Graham (2018) also agreed that the large enterprises tend to use IoT more to assist their businesses to gather, manage, analyse and utilise the huge amount of data to speed up the process as well as monitor asset and machinery inventory. However, it is unsure whether the small and medium companies can achieve parity like the large enterprises in implementing the IoT in their businesses as well.

4.15.3 Attitude of Individual Construction Practitioner towards IoT Adoption on Construction Site

a) Attitude of Individual Construction Practitioner towards IoT Adoption on Construction Site

Half of the respondents are slightly agreed and strongly agreed on "I feel more confident when the data collected is reliable." from the results in Table 4.12. This is in line with the U.S. Small Business Administration (2017) which stated that reliability is one of the critical attributes associated with the quality of an IoT-based system. When the data collected through IoT is reliable, it indicates that the IoT-based system can be trusted (Small Business Innovation Research, 2017).

Meanwhile, the results are also in line with Fruehe (2015) which mentioned that the data collected by IoT needs to be reliable. The reliable data indicates the measurement carried out is accurate which prevents IoT users from producing wrong interpretation and making bad decisions.

On the other hand, nearly 60% of respondents disagree over "I am willing to learn IoT during my personal time.". Despite the rapid growth of the IoT adoption in the construction industry, it shows that the construction practitioners are unwilling to sacrifice their own personal time to pick up the knowledge and skill of IoT technology. According to Ernst & Young

Consulting Sdn Bhd (EY) 2021 Work Reimagined Employee Survey, 45% of the respondents emphasis on work-life balance by establishing a clear working hour. In that survey, nearly half of the respondents are unlikely to engage in work-related matters beyond their working hour. It reveals the reason why more respondents in this study have disagreed with learning IoT during their personal time (Sunbiz, 2021).

b) Relationship between Attitude of Individual Construction Practitioner towards IoT Adoption on Construction Site and the Attributes of the Respondents

The respondents aged below 25 and respondents aged between 26 to 30 years old are more agreed on “I prefer using IoT devices than traditional devices.” than the respondents aged 31 – 40 years old. This is concurred with the Internet Users Survey 2020 that shows the non-internet users among 20 to 30 years old is 6% which is higher than the non-internet users among 30 to 40 years old is 4.4% (Malaysian Communications and Multimedia Commission, 2020).

The respondents working for large organisation have agreed on “I feel more confident when the data collected is reliable.” than the respondents working for small and medium organisation. When adopting IoT in the system, a huge volume of data will be collected, evaluated and interpreted to ensure their reliability and accuracy before being used by an individual to make any decision or response. However, how much of the data collected is actually reliable and accurate is unknown (Pratt, 2021). Moreover, Pratt also quoted that bad and unreliable data will not produce good decisions. In large construction organisations, they tend to have more complex and big projects with higher contract sums than small and medium construction organisations. Hence, a bad decision that is caused by unreliable data collected from any IoT device on-site or off-site will leave great impacts to the large organisation in terms of project cost, risk and time. Hence, the respondents working for large organisations tend to emphasis more on the reliability of data in order to be more confident when making any decision.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

As the last chapter of the research, the accomplishments of the research objectives are reflected in Section 5.2, research contributions are discussed in Section 5.3, research limitations are identified in Section 5.4 and Research recommendations are provided in Section 5.5.

5.2 Accomplishments of Research Objectives

Construction site plays an important role in the construction industry as most of the crucial activities involve the site. Besides, many construction practitioners are also involved in the activities on the construction site which include the architect, contractor, surveyor, sub-contractor, engineer, etc. By incorporating the IoT on the construction site, there will be a massive transformation and impact many parties working on the site. As the businesses and operations around the world are adopting IoT to enhance the performance, it is important to adopt the IoT on the construction site as well in order to stay competitive and productive.

During the literature review, it is found out that most of the researches focus on the impacts of IoT majorly in healthcare. There is limited study on the IoT in construction despite the massive effects IoT has in construction. With the introduction of Construction 4.0, people are slowly noticing the need to raise the awareness of IoT in the construction industry as well as incorporate and adopt the IoT on construction site. Hence, this research is aimed to evaluate the adoption of IoT on construction site to find out the current performance of the construction site. The objectives outlined in this research are to explore the current practices of IoT application on construction site, to analyse the importance of IoT application on construction site and to evaluate the attitude of the individual construction practitioners towards IoT application adoption on construction site.

In view of data collection, the sampling design used is convenience sampling of non-probability sampling as it is time saving and quick. The sampling size of the research is based on the central limit theorem where 117 responses are collected out of 300 questionnaires distributed majorly within Klang Valley district.

The research findings have identified the current practices of IoT on the construction site. They are drone technology, IoT-based sensor, RFID tagging system and cloud-based IoT platform. However, the adoption level of the IoT stated above is very low on construction site. Even though robotics and the 5G network are also discussed in Chapter 2, unfortunately they are not adopted on Malaysian construction site yet.

Meanwhile, the research findings have revealed that the respondents have higher agreement on the importance of robotics, drone technology and 5G network as discussed in Chapter 2. More than half of the respondents have agreed that robotics carries out repetitive works efficiently and robotics carries out dangerous and high risk works. Besides, more than half of the respondents also have agreed on that drone technology carries out remote monitoring and drone technology carries out high-elevation inspection. Lastly, nearly half of the respondents agreed that the 5G network provides better and more stable connectivity for the construction site. In general, the respondents from large organisation consistently agreed on most of the importance of IoT on construction site than the small and medium organisation. This is due to the large organisations have better preparations, resources and investments to adopt IoT on construction sites than small and medium organisations.

The research findings have shown that the overall attitude of the majority of respondents remains neutral on the adoption of IoT on construction site. The respondents are neutral on recommending others to use IoT devices, feeling the use of IoT devices is helpful to their tasks, initiating the culture of IoT in their organisation and prefer using IoT devices than traditional devices. By comparing the attitude between the younger generation below 25 years old and the older generation above 30 years old, it can be observed that the younger generation tends to have a more positive attitude on adopting IoT on construction site than the older generation which is discussed in Chapter 4.

After all analysis have been carried out, the aim and objectives are fully identified and met. The framework of this research has also become clearer and more logical. Hence, some adjustments are carried out in the framework to better represent the whole research by rearranging the sequence of the elements in the framework.

5.3 Research Contributions

Overall, this research provides an overview on the adoption of IoT on the construction site. It can be observed from the overall research outcomes, the adoption of IoT on construction site is very low. However, several studies have shown that the adoption of IoT on construction site is on the rise as discussed in Chapter 2 and Chapter 4.

This research will benefit and contribute the most to the construction industry. For the construction companies, they can gain more understanding on how IoT can mitigate the issues they are currently facing on construction site amidst this Covid-19 pandemic. Through this research, they are able to discover how other construction companies are practising the IoT on the construction site and generate their own strategic solutions by utilising IoT into their systems. Furthermore, there is no construction practitioner above 40 years old taking part in the questionnaire because the majority of them either have never heard of IoT or have never used IoT before. This research can act as a sign of reminder of the digital revolution in the construction industry as well as study materials to those construction practitioners aged above 40 years old in order to equip themselves with fundamental IoT knowledge in order to keep up with the changes. In addition, the outcomes have also revealed the lack of attention and investment of small and medium organisation on the IoT adoption on construction site. This research acts as a guideline for them on which IoT should be prioritised and adopted on construction site to improve the overall construction quality, management and efficiency as well as to be more competitive in the industry. This will assist the small and medium organisations to bridge the gap between them and the large construction organisations.

This research will benefit and contribute to the policy makers to anticipate the impacts of IoT on the workforce in the future. There will be more jobs created with the IoT boom in different industries. In order to obtain full advantages of the IoT for the country, policy makers have to ensure the workers are highly skilled and competent in IoT technology in order to encourage employment for IoT jobs. The increasing employment will also stimulate a healthy economic growth of the country.

Additionally, education institutions will also be benefited from this research as they play another important role in IoT development. Education institutions should be able to foresee the demand in IoT job market and prepare the students with necessary IoT knowledge before the students enter the workforces. The education institutions should emphasis more on science, technology, engineering and mathematics (STEM) in the students' programmes as STEM education is able to lead the students to be more prepared towards the era of Fourth Industrial Revolution (Sani, 2019).

5.4 Research Limitations

This research consists of several limitations. Firstly, the sample size of this research is the central limit theorem (CLT) due to time constraints. This method is unable to cover every construction organisation and practitioner as any group receiving less than 30 responses is not accepted to represent that particular group for analysis purposes in Chapter 4.

Additionally, the sampling method of this research is convenience sampling. It is a non-probability sampling which is not the best sampling design to be adopted as not every organisation or practitioner has the same opportunity or possibility to take part in this research. The results of the research could not reflect the whole population and majority of the respondents are from several same organisations due to availability and accessibility.

This research lacks the participation of senior level construction practitioners that are aged 40 years old and above. This is because most of the respondents above 40 years old have never heard of or used any IoT on the construction site before. Hence, their responses are invalid as this research requires the respondents to have fundamental knowledge and understanding on the IoT. Without the age group of 40 years old above, the results of the data collected may not be able to give an accurate inference on the whole population of construction practitioners on the construction site.

Lastly, the target respondents are all located in Klang Valley due to the convenience sampling method used in this research. This has led to small coverage of geographical location. The results of the data collected are unable to represent the targeted population properly as the coverage of respondents in different locations is too low.

5.5 Research Recommendations

The stratified random sampling is more recommended to be conducted in other upcoming studies. It gives a fair opportunity for the pre-determined respondents from different sub-group without overlapping to participate in the survey. With this sampling, the results produced will better represent the population.

Moreover, instead of conducting quantitative method only, the mixed method which engages both quantitative and qualitative methods should be considered. Quantitative method could collect the data effectively while qualitative method could provide insights into the data. Hence, the study produced will be more comprehensive and completed with answers from the respondents and why the respondents have given that answers.

The research should have wide geographical area coverage. For instance, further research should be able to cover the construction practitioners from various areas or locations in Peninsular Malaysia with a larger sample size. With these requirements met, the findings produced will be more powerful and convincing as it has a better ability to reveal the significant results among the respondents in the construction industry.

As the IoT is still very new in the construction industry, there are still many hidden legal challenges and ethical issues in using IoT. This is because everyone can use IoT freely, there is no contract or restriction among the IoT users which will easily lead to a complexity once there is a dispute. Hence, it is suggested the future researches may emphasis on the law, enactment or act regarding the IoT legal challenges and ethical issues as well as identifying other possible measures for them.

REFERENCES

ABB, 2021. *ABB robotics advances construction industry automation to enable safer and sustainable building.* [online] Available at: < https://new.abb.com/news/detail/78359/abb-robotics-advances-construction-industry-automation-to-enable-safer-and-sustainable-building> [Accessed 25 August 2021].

Abdulkareem, N.M., Zeebaree, S.R.M., Sadeeq, M.A.M. and Ahmed, D., 2021. Iot and cloud computing issues, challenges and opportunities: a review. *Qubahan Academic Journal*, [e-journal]. https://doi.org/10.48161/qaj.v1n2a36.

Abruzzese, D., Micheletti, A.,Tiero, A.,Cosentino, M.,Forconi, D.,Grizzi,G., Scarano, G.,Vuth, S. and Abiuso, P., 2020. IoT sensors for modern structural health monitoring. A new frontier. *Procedia Structural Integrity*, 25, pp. 378–385.

Ahmad Zaidi, M. F., 2017. *The iot readiness of smes in malaysia : are they worthwhile for investigation ?*. In: Universiti Utara Malaysia, International Conference on International Business, Marketing and Humanities (ICIBMAH 2017). Alor Setar, Malaysia, 26 - 27 August 2017. Sintok: UUM.

Akeem B.W., 2020. Applications of drone technology in the management of disaster and risk associated with covid-19 pandemic in the built environment: the nigerian experience. *International Journal of Real Estate Studies*, 14(1), pp. 73–81.

Aloufi, K., Malik, K., Naeem, T. and Mir, R., 2019. Data transmission and capacity over efficient iot energy consumption. *International Journal of Computer Science and Network Security*, 19(12), pp. 102-111.

Alshaer, J., 2018. Challenges of internet of things and big data integration. *Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2018*, pp. 47–55.

Aly, M., Khomh, F., Gueheneuc, Y., Washizaki, H. and Yacout, S., Is fragmentation a threat to the success of the internet of things?. *IEEE Internet of Things Journal*, 6(1), pp. 472-487.

Aly, M., Khomh, F.,Gueheneuc, Yann,G.,Washizaki, H. and Yacout, S., 2018. Is fragmentation a threat to the success of the internet of things?. *IEEE Internet of Things Journal*, 6(1), pp. 472-487.

American International Group, n.d. *The Internet of Things: Evolution or Revolution?* New York: AIG.

American International Group., n.d. The internet of things: evolution or revolution?. *American International Group (AIG)*. Available at:

<https://www.aig.co.uk/content/dam/aig/emea/united-kingdom/documents/aig-white-paper-iot-june2015-brochure.pdf> [Accessed 17 February 2021].

Amorim, R., Nguyen, H., Mogensen, P., Kovacs, I.Z., Wigard, J. and Sorensen,T B., 2017. Radio Channel modeling for UAV communication over cellular networks. *IEEE Wireless Communications Letters,* 6(4), pp. 514–517.

Andrea, I., Chrysostomou, C. and Hadjichristofi, G., 2015. Internet of Things: security vulnerabilities and challenges. *2015 IEEE Symposium on Computers and Communication (ISCC),* pp. 180–187.

Angelakis, V., Avgouleas, I., Pappas, N., Fitzgerald, E. and Yuan, D., 2016. Allocation of heterogeneous resources of an iot device to flexible services. *IEEE Internet of Things Journal,* 3(5), pp. 691–700.

Anwar, N., Najam, F. and Amir I.M., 2018. *Construction monitoring and reporting using drones and unmanned aerial vehicles (UAVs).*In: CITC (Construction in the 21st Century), 10th International conference on construction in the 21st century. Colombo, Sri Lanka. 2-4 July 2018. Basel: MDPI.

Arslan, V., Ulubeyli, S. and Kazaz, A., 2019. *The use of internet of things in the construction industry*. In: UEMK (Gaziantep University International Energy and Engineering Congress), 4th International energy & engineering congress. Gaziantep, Turkey. 24-25 October 2019. New York: Springer.

Attia, M., Haidar, N., Senouci, S. M. and Aglzim, E., 2018. *Towards an efficient energy management to reduce CO2 emissions and billing cost in smart buildings*. In: CCNC (Consumer Communications & Networking Conference), 15th IEEE annual consumer communications & networking conference. Las Vegas, United States of America. 12-15 January 2018. New York: IEEE.

Awolusi, I., Nnaji, C., Marks, E. and Hallowell, M., 2019. *Enhancing construction safety monitoring through the application of internet of things and wearable sensing devices: a review*. In: ASCE (American Society of Civil Engineers), ASCE International conference on computing in civil engineering 2019. Atlanta, Georgia. 17-19 June 2019. Virginia: ASCE.

Babar, S, Stango,A., Prasad, N., Sen , J. and Prasad, R., 2011. *Proposed embedded security framework for internet of things (IoT).* In: Wireless VITAE. 2nd International conference on wireless communication, vehicular technology, information theory and aerospace & electronic systems technology. Chennai, India. 28 February-3 March 2011. New York: IEEE.

Bellavista, P., Giannelli, C., Lagkas, T. and Sarigiannidis, P.,2018. Quality management of surveillance multimedia streams via federated sdn controllers in fiwi-iot integrated deployment environments. *IEEE Access*, 6, pp. 21324–21341.

Bilal, M., Oyedele, L. O., Qadir, J., Munir, K., Ajayi, S. O., Akinade, O. O., Owolabi, H. A., Alaka, H.A. and Pasha, M., 2016. Big data in the construction industry: a review of present status, opportunities, and future trends. *Advanced Engineering Informatics*, 30(3), pp. 500–521.

Bock, T., 2007. Construction robotics. *Autonomous Robots*, 22(3), pp. 201–209.

Boyes, H., Hallaq, B., Cunningham, J., and Watson, T., 2018. The industrial internet of things (IIoT): an analysis framework. *Computers in Industry*, 101, pp. 1–12.

Brous, P., Janssen, M. and Herder, P., 2020. The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations. *International Journal of Information Management*, 51, pp. 101952.

Burrell, G. and Morgan, G., 2017. *Sociological paradigms and organisational analysis: elements of the sociology of corporate life.* Oxfordshire: Routledge.

Carcary, M, Doherty, E., Conway, G. and McLaughlin, S., 2014. Cloud computing adoption readiness and benefit realization in irish smes—an exploratory study. *Information Systems Management*, [e-journal] 31, pp.313-327. https://doi.org/10.1080/10580530.2014.958028.

Carra, G., Argiolas, A., Bellissima, A. and Niccolini, M., 2018. *Robotics in the construction industry: state of the art and future opportunities.* In: International Association for Automation and Robotics in Construction (IAARC), 35th International Symposium on Automation and Robotics in Construction (ISARC 2018). Berlin, Germany, 20 - 25 July 2018. New York: Curran Associates Inc.

Charadva, M. J., 2014. A study of motion detection method for smart home system. *General*, 1(5), pp. 148–151.

Chen, W., Liu, C., Liang, W., and Tsai, M., 2018. *ICAT: An IoT device compatibility testing tool*. In: ASPEC. *25th Asia-Pacific software engineering conference.* Nara, Japan. 4-7 December 2018. New York: IEEE.

Chew, M.Y.L., Teo, E.A.L., Shah, K.W., Kumar, V. and Hussein, G.F., 2020. Evaluating the roadmap of 5G technology implementation for smart building and facilities management in singapore. *Sustainability 2020*, [e-journal]. https://doi.org/10.3390/su122410259.

Chew, M.Y.L.; Teo, E.A.L.; Shah, K.W.; Kumar, V.; and Hussein, G.F. Evaluating the Roadmap of 5G Technology Implementation for Smart Building and Facilities Management in Singapore. *Sustainability 2020* ,12(24), pp. 10259.

Chitnis, S., Deshpande, N. and Shaligram, A., 2016. An investigative study for smart home security: issues, challenges and countermeasures. *Wireless Sensor Network*, 8, pp. 77–84.
Colakovic, A. and Hadzialic, M., 2018. Internet of Things (IoT): A review of enabling technologies, challenges, and open research issues. *Computer Networks*, 144, pp. 17–39.

Collis, J. and Hussey, R., 2014. *Business research: a practical guide for undergraduate and postgraduate students*. Hampshire: Palgrave Macmillan Higher Education.

Construction Industry Development Board, 2020. Leadership in the time of pandemic. *Construction Industry Development Board Economic Outlook 2021* [Online] Available at: <https://www.cidb.gov.my/en/about-us/publication/heights-cidb-magazine > [Accessed 27 February 2021].

Construction Products Association, 2016. *The Future for Construction Product Manufacturing. Digitalisation, Industry and the Circular Economy*. London: CPA.

Cousins, S., 2020. *5G - the great construction site moderniser*. [online]. Available at: <https://ww3.rics.org/uk/en/modus/technology-and-data/harnessing-data/5g---the-great-construction-site-moderniser.html> [Accessed 25 August 2021].

Creswell, J. W.and Creswell, J. D., 2018. *Research design: qualitative, quantitative, and mixed methods approaches. 5th edi*. Los Angeles: SAGE.

Cropp, C., 2021. *How automation and robotics will impact construction in 2021*. [online] Available at: <https://info.vercator.com/blog/how-automation-and-robotics-will-impact-construction> [Accessed 25 August 2021].

Delgado, J.M.D., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M. and Owolabi, H., 2019. Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *Journal of Building Engineering,* [e-journal] 26, pp.1-11. https://doi.org/10.1016/j.jobe.2019.100868.

Deloitte, 2015. *Every thing connected*. [online] Available at: < https://www2.deloitte.com/dk/da/pages/strategy/monitor/iot-danish-companies.html> [Accessed 25 August 2021].

Domdouzis, K., Kumar, B. and Anumba, C., 2007. Radio-frequency identification (RFID) applications: a brief introduction. *Advanced Engineering Informatics*, 21(4), pp. 350–355.

Drone Deploy, 2018. *The rise of drones in construction*. Drone Deploy Explore Blog, [blog] 7 June. Available at:

<https://www.dronedeploy.com/blog/rise-drones-construction/> [Accessed 25 August 2021].

Du, J., Wang, S. and Zhang, H., 2013. Layered clustering multi-fault diagnosis for hydraulic piston pump. *Mechanical Systems and Signal Processing*, 36(2), pp. 487–504.

EDUCBA, 2021. *IoT cloud Platform.* [online] Available: <https://www.educba.com/iot-cloud-platforms/ > [Accessed 20 February 2021].

Ejaz, W., Anpalagan, A., Imran, M.A., Jo, M., Naeem, M., Qaisar, S and Wang, W., 2016. Internet of Things (IoT) in 5G Wireless Communications. *IEEE Access*, 4, pp. 10310-10314.

Fantana, N., Riedel, T., Schlick,J. and Ferber, S., 2013. IoT Applications: value creation for industry. In: O.Vermesan and P.Friess. *Internet of Things - converging technologies for smart environments and integrated ecosystems*. Aalborg: River Publisher. pp. 153–204.

Flach, P.A. and Kakas, A., 2000. On the relation between abduction and inductive learning. *Handbook of Defeasible Reasoning and Uncertainty Management Systems*, 4, pp. 1-33.

Fleetwood, S., 2005. Ontology in organization and management studies: a critical realist perspective. *Organization*, 12(2), pp. 197–222.

Fokaides, P. A., Apanaviciene., Cerneckiene, J., Jurelionis, A., Klumbyte, E., Kriauciunaite,N.V.,Pupeikis, D.,Rekus, D.,Sadauskiene, J.,Seduikyte, L., Stasiuliene, L.,Vaiciunas, J.,Valancius, R, and Zdankus, T., 2020. Research challenges and advancements in the field of sustainable energy technologies in the built environment. *Sustainability*, 12(20), pp. 8417.

Forcael, E., Ferrari, I., Opazo-Vega, A. and Pulido-Arcas, J. A., 2020. Construction 4.0. *Sustainability*, 12 (22), pp. 9755.

Forkan, A., Montori, F.,Georgakopoulos, D.,Jayaraman, P. P.,Yavari, A. and Morshed, A., 2019. *An industrial iot solution for evaluating workers' performance via activity recognition*. In: ICDCS (International Conference on Distributed Computing Systems), 39th International conference on distributed computing systems. Dallass, United States of America. 7-9 July 2019. New York: IEEE.

Fruehe, J., 2015. *The internet of things is about data, not things*. [online] Available at: < https://www.forbes.com/sites/moorinsights/2015/07/30/the-internet-of-things-is-about-data-not-things/?sh=66f2b71027cf> [Accessed 25 August 2021].

Ganti, A., 2021. *Median.* [online]. Available at: < https://www.investopedia.com/terms/m/median.asp> [Accessed 23 September 2021]

.Ganti, A., 2021. *Central limit theorem (clt).* [online]. Available at: <https://www.investopedia.com/terms/c/central_limit_theorem.asp> [Accessed 25 August 2021].

Gatti, U., Migliaccio, G., and Schneider, S., 2011. Wearable physiological status monitors for measuring and evaluating worker's physical strain: preliminary validation. *Computing in Civil Engineering 2011*, 413, pp. 194–201.
Ge, M., Hong, J.B, Guttmann, W. and Kim, S.S., 2017. A framework for automating security analysis of the internet of things. *Journal of Network and Computer Applications*, 83, pp. 12-27.

Gil, D., Johnsson, M., Mora, H. and Szymanski, J., 2019. Review of the complexity of managing big data of the internet of things. *Complexity*, 2019(6), pp. 1-12.

Gnoni, M. G., Bragatto, P. A., Milazzo, M. F. and Setola, R., 2020. Integrating IoT technologies for an "intelligent" safety management in the process industry. *Procedia Manufacturing*, 42, pp. 511–515.

Goodrum, P. M., McLaren, M. A. and Durfee, A., 2006. The application of active radio frequency identification technology for tool tracking on construction job sites. *Automation in Construction*, 15(3), pp. 292–302.

Gravic Group, 2021. *Rfid electronic tags.* [online] Available: <https://gravicgroup.com/en/printed-and-cut-parts/adhesive-labels/rfid-tags/ > [Accessed 20 February 2021].

GSM Association, 2020. *5G network slicing*. [online]. Available at: <https://www.gsma.com/futurenetworks/ip_services/understanding-5g/network-slicing/> [Accessed 25 August 2021].

Hameed, A. and Alomary, A., 2019. *Security issues in IoT: a survey*. In: The College of Information Technology, University of Bahrain. 2019 International conference on innovation and intelligence for informatics computing, and technologies. Sakhier, Bahrain. 22-23 September 2019. New York: IEEE.

Han, T., Jiang, D. and Wang, N., 2016. The fault feature extraction of rolling bearing based on emd and difference spectrum of singular value. *Shock and Vibration*, 2016, pp. 1–14.

He, X., Xiao,B., Hu,B., Tan, L., Tang, H., He, S. and He, Z., 2020. The applications of energy regeneration and conversion technologies based on hydraulic transmission systems: a review. *Energy Conversion and Management*, 205, p. 112413.

Hermerschmidt, L., Perez, A. and Rumpe, B., 2014. A model-based software development kit for the sensorcloud platform. *Trusted Cloud Computing*, pp. 125–140.

Hilti, 2021. *Concrete Sensors.* [online] Available: < https://www.hilti.com/content/hilti/W1/US/en/services/tool-services/internet-of-things/concrete-sensors.html> [Accessed 20 February 2021].

Humayun, M., Hamid, B., Jhanjhi, N.N, Suseendran, G. and Talib. M.N., 2021. 5G network security issues, challenges, opportunities and future directions: a survey. *Journal of Physics: Conference Series,* [e-journal]. https://doi.org/10.1088/1742-6596/1979/1/012037.

Ibrahim, F.S., Esa, M. and Rahman, R.A., 2021. The adoption of iot in the malaysian construction industry: towards construction 4.0. *International Journal of Sustainable Construction Engineering and Technology*, 12(1), 56-67.

International Labour Organization, 2021. World statistic. *International Labour Organization (ILO).* Available at: <https://www.ilo.org/moscow/areas-of-work/occupational-safety-and-health/WCMS_249278/lang--en/index.htm.> [Accessed 20 February 2021].

ITU, 2019. 5G - Fifth generation of mobile technologies. *International Telecommunication Union (ITU).* Available at: <https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx> [Accessed 21 June 2021].

Jindal, F., Jamar, R. and Churi, P., 2018. Future and challenges of internet of things. *International Journal of Computer Science and Information Technology,* 10(2), pp. 13–25.

Jones, N. and Graham, C.M., 2020. Can the iot help small businesses?. *Bulletin of Science Technology & Society,* [e-journal] 38(1), pp.3-12. https://doi.org/10.1177/0270467620902365.

Kasim, N., Ahmad Latiffi, A. and Fathi, M. S., 2013. RFID Technology for materials management in construction projects – a review. *International Journal of Construction Engineering and Management,* 2, pp. 6.

Kelemen, M. and Rumens, N., 2008. *An introduction to critical management research*. London: Sage.

Kerlinger, F.N. and Lee, H., 2000. *Foundations of behavioral research*. California: Wadsworth.

Kumar, S., Tiwari, P. and Zymbler, M., 2019. Internet of Things is a revolutionary approach for future technology enhancement: a review. *Journal of Big Data*, 6(1), pp. 111.

Laerd Statistics, 2020. *Descriptive and inferential Statistics*. [online] Available at: <https://statistics.laerd.com/statistical-guides/descriptive-inferential-statistics.php> [Accessed 15 August 2021].

Laerd Statistics, 2020. *Testing for normality using spss statistics*. [online] Available at: < https://statistics.laerd.com/spss-tutorials/testing-for-normality-using-spss-statistics.php> [Accessed 30 August 2021].

Lagkas, T., Argyriou, V., Bibi, S., and Sarigiannidis, P., 2018. UAV IoT framework views and challenges: towards protecting drones as "things". *Sensors*, 18(11), pp. 4015.

Lakshmi, N.R.G. and Ibe, O. C., 2015. Joint network for disaster relief and search and rescue network operations. *Wireless Public Safety Networks 1*, pp. 163–193.

LetsBuild, 2019. *Construction site inspection: Why it's important to your construction project and business.* [online] Available at: < https://www.letsbuild.com/blog/construction-site-inspection-why-its-important-to-your-construction-project-and-business> [Accessed 25 August 2021].

Levy, J., 2017. *4 BIG Ways The Internet Of Things Is Impacting Design And Construction.* [online] Available: <https://www.ibm.com/blogs/internet-of-things/4-big-ways-the-iot-is-impacting-design-and-construction/> [Accessed 20 February 2021].

Lin, L., Luo B. and Zhong, S., 2018. Multi-objective decision-making model based on cbm for an aircraft fleet with reliability constraint. *International Journal of Production Research*, 56(14), pp. 4831–4848.

Lin, Z., Li, Y., Liu, C., Liao, I., Hsieh, S. and Tsai, M., 2020. Machine maintenance management and repair prediction system. *Molecular Diversity Preservation International*, 9(3), pp. 1–3.

Lind, H., 2013. Construction quality: do it right or pay the price. *Construction Management and Economics*, 31(9), pp. 1018–1019.

Liu, B., 2017. *Construction robotics technologies 2030.* Degree, Delft University of Technology. Available at: <https://repository.tudelft.nl/islandora/object/uuid%3Afcacf6fb-112c-453f-9903-8ec53274153f> [Accessed 20 February 2021].

Lopez, Y.A., Franssen, J., Narciandi, G.A., Pagnozzi, J., Arrillaga, I.G.P. and Andres, F.L.H., 2018. RFID Technology for management and tracking: e-health applications. *Sensor*, 18(8), pp. 2663.

Lu, M., Chen, W., Shen, X., Lam, H., and Liu, J., 2007. Positioning and tracking construction vehicles in highly dense urban areas and building construction sites. *Automation in Construction*, 16, pp. 647–656.

Luo, C., Nightingale, J., Asemota, E. and C. Grecos., 2015. *A UAV-cloud system for disaster sensing applications.* In: IEEE. IEEE *81st Vehicular technology conference.* Glasgow, UK. 11-14 May 2015. New York: IEEE.

Mabe, J., Zubia, J. and Gorritxategi, E., 2017. Photonic low cost micro-sensor for in-line wear particle detection in flowing lube oils. *Sensors.* 17(3), pp. 586.

Mahmud, S. H., Assan, L. and Islam, R., 2018. Potentials of internet of things (iot) in malaysian construction industry. *Annals of Emerging Technologies in Computing (AETiC)*, 2(1), pp. 44–52.

Malaysian Communications and Multimedia Commission, 2020. *Internet users survey 2020*. Cyberjaya: MCMC.

Mao, Y., Bhuse, V., Zhou, Z., Pichappan, P., Abdel-Aty, M., and Hayafuji, Y., 2014. Applied mathematics and algorithms for cloud computing and IoT. *Mathematical Problems in Engineering*, 2014, pp. 1–2.

Mazhandu, F., 2020. *How covid-19 is accelerating adoption of iot in construction.* [online] Available at: <https://www.iotforall.com/covid19-accelerating-iot-construction> [Accessed 25 August 2021].

Morgan, D, 2007. Paradigms lost and pragmatism regained: methodological implications of combining qualitative and quantitative methods. *Journal of Mixed Methods Research*, 1(1), pp. 48–76.

Mouser Electronics, 2021. *Embedded sensor solutions.* [online] Available: <https://www.mouser.com/new/te-connectivity/te-connectivity-embedded-sensor-solutions/ > [Accessed 20 February 2021].

New Straits Time, 2021. *NTIS powers tech innovation for malaysia*. [online] Available at: < https://www.nst.com.my/news/nation/2021/01/656915/ntis-powers-tech-innovation-malaysia> [Accessed 25 August 2021].

Nnaji, C., Okpala, I. and Awolusi, I., 2020. Wearable sensing devices: potential impact & current use for incident prevention. *Professional safety*, 65, pp. 16–24.

Oesterreich, T. D. and Teuteberg, F., 2016. Understanding the implications of digitisation and automation in the context of Industry 4.0: a triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, 83, pp. 121–139.

Oh, S.R. and Kim, Y.G., 2017. *Security requirements analysis for the iot*. in: ict platform society. *2017 International conference on platform technology and service.* Busan, Korea. 13-15 Febraury 2017. Basel: MDPI.

Oladiran, O. J., and Sotunbo, A. S., 2009. Accidents on building sites: rate of occurence and causes. *The Professional Builders*. Available at: < https://www.academia.edu/8450490/accidents_on_building_sites_rate_of_occurrence_and_causes> [Accessed 20 February 2021].

Oregon Department of Transportation, 2018. *Eyes in the sky: bridge inspections with unmanned aerial vehicles*. Salem: ODOT.

Oxford Reference, 2021. *Overview: research.* [online] Available: <https://www.oxfordreference.com/view/10.1093/oi/authority.20110803100415273> [Accessed 10 March 2021].

Papalkar, R. R., Nerkar, P. R. and Dhote, C. A., 2017. *Issues of concern in storage system of IoT based big data*. In: ICIC International. 2017 International conference on information, communication, instrumentation and control. Indore, India. 17-19 August 2017. New York: IEEE.

Patel, K., Patel, S., Scholar, P. and Salazar, C., 2016. Internet of Things-IoT: definition, characteristics, architecture, enabling technologies, application & future challenges. *International Journal of Engineering Science and Computing*, 6(5), pp. 6122-6131.

Pateriya, R. K. and Sharma, S., 2011.*The evolution of RFID security and privacy: a research survey*. In: MIR Labs India. 2011 International conference on communication systems and network technologies. Katra, India. 3-5 June 2011. New York: IEEE.

Paul, S., Nail, B and Bagal, D.K., 2020. *Enabling technologies of iot and challenges in various field of construction industry in the 5g era: a review*. In: IOP (Institute of Physics). IOP Conference series: materials science and engineering. Odisha, India. 17-18 September 2020. Bristol: IOP Publishing Ltd.

Phelan, C. and Wren, J., 2005. *Exploring reliability in academic assessment*. [online] Available at: <https://chfasoa.uni.edu/reliabilityandvalidity.htm> [Accessed 15 August 2021].

Pratt, M.K., 2021. *IoT data quality determines project profitability*. [online]. Available at: <https://internetofthingsagenda.techtarget.com/tip/IoT-data-quality-determines-project-profitability> [Accessed 25 August 2021].

Rad, B.B. and Ahmada, H.A., 2017. Internet of things : trends , opportunities , and challenges. *International Journal of Computer Science and Network Security*, *17*(7), 89–95.

Rahim, M. A., Rahman, M.A., Rahman, M. M., and Asyhari, T., and Bhuiyan, M. and Devarajan, R., 2020. Evolution of IoT-enabled connectivity and applications in automotive industry: a review. *Vehicular Communications*, 27, pp. 100285.

Rao, B. B. P., Saluia,P., Sharma,N., Mittal, A. and Sharma, S. V., 2012. *Cloud computing for Internet of Things & sensing based applications*. In: ICTS (International Conference on Sensing Technology), Sixth International conference on sensing technology. Kolkata, India. 18-21 December 2012. New York: IEEE.

Reja, V.K. and Varghese, K., 2019. Impact of 5G Technology on IoT Applications in Construction Project Management. *36th International Symposium on Automation and Robotics in Construction*, pp. 209-217.

Research and Markets, 2020. *Construction in Malaysia - key trends and opportunities to 2024. Malaysia*: Research and Markets.

Robert, B., 2018. What are the prospects for robots in the construction industry?. *Industrial Robot: An International Journal*, 45(1), pp. 1–6.

Robotech Shop, 2021. *Vibration sensor.* [online] Available: <http://robotechshop.com/shop/%E2%80%A2sensors/vibration-sensor/ > [Accessed 20 February 2021].

Roland Berger., 2016. *Digitization in the Construction Industry: Building Europe's Road to Construction 4.0*. Germany: Roland Berger GMBH.

Royal Institution Chartered Surveyors, 2019. *Drones: applications and compliance for surveyors*. London: RICS.

Saidi, K.S., O'Brien, J. B. and Lytle, A. M., 2008. Robotics in construction. In: Siciliano B., Khatib O. (eds). *Springer handbook of robotics*. Springer: Berlin. pp. 1079-1099.

Sani, R., 2019. Making sense out of stem and iot. *New Straits Times,* [online] 2 January. Available at: < https://www.nst.com.my/education/2019/01/446212/making-sense-out-stem-and-iot> [Accessed 30 August 2021].

Sanson, J., 2019. *Drone use in the construction industry leads to integration into the current civil and construction engineering technology curriculum.* [online] Available at: <https://peer.asee.org/drone-use-in-the-construction-

industry-leads-to-integration-into-the-current-civil-and-construction-engineering-technology-curriculum.pdf> [Accessed 25 August 2021].

Sarwesh, P., Shet, S. and Chandrasekaran, K., 2017. Energy-efficient network architecture for iot applications. *Internet of Things*, pp. 119–144.

Sastry,J.K.R. and Bhupathi., 2020. enhancing fault tolerance of iot networks within device layer. *International Journal of Emerging Trends in Engineering Research*, 8(2), pp. 491–509.

Saunders, M., Lewis, P., and Thornhill, A., 2015. *Research methods for business students. 7th edi*. Harlow: Pearson.

Scarlet Tech, 2021. *Construction iot：the lifesaving technology amidst covid-19.* [online] Available at: <https://scarlet-tech.com/2021/05/11/construction-iot%EF%BC%9Athe-lifesaving-technology-amidst-covid-19/> [Accessed 25 August 2021].

Schenkelberg, F., 2020. *The non-parametric friedman test*. [online]. Available at: <https://accendoreliability.com/non-parametric-friedman-test/> [Accessed 25 August 2021].

Seliem, M., Elgazzar, K. and Khalil, K., 2018. Towards privacy preserving iot environments: a survey. *Wireless Communications and Mobile Computing,* 2018, pp. 1032761.

Showkat, N. and Parveen, H., 2017. *Non-probability and probability sampling.* [online] Available at: <https://www.researchgate.net/publication/319066480_Non-Probability_and_Probability_Sampling> [Accessed 15 August 2021].

Singh, R. P.,Javaid, M., Haleem, A. and Suman, R., 2020. Internet of things (IoT) applications to fight against Covid-19 pandemic. *Diabetes & Metabolic Syndrome 2020*, 14(4), pp. 521–524.

Small Business Innovation Research, 2017. *Facilitating security, reliability, and privacy in networked internet of things (iot) devices*. [online] Available at: <https://static1.squarespace.com/static/551eaf33e4b0ab14538484d1/t/5e2749d3c179bf7b311c871d/1579633142936/Triax_IOT_eBook_final.pdf> [Accessed 25 August 2021].

SME Corp. Malaysia, 2021). *SME definitions*. [online] Available at: <https://www.smecorp.gov.my/index.php/en/policies/2020-02-11-08-01-24/sme-definition> [Accessed 23 September 2021].

Song, J., Haas, C,T. and Caldas, C.H., 2006. Tracking the location of materials on construction job sites. *Journal of Construction Engineering and Management*, 132(9), pp. 911.

Soni, V. D., 2019. Security issues in using iot enabled devices and their impact. *International Engineering Journal For Research and Development*, 4(2), pp. 1–7.

Srinidhi, N.N., Dilip Kumar, S. M. and Venugopal, K. R., 2019. Network optimizations in the internet of things: a review. *Engineering Science and Technology, an International Journal*, 22(1), pp. 1–21.

Sruthy, S., Yamuna, S. and George, S., 2020. *An IoT based active building surveillance system using raspberry pi and node MCU*. Degree. National Institute of Technology. Available at: <https://arxiv.org/ftp/arxiv/papers/2001/2001.11340.pdf> [Accessed 22 February 2021].

STHDA, n.d. *Kruskal-wallis test in r*. [online]. Available at: <http://www.sthda.com/english/wiki/kruskal-wallis-test-in-r> [Accessed 25 August 2021].

Sunbiz, 2021. Most malaysian employees want work flexibility post-covid pandemic: ey survey. *The Sun Daily*, [online] 5 July. Available at: <https://www.thesundaily.my/business/most-malaysian-employees-want-work-flexibility-post-covid-pandemic-ey-survey-FF8034025> [Accessed 25 August 2021].

Swan, M., 2012. Sensor mania! the internet of things, wearable computing, objective metrics, and the quantified self 2.0. *Journal of Sensor and Actuator Networks*, 1(3), pp. 217–253.

Tatum, M. C. and Liu, J., 2017. *Unmanned aerial vehicles in the construction industry*. In: ASC (Associated School of Construction). 53rd ASC Annual International Conference Proceedings. Seattle, Washington. 5-8 April 2017. Colorado: ASC.

Teizer, J., 2015. Wearable, wireless identification sensing platform: self-monitoring alert and reporting technology for hazard avoidance and training (smarthat). *Journal of Information Technology in Construction*, *20*, 295-312.

The Asean Post, 2019. *Drones in the construction industry*. [online] Available at: <https://theaseanpost.com/article/drones-construction-industry> [Accessed 25 August 2021].

Tkac, M. and Mesaros, P., 2019. Utilizing drone technology in the civil engineering. *Journal of Civil Engineering*, 14(1), pp. 27–37.

Triantafyllou, A., Sarigiannidis, P. and Lagkas, T., 2018. Network Protocols, Schemes, and Mechanisms for Internet of Things (IoT): Features, Open Challenges, and Trends. *Wireless Communications and Mobile Computing*, 2018, pp. 1–24.

Triax, n.d. *Demystifying the internet of things for construction*. [online] Available at: <https://static1.squarespace.com/static/551eaf33e4b0ab14538484d1/t/5e2749d3c179bf7b311c871d/1579633142936/Triax_IOT_eBook_final.pdf> [Accessed 25 August 2021].

Turner, A., 2015. Generation z: technology and social interest. *The Journal of Individual Psychology*, 71(2), pp. 103-113.

UK Government, 2017. *Made SmarterReview 2017*. London: Gov.UK.

Veras, P. R., Suresh, S. and Renukappa, S., 2018. *The adoption of big data concepts for sustainable practices implementation in the construction industry*. In UCC Companion. 2018 IEEE/ACM International conference on utility and cloud computing companion. Zurich, Switzerland. 17-20 December 2018. New York: IEEE.

Vikas,B. O., 2015. Internet of Things (IoT): a survey on privacy issues and security. *International Journal of Scientific Research*, 1(3), pp. 168.

Wan, K. T. and Leung, C. K. Y., 2007. Fiber optic sensor for the monitoring of mixed mode cracks in structures. *Sensors and Actuators A: Physical*, 135(2), pp. 370–380.

Warrior, J., McHenry, E. and McGee, K., 2003. They know where you are [location detection]. *IEEE Spectrum*, 40(7), pp. 20–25.

Western Sydney University, 2021. *Research service: definition of research*. [online] Available: <https://www.westernsydney.edu.au/research/researchers/preparing_a_grant_application/dest_definition_of_research> [Accessed 20 February 2021].

World Construction Today, 2021. *Fastbrick Australia company FBR completes walls of first display home using bricklaying robot.* [online] Available: <https://www.worldconstructiontoday.com/uncategorized/fastbrick-australia-company-fbr-completes-walls-of-first-display-home-using-bricklaying-robot/ > [Accessed 20 February 2021].

World Economic Forum, 2016. *Shaping the Future of Construction. A Breakthrough in Mindset and Technology.* Geneva: WEF.

Wozniak, D. , Kukielka, L. and Wozniak, J., 2013. Modern active and passive safety systems in cars : chosen aspects. *Autobusy : Technika, Eksploatacja, Systemy Transportowe*, 14(10), pp. 272–277.

Yaici, K., 2019. Business survey 2019: improving the awareness of IoT is key to increasing the adoption of IoT solutions, [online] Available at: <https://www.analysysmason.com/research/content/comments/iot-awareness-adoption-rdme0/> [Accessed 25 March 2019].

Yu, S.N., Ryu, B.G., Lim, S,J., Kim, C.J., Kang, M.K. and Han, C.S., 2009. Feasibility verification of brick-laying robot using manipulation trajectory and the laying pattern optimization. *Automation in Construction*, 18(5), pp. 644–655.

Zahoor, S. and Mir, R. N., 2018. Resource management in pervasive Internet of Things: a survey. *Journal of King Saud University - Computer and Information Sciences*, 32(10), pp. 1204-1205.

Zainea, E., Martian, A., Marcu, I. and Fratu, O., 2012. *Transition from analog to digital broadcasting a spectral efficiency review*. In: IEEE(Institute of Electrical and Electronics Engineers). *10th International symposium on electronics and telecommunications.* Timisoara, Romania. 15-16 November 2012. New York: IEEE.

Zaldivar, D., Tawalbeh, L. A. and Muheidat, F., 2020. *Investigating the security threats on networked medical devices*. In: IEEE(Institute of Electrical and Electronics Engineers). 10th Annual computing and communication workshop and conference. Las Vegas, United States of America. 6-8 January 2020. New York: IEEE.

Zhang, K., Yao, J. and Jiang, T., 2014. Degradation assessment and life prediction of electro-hydraulic servo valve under erosion wear. *Engineering Failure Analysis*, 36, pp. 284–300.

Zhang, M. Y., Cao, T. Z. and Zhao, X. F., 2017. Applying sensor-based technology to improve construction safety management. *Sensors,* 17, pp. 1841.

APPENDICES

APPENDIX A: Survey Questionnaire

UNIVERSITI TUNKU ABDUL RAHMAN

Wholly owned by UTAR Education Foundation

(Co. No. 578227-M)

DU012(A)

ADOPTION OF INTERNET OF THINGS (IOT) ON CONSTRUCTION SITE

Dear Sir/Madam,

I am a final year undergraduate student currently pursuing Bachelor of Science (Honours) Quantity Surveying in Universiti Tunku Abdul Rahman (UTAR), Lee Kong Chian Faculty of Engineering and Science (LKC FES). You are invited to take part in a survey regarding “Adoption of Internet of Things (IoT) On Construction Site”. It would be appreciated if you could spare around 10 minutes to answer this questionnaire survey. Participation is voluntary and you may refuse to participate at any time. All the data collected will be kept private and confidential and will be strictly used for academic purposes only. If you have any questions or further enquiries, please do not hesitate to contact me at cwx1998@1utar.my. Thank you for your participation and have a nice day.

Thank you.

Yours faithfully,

Chong Wen Xin
Bachelor of Science (Honours) Quantity Surveying
Universiti Tunku Abdul Rahman

The type of your organisation

- o Developer Company
- o Consultancy Company
- o Construction Company
- o Supplier/ Subcontractor/ Specialist Company

Your role on construction site

- o Construction Manager
- o Site Supervisor
- o Consultant
- o Supplier/ Subcontractor/ Specialist

What is your age?

- o Below 25
- o 26 - 30
- o 31 - 40
- o 41 - 50
- o Above 51

How many year(s) of working experience do you have?

- o 0 - 2 year
- o 3 - 5 years
- o 6 - 10 years
- o 11 - 20 years
- o More than 20 years

What is your company size?

- o Small (5 – 30 Employees)
- o Medium (30 – 75 Employees)
- o Large (> 75 Employees)

What is your qualification?

- o Secondary

- Diploma
- Bachelor Degree
- Master
- PhD

What is your experience year(s) in using IoT?

- 0 year
- 1 – 3 years
- 4 – 5 years
- 6 years and above

Section A: Fundamental Knowledge of IoT

1. Which definition best describe the term Internet of Things (IoT)?
   - The general idea of devices in daily life that are manageable via the Internet.
   - The communication between anything from anywhere at any time through digital applications.
   - The integration of multiple processes which are sensing, identifying, networking and computing the data.
   - The growing network of physical objects which are able to communicate among themselves and with other internet-enabled devices over the Internet.

2. How important are the listed IoT to the construction site?

[0= Not Important, 1= Slightly Important, 2= Important, 3= Much Important, 4= Very Much Important]

Statements	0	1	2	3	4
IoT-based Sensor	o	o	o	o	o
Drone Technology	o	o	o	o	o
Cloud-based IoT Platform	o	o	o	o	o
Robotics	o	o	o	o	o
RFID Tagging System	o	o	o	o	o
5G Network	o	o	o	o	o

3. Please rate your level of agreement with the importance of IoT.

[0= Strongly Disagree, 1= Disagree, 2= Neutral, 3= Agree, 4= Strongly Agree]

Statements	0	1	2	3	4
IoT is important in remote Inspection and progress report	o	o	o	o	o
IoT is important in locating and tracking of site resources	o	o	o	o	o
IoT is important in monitoring and maintenance of machinery	o	o	o	o	o
IoT is important for safety and health of site workers	o	o	o	o	o
IoT is important for security of site	o	o	o	o	o
IoT-based sensor collects and gathers the relevant data	o	o	o	o	o
IoT-based sensor monitors site conditions	o	o	o	o	o
IoT-based sensor ensures safety of workers	o	o	o	o	o
IoT-based sensor improves performance of equipment	o	o	o	o	o
Drone technology carries out high-elevation inspection	o	o	o	o	o
Drone technology carries out remote monitoring and surveillance	o	o	o	o	o
Drone technology obtains real-time information	o	o	o	o	o
Cloud-based IoT platform manages huge data generated by IoT devices	o	o	o	o	o
Cloud-based IoT platform provides infinite storage for data	o	o	o	o	o

Cloud-based IoT platform analyses data generated by IoT devices	o	o	o	o	o
Robotics carries out repetitive works efficiently	o	o	o	o	o
Robotics carries out dangerous and high risk works	o	o	o	o	o
Robotics saves cost and time	o	o	o	o	o
RFID tagging system tracks materials and equipment	o	o	o	o	o
RFID tagging system provides identification of objects	o	o	o	o	o
RFID tagging system allows better planning of project schedules	o	o	o	o	o
5G provides better and more stable connectivity.	o	o	o	o	o
5G allows faster transmission of huge data and big files	o	o	o	o	o
5G supports higher IoT user density.	o	o	o	o	o

Section B: Adoption of IoT

1. What is the scale of your intention on adopting IoT on the construction site ? [0= No Intention, 1= Neutral, 2= Fair Intention, 3= Much Intention, 4= Very Much Intention]

Statement	0	1	2	3	4
Intention on Adopting IoT	o	o	o	o	o

2. How likely you will adopt the following technology on construction site? [0= No Idea, 1= Never Consider, 2= Not Likely, 3= Somewhat Likely, 4= Very Likely]

Statements	0	1	2	3	4

IoT-based Sensor	o	o	o	o	o
Drone Technology	o	o	o	o	o
Cloud-based IoT Platform	o	o	o	o	o
Robotics	o	o	o	o	o
RFID Tagging System	o	o	o	o	o
5G Network	o	o	o	o	o

3. Please rate the following statements based on your perception towards IoT on construction site.

[0= Strongly Disagree, 1= Slightly Disagree, 2= Neutral, 3= Slightly Agree, 4= Strongly Agree]

Statements	0	1	2	3	4
I have the intention to use IoT devices.	o	o	o	o	o
I prefer using IoT devices than traditional devices.	o	o	o	o	o
I feel more confident when my data in IoT devices are protected.	o	o	o	o	o
I feel more confident when the data collected is reliable.	o	o	o	o	o
I foresee i will have more opportunities to use IoT devices.	o	o	o	o	o
I will recommend others to use IoT devices.	o	o	o	o	o
I feel using IoT devices is helpful to my tasks.	o	o	o	o	o
I am willing to undergo IoT workshop training on my own cost.	o	o	o	o	o
I am willing to learn IoT during my personal time.	o	o	o	o	o
I am willing to initiate culture of IoT in my organisation.	o	o	o	o	o

4. To what extent the following IoT is adopted at your construction site?

[0= No Idea, 1= Not Adopting, 2= Will Be Adopting, 3= Adopting Less Than 1 Year, 4= Already Adopted More Than 1 Year]

Statements	0	1	2	3	4
IoT-based Sensor	o	o	o	o	o
Drone Technology	o	o	o	o	o
Cloud-based IoT Platform	o	o	o	o	o
Robotics	o	o	o	o	o
RFID Tagging System	o	o	o	o	o
5G Network	o	o	o	o	o

5. To your knowledge, to what extend your company adopt IoT in the following construction activities?

[0= No Idea, 1= Not Adopting, 2= Will Be Adopting, 3= Adopting Less Than 1 Year, 4= Already Adopted More Than 1 Year]

Statements	0	1	2	3	4
Design	o	o	o	o	o
Site inspection	o	o	o	o	o
Site progress monitoring	o	o	o	o	o
Site resource management (labour, equipment, material)	o	o	o	o	o
Site logistic	o	o	o	o	o
Site construction work	o	o	o	o	o
Site quantity taking off	o	o	o	o	o
Site maintenance work	o	o	o	o	o
Site security and safety	o	o	o	o	o

6. To your knowledge, to what extend do you agree with IoT adoption will transform the following activities in your organization?

[0= No Idea, 1= Not Adopting, 2= Will Be Adopting, 3= Adopting Less Than 1 Year, 4= Already Adopted More Than 1 Year]

Statements	0	1	2	3	4
Design	o	o	o	o	o

Site inspection	o	o	o	o	o
Site progress monitoring	o	o	o	o	o
Site resource management (labour, equipment, material)	o	o	o	o	o
Site logistic	o	o	o	o	o
Site construction work	o	o	o	o	o
Site quantity taking off	o	o	o	o	o
Site maintenance work	o	o	o	o	o
Site security and safety	o	o	o	o	o

7. Which of the following concern you the most when adopting IoT on construction site ?

[0= No Concern, 1= Slight Concern, 2= Neutral, 3= Concern, 4= Very Much Concern]

Statements	0	1	2	3	4
Security Concerns	o	o	o	o	o
Privacy Concerns	o	o	o	o	o
Data Storage and Data Analysis	o	o	o	o	o
Network Failure	o	o	o	o	o
System Fragmentation and Interoperability	o	o	o	o	o
Resource Availability and Cost Consumption	o	o	o	o	o