READINESS OF DIGITAL TECHNOLOGY ADOPTION IN THE MALAYSIAN CONSTRUCTION PROJECT MANAGEMENT

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

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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.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"READINESS OF DIGITAL TECHNOLOGY ADOPTION IN THE MALAYSIAN CONSTRUCTION PROJECT MANAGEMENT"** was prepared by **ONG JIUN REN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) in Quantity Surveying at Universiti Tunku Abdul Rahman.

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ABSTRACT

Emerging technologies are changing the way people work and live. A new digital world has coexisted with the physical world as a result of creative disruption by the emerging technologies. These digital technologies impact all kinds of businesses and it will have no exception to the construction industry. McKinsey Global Institutes industry digitisation index 2015 shows that construction industry is the second least digitalised sectors among the 22 sectors studied. This research explores the adoption of digital technology by the Malaysian construction industrial practitioners, assess the awareness of construction practitioners towards digital adoption and analyse the preparedness in digital technology adoption. A theoretical framework was synthesised after the literature related to the application, current technology adoption and lesson learnt in digitalisation in the construction industry has been reviewed. A questionnaire encompassed the theoretical framework were used as research instrument to collect the raw data from the industry. Based on the 122 responses from the questionnaire survey, this research found that the Malaysian construction industry adopted digital technology mainly used for real time communication. However, they are yet to unleash the potentials of digital technologies such as data analytics and data representation. It has also revealed that the younger generation are more willing to adopt new digital technologies Among them, Architects are more receptive towards digital technology adoption. The above conclusion is beneficial for the local construction community and authority towards strategical charting and policies formulations of the industry to embrace the benefits of digital economy which is already here.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

ρ	Spearman's Correlation Coefficient
p-value	Asymptotic Significance
$\chi 2$	Chi-value

AI	Artificial Intelligence
AR	Augmented Reality
BEM	Board of Engineers Malaysia
BIM	Building Information Modelling
BQSM	Board of Quantity Surveyors Malaysia
CEO	Chief Executive Officer
CIDB	Construction Industry Development Board
CLT	Central Limit Theorem
E&C	Engineering and Construction
EY	Ernst & Young
GPS	Global Positioning System
IoT	Internet of Things
LAM	Lembaga Arkitek Malaysia
LIDAR	Light-Detection-and-Ranging
MR	Mixed Reality
NBS	National Institute of Standards and Technology
NFC	Near-field-communication
PMBoK	Project Management Book of Knowledge
PMI	Project Management Institute
PMO	Project Management Office
RIBA	Royal Institute of British Architects
ROI	Return on Investment
UAVs	Unmanned Aerial Vehicles
UK	United Kingdom
US	United States
VR	Virtual Reality

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Emerging technologies are innovating the way people work and live. A new digital world has coexisted with the physical world as a result of creative disruption by such emerging technologies. These creative disruptive technologies impact global business and the method of managing a project (Langley, 2018). The construction sector is no exception in this new normal. The COVID-19 pandemic lockdowns witnessed the essentials and urgency of digital readiness which is the only way to allow business and life to continue as usual as possible (Xiao and Fan, 2020).

The construction industry has huge impact to Malaysian economy. It contributed 5.9% to the GDP in Malaysia in 2017 (Bernama, 2017). The Malaysian Ministry of Finance (MoF) has increased the allocated budget for development expenditure (DE) in 2020 compared to 2019 (Bernama, 2019). The infrastructure sector is capable to act as a buffer for economic slowdown and job opportunities all across the supply chain in the industry (Wong, 2019). However, statistics shows that there is still an investment gap of RM 8.66 billion in Malaysian infrastructure sector in 2020 (Global Infrastructure Hub, 2020). In addition, the MoF has the initiative to digitalise the economy. Various initiatives and incentives for the development of digital applications, digital companies and digital Malaysians were announced in the National Budget 2020 (Tan, 2019).

A success of any project undertaken heavily depend on project administration and management. Project management is proven to be one of the most critical factors to determine the success or failure of a project (Gudienė et al., 2014). An effective project management can increase the productivity of a project by 50% to 60%. It includes a proper site management; a strategic procurement and supply chain management; an adoption of digital technology, new materials and advanced automation, team of skilful workforce and rewiring the contractual framework (Barbosa, Mischke and Parsons, 2017).

Construction projects are becoming increasingly competitive, the Malaysian construction industry needs to make advancement in technology adoption, such as Building Information Modelling (BIM). BIM offers a more cost and time-sensitive solution as compared to the traditional process of construction. In fact, reduction of construction costs and design problems in the planning phase can be achieved with the use of BIM (Sharifuddin, 2019). The government might consider making BIM adoption mandatory for all developers, both public and private, in the future (Amiruddin, 2019).

1.2 Problem Statement

Productivity of the construction industry has grown by 1% each year for the past few decades, compared with a 2.8% growth rate for the global economy and 3.6% in manufacturing industry (Barbosa et al., 2017). This phenomenon occurs as there is rarely an investment in tech or IT in the construction sector, so it has been performing the same way since 1940s until 2013. McKinsey Global Institute industry digitisation index 2015 shows that the construction industry is the second least digitalised sectors among the 22 sectors studied (Agarwal et al., 2016). Barbosa et al. (2017) suggested that if the construction industry was to improve its performance, it will cause a rise about 2% to the global economy.

Furthermore, the Ministry of Housing and Local Government Malaysia (2020) reported that there are 402 housing projects in Malaysia that their work progress is far behind their schedule. The research carried out by Shehu et al. (2014) found out that 55% of construction projects in Malaysia suffer from cost overran. Moreover, Chia et al. (2019) mentioned that much efforts and policy making are needed in order to unlock the potential of digital transformation. It simply indicates that the Malaysian construction industry is not ready for the transformation.

Besides, there are few researches related to digital technology adoption in the Malaysian construction industry. For example, Al-Ashmori et al. (2020) studied on Building Information Modelling (BIM) Benefits and its Influence on the BIM Implementation in Malaysia. Davila Delgado et al. (2019) studied on Robotics and Automated Systems in Construction: Understanding Industry Specific Challenges for Adoption. Muthusamy and Chew (2020) studied on the Critical Success Factors for the Implementation of Building Information

Modelling (BIM) among Construction Industry Development Board (CIDB) G7 Contractors in the Klang Valley, Malaysia. Musa et al. (2016) studied on Adoption of Modular Construction in the Malaysian construction industry. Although BIM, robotics and digital fabrication are part of digitalisation of the construction industry, but it does not represent the whole of it. Thus, does the Malaysian construction industry make use of digital technologies on their practice? Is the industry ready to adopt these disruptive technologies? The research intended to answer these questions.

1.3 Research Aim

This research aims to uncover the preparedness in digital technology adoption in construction project management in Malaysia.

1.4 Research Objectives

In order to achieve the research aim mentioned above, the following research objectives are established:

1. to explore the adoption of digital technology in the construction industry.
2. to assess the awareness of construction practitioners towards digital technology adoption.
3. to analyse the preparedness in digital technology adoption.

1.5 Research Method

This research is exploratory in nature. The primary data for this research is collected using questionnaire survey and its reliability is validated by Cronbach Alpha Test. The data is first analysed descriptively to show a brief summary of the data and inferentially to make generalisation about the larger population of subjects.

Krukal-Wallis Test is one of the inferential statistics adopted to determine the significant differences in frequency of digital technology usage and digital awareness among different respondents' attributes. Besides, Friedman test compares the mean ranks and indicates their differences in the extent of agreement towards the usefulness and preparedness in digital transformation. Spearman correlation evaluates relationships between organisations' current project performance and their preparedness in digital transformation. Chi-square test is also used to determine whether if a difference between observed data and expected data is due to relationship between variables in this research or due to chance.

1.6 Research Scope and Limitations of the Research

The data are obtained from any individuals who work in the Malaysian construction industry. The target respondents are from different professionals, nature of business and years of experience. The limitation of this research is that the scope of research is very broad as it covered the whole Malaysia.

1.7 Structure of Report

Chapter 1 provides a backdrop of digital transformation and a brief account of Malaysian construction industry. It defines the research problems and outlines research aim, objective, research methods, scope and limitations of this research.

Chapter 2 reviews the nature of construction project management. This chapter explores the digital technology in used and potential applications in the construction industry.

Chapter 3 elaborates the nature of research and research designs adopted. It explains the structure of research instrument (e.g. questionnaire) in the context of theoretical framework. It details the sampling methods and justification of sample size. The chapter also highlights methods of data analysis and the different statistical test used in this research.

Chapter 4 presents the processed data of questionnaire survey. The analysis presented are summarised. The collected data is tested with reliability test to justify the internal construct of the questionnaire, descriptive statistic and inferential statistic to generalise the findings.

Lastly, Chapter 5 concludes the entire research and the current situation of the digitalisation of the Malaysian construction industry. The implications of this research to the industry, regulators and researchers are outlined. It also reflects the limitations of this research and recommends improvement as well as extensions of similar research in future.

CHAPTER 2`

LITERATURE REVIEW

2.1 Introduction

This chapter reviewed the research topic by examining the components of the topic, i.e. project management, construction management and digital technologies in the construction industry. Section 2.2 elucidates project management as a methodology to effectively manage projects in all sectors of economy. Section 2.3 examines construction management as a narrower project management approach exist within the construction industry. Section 2.4 reviews the digital technologies applicable in the construction project management. The theoretical framework was synthesised in the Section 2.5 of this chapter to integrate the theoretical aspects of literature reviewed in this chapter.

2.2 Project Management

According to Project Management Institute (2017), project management is defined as the utilisation of knowledge, expertise, tools and strategies to fulfil the requirements of a project. Association of Project Management described that the management of a project is carried out by implementing and incorporating project management processes defined for a specific project (Murray-Webster and Dalcher, 2019). In a nutshell, project management helps companies to quickly and efficiently execute projects.

*A Guide to the Project Management Body of Knowledge (*PMBoK), published by Project Management Institute is an entire collection of processes, best practices, terminologies, and guidelines that are accepted as standards within the project management community (PMI, 2017). PMBoK encompassed 48 project management processes which are grouped into five project management process groups and ten knowledge areas. The project management processes are the systematic series of activities directed toward causing an end result where one or more inputs will be acted upon to create one or more output, while the five project management process groups are logical grouping of project management inputs, tools and techniques, and output. The Project Management Process Groups include Initiating, Planning, Executing, Monitor and Controlling, and Closing. The project management knowledge areas are the identified area of project management defined by its knowledge requirements and described in terms of its component processes, practices, inputs, outputs, tools, and techniques. The following table 2.1 shows the ten knowledge areas.

Table 2.1: Ten Knowledge Areas of Project Management

Knowledge Areas	**Functions**
Project Integration Management	Categorise, describe, combine, integrate and organise different activities in project management.
Project Scope Management	Ensure that the project only contains all the necessary work only.
Project Schedule Management	Draft a schedule and monitor the project’s timely completion.
Project Cost Management	Forecast, finance, control, reduce cost needed for a project in order to execute the project within the budget.
Project Quality Management	Enforce the quality policy of a company to ensure the quality of a project or product to an acceptable standard in order to satisfy the client.
Project Resource Management	Ensure the required resource is being procured and managed at the right time and right place.
Project Communication Management	Ensure the required information that is needed by the project and stakeholders are met.
Project Risk Management	Plan, identify, assess, organise responses, implementing responses and tracking risks on a project.
Project Procurement Management	Deal with external project parties to obtain appropriate goods, facilities or outputs.
Project Stakeholder Management	Involve stakeholders in making decisions and implementation in a project and ensure effective communication with all stakeholders.

Source: Summarised from PMBOK (PMI, 2017)

2.3 Construction Management

Construction management is a professional service that provides a project’s owner with effective management of a project’s schedule, cost, quality, safety, scope and function (CMAA, 2020). Construction management is used to provide the client of a construction project with skilled management services with the goal of achieving high quality at minimal cost (Sears et al., 2015).

2.3.1 Scope of Construction Management

Harris, McCaffer and Edum-Fotwe (2013) examine on the planning techniques available in the production of project schedule. Besides, the authors remark that bidding strategies and tendering procedures are part of project procurement. Cost estimation and cost control are crucial to prevent cost overrun. The authors mention that communication tools such as information and communication technology (ICT) are used to improve collaboration between stakeholders.

Pellicer et al. (2014) emphasise on the preparation for site planning in the pre-construction phase. In addition, productivity and performance of workforce are tracked to manage project resources efficiently. The authors mentioned that health, safety and supply chain management are important processes in managing construction project.

Sears et al. (2015) focus on project planning and coordination prior to commencement of construction project. Project scheduling concepts and its applications were then pointed out by the authors. In addition, the authors discuss the role and implementation of financial management in construction project.

The course syllabus of Diploma in Construction Site Management published by Chartered Institute of Building (CIOB, 2015) focuses on project control and ways to manage sub-contractors within the construction environment. Contractual and legal responsibilities of various parties in a construction project are emphasised. The course content also includes health, safety, welfare and risk of workforce.

Table 2.2 maps the scope of construction management advocated by the above learned authors with the Project Management Knowledge Areas included in the PMBoK (PMI, 2017). It shows all the scope of construction management can be encapsulated in the Project Management Knowledge Areas.

Table 2.2: Mapping of of Scope of Construction Management Literatures and Project Management Knowledge Areas

PMI (2017)	Harris, McCaffer and Edum-Fotwe (2013)	Pellicer et al. (2014)	Sears et al. (2015)	CIOB (2015)
Project Integration Management			√	√
Project Scope Management	√		√	
		√		
Project Schedule Management	√			
			√	
Project Cost Management	√	√	√	
Project Quality Management	√	√		√
Project Resource Management	√	√	√	√
Project Communication Management	√	√		
Project Risk Management		√		√
Project Procurement Management	√	√		√
Project Stakeholder Management				√

2.3.2 Life Cycle of a Construction Project

The life cycle of a construction project started with the conceptual phase whereby the client researches for the right location and the specifications or standards that should be adhered in a development (Koutsogiannis, 2019). Client briefs the architect on his desired design. Then, the design phase is usually led by a primary designer, architect who is responsible for the detailed design of a scheme to ensure that the state regulations and codes is met and satisfy the brief instructed by the developer, including all the objectives of the development proposal. Once the detailed design is developed, contract documents will be finalised and are used in the tendering process for the project (RIBA, 2020). As soon as the contractor has been chosen to undertake the project, the project team will procure materials, equipment and workforce. A pre-construction meeting is done before the construction work began. This ensures that stakeholders are on the same page when the construction starts. Finally, the work on job site has been completed and the project is handed over to the client marks that the project has come to a close (RIBA, 2020). The construction life cycle reviewed here is in consistent with the five project management processes groups included in the PMBoK.

2.4 Digital Technology Applicable in the Construction Industry

Mills (2016) defines digital construction as the use and application of digital tools to improve the process of delivering and operating the built environment. It makes the delivery, operations and renewal of the built environment safer, more efficient and collaborative (Walker, 2019). Digital construction enables builders to build digitally in software before actually building it on site. Chia et al. (2019) proposed a model A + B + C = D which represents digital construction (D) comprises of algorithm (A), big data (B) and computational power (C). In the proposed model, the data (B) act as the fuel to be processed with algorithm (A) with the required computational power (C). Digital construction comes in many different forms such as drones, 3D printing, Internet of Things, etc. (Borg, 2019). These emerging technologies have changed the way we work and bring it up to another level. The trend of digital construction is predicted to be here within 5 years (Hamil, 2019). The change is inevitable and it is hard to stay away irrespective of whether one wished (Castagnino et al., 2018). In the UK, Digital Construction Week is a free exhibition to expose construction practitioners to the latest digital technology available in the construction industry. This annual exhibition focuses on the tools and processes in shaping the future of the built environment.

2.4.1 Essential Digital Technology in Construction Industry

The emergence of digital technology has affected numerous industries across the globe. The construction industry must be able to adopt the disruption in order to be benefited from it (Jones, 2020). McKinsey Global Institute (Koeleman et al., 2019) indicates that digital transformation can result in cost reductions of 4% to 6% of the entire project. The word digital is confusing (Mills, 2016). Digital technology in the construction industry could take many forms. It ranges from simple tools that like social messaging applications to more advanced technology such as drones, robotics, 3D printing or artificial intelligence (AI) (Mills, 2016). The available digital technologies identified from the literature reviewed are grouped into the following four groups, i.e. data generation, data analysis, data representation and digital applications, and ungrouped digital technology.

(a) Data Generation

Construction projects generate huge volume of data (Jones, 2018). These useful data come from previous construction projects, machinery and equipment, supply chains, accounting department, and the actual workers on the jobsite (LetsBuild, 2019). This valuable raw data is known as fuel, a fundamental resource to be inputted to the analytics process (Chia et al., 2019). These data provide more insights for better decision making in construction management (Burger, 2019). As technology advances, construction organisations are able to capture more data than ever before through smartphones, drones, wearables, jobsite sensors, etc.

i) Unmanned Aerial Vehicles (UAVs)

Drones, also known as Unmanned aerial vehicles (UAVs) are machines operated by remote control, usually a small flying machine, but they can also be ground-based (Rodriguez, 2018). Drones plays two important roles at construction site which are to enhance safety and provide oversight. McGunnigle (2018) mentioned that drones can help in real-time monitoring and tracking progress of large construction sites with the help of infrared cameras, radar or laser-based range finders to provide detailed imaging of a site. In respect of site safety, drones can be used for inspection of hazardous conditions and materials without placing workers at risk (Howard, Murashov and Branche, 2017). Drones are also adopted to prevent theft and vandalism on site to improve overall security of the site (McPartland, 2017).

ii) Internet of Things (IoT)

Internet of things is the process of turning everyday objects, devices, and machines into "intelligent" objects that are connected to the Internet and with one another (Morgan, 2014). On a construction site, the Internet of Things enable the machinery, equipment, materials, structure, and even formwork to connect to a central data platform to capture critical performance parameters. Sensors and near-field-communication (NFC) devices can help monitor productivity and reliability of both staffs and assets. For instance, advanced sensors fitted in the machinery can detect and communicate maintenance requirements, send automated alerts for preventive maintenance, and compile usage and maintenance data. Energy efficiency of equipment can be improved with the use of sensors that monitor ambient conditions and fuel consumption (Agarwal et al., 2016). Moreover, wearable technology such as smart construction helmets can assist in taking measurements, photos and videos as well as display updated information in real time (McKnight, 2016). The structures that are fitted with vibration sensors are able to generate data for quality assessment. In addition, procurement managers can place orders for materials in advance before it ran out based on the forecast made by the connected system of inventory management. NFC tagging on building materials allow their location and movement to be tracked easily (Agarwal et al., 2016).

iii) Big Data

Big data refers to data that is enormous, fast or complex that is impossible to process using traditional methods. The effective data gathering and the method it is shared is one of the most significant topics in digital transformation (Radley, 2019). Big data applications rely on real-time, instant transfer of data between project sites. The construction sites are getting denser due to the number of individuals involved, large amount of equipment and tasks taking place at the same time. For example, a large infrastructure project requires an average of 130 million emails, 55 million documents and 12 million workflows. However, construction team spent 13% of their working hours to look for project data and information. Up to 95.5% of data captured in construction project goes unused (Ellis, 2019). Big data provides construction organisations to generate a more accurate estimates and a better understanding of timelines and costs (Kovacevic, 2018). Big data is not useful on its own, it has to be paired with data analytics programs to gain more insights and make better decisions such as risk and performance appraisals (Burger, 2019).

(b) Data Analysis

Data analysis can be defined as a method in which data is collected and organised so that one can derive helpful information from the data. The main purpose of this process is to observe what the data is trying to tell us (Durcevic, 2020). In this digitalisation era, data generated from the construction site can be analysed with data analytics tools which are empowered by artificial intelligence (Kaput, 2019).

i) Artificial Intelligence (AI)

Artificial intelligence is the machine that imitate the human intelligence to carry out works (Rouse, 2018); while machine learning is the subset of artificial intelligence that find patterns in massive amounts of data and learn itself without being explicitly programmed (Hao, 2018). Machine learning excels at findings insights and patterns in large datasets that cannot be perceived by humans (Kaput, 2019). A machine becomes better at understanding and providing insights as it is exposed to more data (Rao, 2019). The use of machine learning enables organisations to spot and catch potential issues faster than humans (Walch, 2020). Artificial Intelligence algorithm may gather the current and past project information so that it can provide design alternatives, analyse problems and provide solution to the construction manager. AI is also helpful with scheduling related tasks in order to prevent delays, conflicts and other issues (Walch, 2020).

One of the applications of AI is risk predictive analytics developed from Smartvid.io. The predictive analytics software makes use of videos or photos taken by drones as data input to the machine learning. The analytics will forecast the possible risks to the project based on the work behaviours (i.e. not wearing personal protective equipment) of the on-site workers (Bharadwaj, 2019).

(c) Data Representation and Digital Applications

i) Immersive Technology

Virtual reality is a fully immersive technology where it immerses users into a completely artificial environment with the use of screen-enabled headset (Bardi, 2019). Augmented reality uses the existing real-world environment and puts virtual information on top of it to enhance the experience (Kenton, 2018). Mixed reality enables digital content to interact with the real world in a three-dimensional display with the use of a headset device (Lorek, 2018). Although the user is immersed in the digital content, he or she is still aware of the physical surroundings (Almagor, 2019).

All these three technologies have the potential to be an invaluable tool for the construction industry especially during pre-construction and construction phase (Simpkins, 2019). These technologies are powerful visualisation tools which makes a construction project much easier to understood by construction professionals, designers and clients. Moreover, it actively involves stakeholders to identify changes that have to be made at the initial design phase. Thus, lesser variation works needed in the future which is expensive and time-consuming (Strohanova, 2018). It provides a safer training environment for workers and improve site safety (Morozova, 2018). It actively warns the workers of site hazards and eliminate hazards during pre-construction planning (Moore and Gheisari, 2019).

ii) Digital Twin

A digital twin is a digital representation of a physical asset which relies heavily on IoT devices and machine learning to learn from the sensor data (Tolliday, 2019). Drones can also be used for data collection (Tobias, 2020). The simulations can be either future-based or present-based (Miskinis, 2018). Present-based simulation enables facilities managers to have better understanding on how the building is performing in real-time. Whereas future-based simulation can help to predict potential failures in water, electrical and ventilation systems (Goodman, 2019). Thus, predictive maintenance can be done and reducing construction and operating costs. A digital twin of a building can be used to stimulate the construction before commencement to optimise the project schedule. Digital twinning improves site safety as workers can get real-time tracking and alerts about the site (Tobias, 2020).

iii) 5D Building Information Modelling

Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a project, forming a reliable basis for decisions during project’s life cycle (Cherkaoui, 2016). BIM has different levels, ranging from 0 to 6. The purpose of these levels is to show how effectively the information is being shared and managed throughout the construction process (Lorek, 2018). 5D Building Information Modelling is able to include 3D parameter of standard spatial design incorporating with schedule and cost of the project at the same time. It also includes information that can be embedded in 3D model such as geometry, specifications, aesthetics, thermal, and acoustic properties (LetsBuild, 2019). This platform allows clients and contractors to identify, analyse, and record the impact of changes on project costs and scheduling. The data is provided in real time as the model is developed or changed (LetsBuild, 2019). Therefore, it gives contractors a better chance to identify risks earlier and thus make better decisions (Agarwal et al., 2016). The experience of 5D Building Information Modelling can be further enhanced through the incorporation of virtual reality and augmented reality technology (Radley, 2019). During the construction process, cables and pipes placements can be easily visualised by using immersive technology (Culbert, 2019).

iv) Robots

The construction industry utilises so few robots as construction tasks are notoriously difficult to automate. However, many projects could be completed more efficiently with the use of right construction robotics, mainly because the related tasks are incredibly repetitive (Matthews, 2019). For example, Construction Robotics debuted its new bricklaying robot, SAM100 in 2015. With the help of robots, the dependent on skilled labours and strain on the workers such as heavy lifting work is reduced. It claims to increase productivity by three to five times with the use of SAM100 (Cao, 2019). In addition, robots can also be used in tiling, welding, spool fabrication and demolition (Agarwal et al., 2016).

v) 3D Printing

3D printing is a procedure used to create 3D objects in which consecutive layers of material are computer-controlled produced (Allouzi, Al-Azhari and Allouzi, 2020). 3D printing has been used in several ambitious initiatives and projects in construction since 2004. For example, a wall is successfully printed in 2004; a 3D-printed mansion in China was completed in 2016 (Ellis, 2020). It is known that 3D printing reduces waste, cost, and duration of construction. In particular, it potentially reduces a two weeks job to just three days. 3D Printers will be able to do most hazardous and dangerous works, minimising the wet construction processes (Sakin and Kiroglu, 2017). However, 3D printing solutions may create problems like logistical or transportation problems and it still requires labours to carry out installation works (Culbert, 2019).

vi) Generative Design

Generative design is used to create more optimised designs autonomously using algorithms and parameters specified by the designer (Vermeulen and Ayoubi, 2019). Generative design can produce better designs as complex design parameters such as maximising the amount of natural light in the building or minimising distance between employees working in the building can be incorporated into the design process. Thus, the designer chooses the favourite design option and integrates this design into the wider design work (Ernstsen, 2019). With the leveraging of artificial intelligence and machine learning, software is able to turn tedious design processes into a more integrated workflow between computer and designer (Wunner, Krüger and Gierse, 2020).

(d) Ungrouped Technology

i) Cloud Computing

Cloud computing is the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer (Frankenfield, 2020). The cloud computing model exists in many forms such as cloud meetings, cloud storage and other collaboration software. Cloud storage is a cloud computing model that stores, maintains, back up data remotely and allows anyone to access the data through network (Rouse, 2016). Cloud meetings, also known as video conferencing allows users in different locations to hold face-to-face meetings remotely (Kagan, 2019). These are inexpensive solutions to improve communication and coordination between construction parties. Various documents such as site plans, schedules, drawings can be accessed via a network link (LetsBuild, 2017). In addition, cloud storage in construction will improve collaboration in real-time. Each project member with network connection is able to update their problem or message and share it with the entire team member. Furthermore, the utilisation of cloud computing can enhance data protection by avoidance of data loss and physical theft.

2.4.2 Current Digital Technology Adoption in the Construction Industry

Building Information Modelling (BIM) should be regarded as the backbone of the whole transformation process (Oliver Wyman, 2018). The adoption level of BIM is 38% in UK, 65% in Singapore and 71% in US (Bernama, 2017). Australia and New Zealand BIM Report 2019 found that there is 90% of BIM usage in sectors such as health projects, mixed-use, retail, transport, and sport and leisure (NBS, 2019). The adoption of BIM is increasing worldwide as the construction industry is becoming largely aware of its benefit (Paul, 2018). However, the adoption level in Malaysia is only 17% (Bernama, 2017).

Construction Technology Report 2019 mentioned that the most important role of mobile devices play in construction are smartphone at 92.8% and laptop at 83% (JBKnowledge, 2019). The report also revealed that 42.6% of construction practitioners are utilising drone in the construction site, an increment of 5% in terms of usage as compared to the previous year. Meanwhile, only several Malaysian construction companies are adopting drone technology (Ayob, 2017).

NBS Construction Technology Report 2019 carried out a survey in United Kingdom. The report revealed that the adoption of digital technology are as follows: cloud computing at 63%, 3D printing of building components at 11%, Artificial Intelligence at 6% and robotics at 4%. Moreover, Kai et al. (2019) mentioned that the concept of cloud computing is still new and it is still in the infant stage of its development in Malaysian construction industry. A research done in Malaysia found that only approximately 1% of the participating companies have mentioned Artificial Intelligence, Big Data and Machine Learning in their annual reports (Aisyah et al., 2017).

2.4.3 Challenges in Digital Transformation

McKinsey & Company found that the construction industry will be constantly shifting within the next five to ten years (Ribeirinho et al, 2020). Covid-19 has accelerated the change and transformation. As construction industry remained as one of the least digitised industries, there must be some challenges that hinder the transformation. ICE and BlueBeam (2019) reported that a lack of training and competence (55%) is holding back digital transformation. This was closely followed by a lack of awareness and understanding of new technology, which was seen as the second biggest barrier to digital transformation (46%). The Knowledge Academy analysed that 49% of the job openings in the construction sector require job-seekers to be equipped with some digital skills (PBCToday, 2020). It indicates a shortage of digital skills in the construction industry. Inadequate funding is also one of the main hurdles (ICE and BlueBeam, 2019). Cost is the primary challenge in adopting new technologies, cited by 69% of architects (Microsoft and RIBA, 2018). It has no doubt that the investment of technology such as robotics, 3D printing, etc. and skills training for employees are costly (Delgado et al., 2019). In addition, there is no clear return on investment (ROI) on digital tools, except for time-saving (Evans, 2019). Currently, the most significant basic of digital transformation is gathering of data itself and shared effectively. This has caused some problems such as the protection and ownership of data (Lee, 2018). This is further supported in another survey conducted nationwide by Dell Technologies (2018) with data privacy and security concerns (34%) as one of the top barriers in digitalisation. In addition, a few characteristics of the E&C industry has caused the digitalisation in the industry more challenging (Okumu, 2019). These characteristics include uniqueness, decentralisation, constant change and fragmentation of a construction project. These characteristics make it more difficult for organisations to develop digital solutions that can extended to several projects.

2.4.4 Strategies in Digital Technology Adoption

Morgan (2019) mentioned that there is a fail rate of 70% in digital transformation. In addition, Everest Group study found that 78% of organisations failed to meet their business objectives after the transformation (Bendor, 2019). Most businesses and managers recognise how important it is to evolve with technology and create digital processes and solutions. However, put it into action is a different story.

One of the Thought Leadership Series Reports (PMI, 2018) has found that a well-designed strategy (31%), choosing the right technology (31%) and the involvement of the project management function (31%) are the top success factors in meeting or exceeding the original business goals and business intent of the projects. The report also reveals that 90% of C-suite executives aware that Project Management Office (PMO) has a very important role in digitally transforming the organisation (PMI, 2018). PMO focuses on the strategic digital objectives along with managing the traditional delivery goals; reskills project leaders by assessing the desired skills and competencies and impart training on them. In addition, the report also revealed that the availability of skills talent, well-defined success metrics and commitment from the Chief Executive Officer are able to increase the chance to succeed in digital transformation (PMI, 2018).

Moreover, the human resource department E&C company has to recruit digital talent with some industry knowledge. Existing employees who show an interest should be given career development opportunities within the digital talent pipeline (Aconex, BCG and Global Industry Council, 2018). Certification programs has to be offered as an investment in digital skill and quality assurance, while preparing employees to get the most out of the technology. It provides a measure of competence and knowledge for existing employees and new hires.

Besides, EY digital survey revealed that a clear vision and strong purpose that is open for digital innovation and change help to ensure successful transformation (Buisman, 2018). A kick-off event can be held to show ambitions as this generates an “alliance” between leadership and operational professionals evidencing that they all are in the same boat. The leadership team has to evolve in terms of mindset to become fully supportive of the change. Moreover, Oliver Wyman (2018) mentioned that support from the top management is very important. Hence, transformation has to be directly led by the leadership team to demonstrate its importance and overcome roadblocks and ensure that the means for success are provided.

2.5 Theoretical Framework

In a nutshell, the literature review can be summarised into theoretical framework as shown in Figure 2.1 below. It is presumed that the readiness of digital technology adoption is dependent on the perception towards digital technology adoption of practitioners; digital practices and strategies of the construction organisations. Whereas the project performance is the responding variables that are affected by the readiness of digital technology adoption in the Malaysian construction project management.

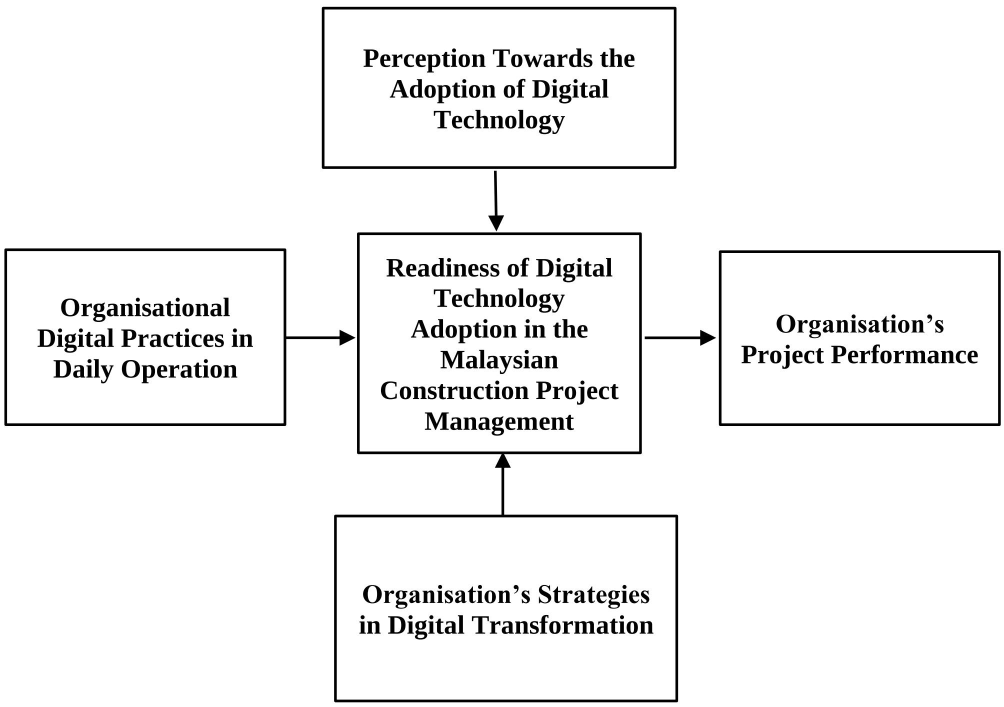

Figure 2.1: Theoretical Framework for Readiness of Digital Technology Adoption

CHAPTER 3

METHODOLOGY

3.1 Introduction

The following sections explain how the theoretical framework (Figure 2.1) synthesised in Section 2.5 is developed into the questionnaire and adopted as research instrument in this research. The research approaches chosen in this study are justified in Section 3.2. The questionnaire design and determination of sampling size are explained in Section 3.3 and 3.4 respectively. Section 3.5 outlined the descriptive and inferential statistical analysis method that were used.

3.2 Nature of Research

The deductive research approach adopted in this research is to better understand the preparedness of the construction industry to undergo digital transformation through questionnaire survey (Saunders, Lewis and Thornhill, 2016). The nature of this research is exploratory, it aims to explore the adoption and awareness towards digital technologies in the building industry and disclose the current strategy used by organisation in preparation of adoption of these technologies (Kumar, Talib and Ramayah, 2013). Closed ended questionnaire were used for primary data collection. The results will be analysed quantitatively with analysis method elaborated in the following Section 3.5. The findings will be inferenced for generalisation.

3.3 Research Instrument

Questionnaire survey is adopted to collect information relates to their current usage of technology, perception on the use and usefulness of digital technology, strategies adopted in digital technology adoption and personal attributes. The questionnaire is distributed through the social media (i.e. LinkedIn, Facebook, WhatsApp) via Google form to collect responses effectively from a huge sampling group (Kumar, Talib and Ramayah, 2013). The data collected will be analysed quantitatively. The sample of the questionnaire can be referred in

Appendix A of this report. The following sections will discuss the questionnaire design in detail.

3.3.1 Questionnaire Design

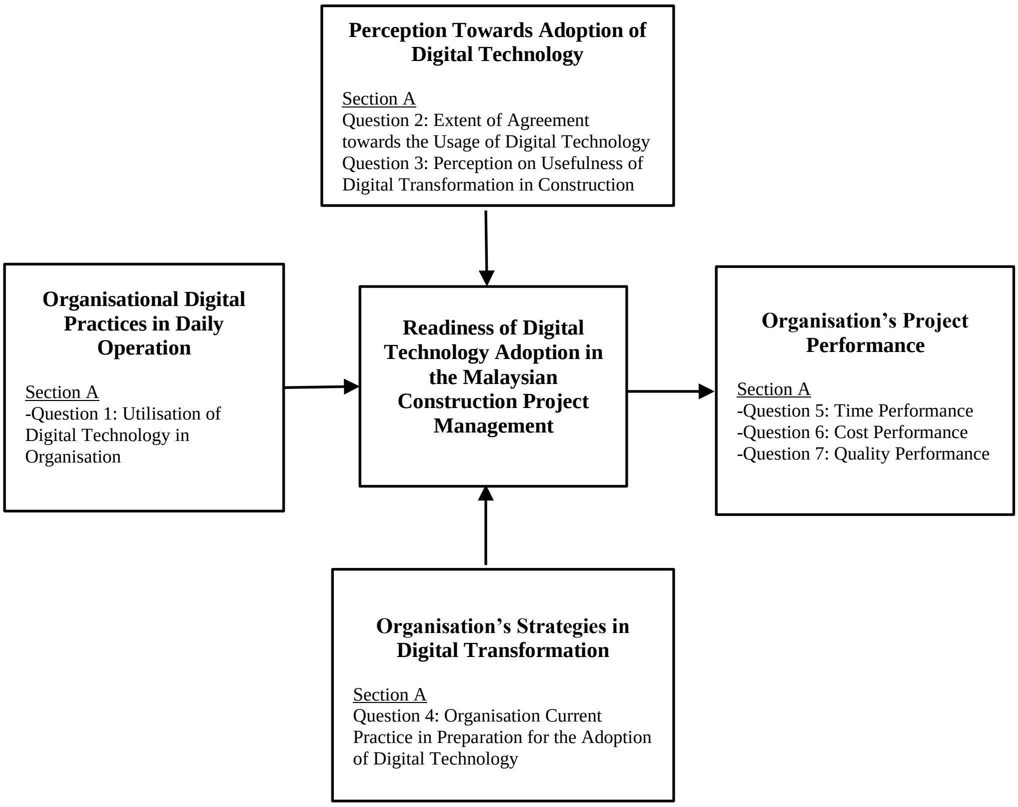

Figure 3.1: Theoretical Framework for Questionnaire

The questionnaire consists of two main sections. Each section is sub-divided into a number of questions. Section A consists of seven questions. Question 1 explores the current usage of digital technologies in the respondents' organisation. Question 2 checks on the respondents' perception on the adoption of digital technology in their works. Table 3.1 summarised the digital technologies reviewed in Section 2.4 of previous Chapter.

Table 3.1: Grouping of Digital Technology in Questions 1 and 2

Data Generating	Data Analysis	Data Representation and Application	Ungrouped Technology
Big Data	Artificial Intelligence	Digital Twin	Collaboration Software
Data Mining	Image Data Processing Algorithm	Generative Design	Cloud Meeting
Electronic Distance Measurement	Machine Learning	Augmented Reality	Cloud Storage
Unmanned Aerial System	Safety Behavior Detection Algorithm	Mixed Reality	
Barcode Scanner	Performance Analytics	Virtual Reality	
QR Code Scanner	Risk Predictive Analytics	Blockchain Technology	
RFID Scanner	Speech Analytics	Building Information Modelling	
Laser Sensor	Text Analytics	Supply Chain Management	
Light Sensor	Video/image Analytics	Light-Detection-and-Ranging (LIDAR)	
Motion Sensor	Facial Recognition	Inventory Management	
Pressure Sensor		Autonomous Equipment	
Temperature Sensor		Robotics	
Time-lapse Camera		3D Printing	
Video Surveillance Camera		Exoskeleton	
Wearable Device			
Smart Helmet			
Smartphone			
Blog			
Facebook			
Line			

Table 3.1 (Continued)

LinkedIn
Twitter
WeChat
WhatsApp
GPS

Question 3 asked the respondents' perception towards the importance of digital transformation to their organisation. Question 4 is to find out the current strategies adopted by the respondents' organisation in digital transformation. In addition, Questions 5, 6 and 7 required the respondents to self-assess the project performance in terms of time, cost and quality performance respectively. These three questions are asked to determine the correlation between the readiness of digital technology adoption and the project performance. The respondents need to indicate their agreements with each of the item listed in the above-mentioned questions based on the likert scale.

Section B collects the demography data of respondents. It includes organisation nature of business, profession, role, duration of service, working experience and email address of the respondents.

3.4 Sample

In general, sample is a group of people, objects or items that are taken from a larger population for measurement. The sample should be representative of the population to ensure that the findings can be generalised from the research sample to the population as a whole. This section justifies the sampling method, sampling size and targeted respondents.

3.4.1 Sampling Method

Simple random sampling is used during data collection. It is a specific type of a probability sampling that every construction practitioner has an equal chance and likelihood of being selected to participate in the survey (Kumar, Talib and Ramayah, 2013). This sampling method eliminates the element of favouritism and the selected samples are usually fairly representative.

3.4.2 Sampling Size

The sample size needed for this study is determined based on the Central Limit Theorem (CLT). The theorem stated if the sample size is equal or greater than 30 number of samples collected is equal to or greater than 30, then the distribution of the samples will be approximately normally distributed. (Chihara and Hesterberg, 2011).

3.4.3 Target Respondents

The target respondents for this research are any individuals who works in Malaysian construction industry. There is no limitation in terms of years of working experience, the nature of business and professionals.

3.5 Data Analysis

The survey data collected are first analysed and tabulated to show the overall result descriptively. The results are subjected to further inferencing tests as explain in the following sections in order to arrive a generalisable conclusions.

3.5.1 Reliability Test

Reliability test is conducted to validate the internal consistency of the questionnaire construct. All the statements within a question asked are tested in terms of their scale reliability with Cronbach's alpha. The assumption made in the reliability test is the respondents should respond equally to the parts being compared, with any discrepancies being due to error of measurement. The questions are considered internal consistent when several statements that proposed to measure the same general construct produce very similar scores. (Leech, Barrett and Morgan, 2005). The alpha coefficient value ranges from 0 to 1. Value of 0.7 and above indicates that the structure of the questionnaire is consistent and is acceptable (George and Mallery, 2002).

3.5.2 Descriptive Statistic

A descriptive analysis is done before the inferential study and is considered the first step for further complicated analysis (Chihara and Hesterberg, 2011). The statements in Questions 1 and 2 which are regarding the frequency usage and extent of agreement towards the use of digital technologies are tabulated with median as its central of tendency as median is a better measure of centrality for ordinal data (Cooper and Schindler, 2014). The statements are rearranged in descending median to find out the usage and extent of agreement towards the usage of digital technology. The median indicates respondents' degree of acknowledgement towards the statement. The statements in Questions 3 and 4 asked about the perceived usefulness and strategies adopted by respondents' organisation in digital technology adoption are tabulated with mean rank computed using Friedman Test. The statements are then rearranged in descending order for further analysis.

3.5.3 Inferential Statistic

a) One-sample Chi-Square Test

The One-sample Chi-square test evaluates whether the proportions of individuals who fall into categories of a variable are equal to hypothesized values. The variable may have two or more categories. This test is more likely to yield significance if the sample proportions for the categories differ greatly from the hypothesized proportions and if the sample is large (Green and Salkind, 2015). The tests are used to evaluate how likely the observed frequencies of the usage of digital technologies in Question 1 and extent of agreement towards the use of digital technologies in Question 2 would be assuming the null hypothesis is true. There are few assumptions made in the chi-square test, if the total sample size is small, the lowest expected frequencies required for a chi-square test is five. However, the observed frequencies can be any value, including zero (Coakes, 2013).

b) Kruskal-Wallis Test

Kruskal-Wallis independent sample test is a non-parametric test introduced by Mood in 1950 to find out the relationship between dependent variables and independent variables that consist three or more variables (Cooper and Schindler, 2014). It is appropriate for data that are collected on an ordinal scale. Data are prepared by converting scores to ranks for each observation being evaluated. The ranks range from the highest to the lowest of all data points in the aggregated samples (Cooper and Schindler, 2014). This test presumed that the observations are independent of each other. A pairwise comparison is conducted for the statement that has rejected the null hypothesis to reveal the pairs of sample groups with significant difference in their perception. The test is adopted to determine the significant differences of the patterns of digital technology usage (Question 1), extent of agreement towards digital technology adoption (Question 2) and strategy adopted in digital transformation (Question 4) with the respondents' attributes.

c) Friedman Test

The Friedman test is a non-parametric test developed by Milton Friedman. It compares the mean ranks between k-related samples and indicates how different they are (Leech, Barrett and Morgan, 2005). The Friedman test allows for the analysis of repeated-measures data if participants are assessed on two or more occasions or matched-subjects data and if participants are matched in pairs, triplets, or in some greater number (Green and Salkind, 2015). Friedman tests are applicable to Questions 3 and 4 which are statements about the usefulness of digital technology adoption and strategies adopted by the respondents' organisation in digital transformation. These are statements with repeated-measure designs or matched-subjects designs. With repeated-measures designs, each participant in a case in the SPSS data file and has scores on K variables, the score obtained on each of the K occasions or conditions. The Friedman test is adopted in this research to determine the perceived usefulness of digital transformation and the strategies adopted by the respondents' organisation changed significantly. Chi-value and asymptotic level computed are to prove that the results are statistically significant and is unlikely to happen due to chance. The test presumed that samples do not have to be normally distributed and the dependent variable are in ordinal scale (Green and Salkind, 2015).

d) Spearman's Correlation

Spearman's correlation coefficient, ρ measures the strength and direction of association between two variables (Saunders, Lewis and Thornhill, 2016). The coefficient ranges from positive one to negative one. This test was used to compare the self-assessed project performance on time, cost and quality by the respondents (Questions 5, 6 and 7) and the digital strategies adopted (Question 4) by the respondents' organisation. The readiness of digital technology adoption is believed to change with respect to confident gained in the project performance. Table 3.2 below shows the correlation coefficient values and their interpretation.

Table 3.2: Correlation Coefficient Values and Their Interpretation (Corder and Foreman, 2014)

Correlation Coefficient for Direct Relationship	Correlation Coefficient for an Indirect Relationship	Relationship Strength of the Variables
0.0	0.0	None/trivial
0.1	-0.1	Weak/small
0.3	-0.3	Moderate/medium
0.5	-0.5	Strong/large
1.0	-1.0	Perfect

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter reports the results of the questionnaire survey. The results gathered are presented descriptively and analysed inferentially for generalisation. Section 4.2 summarised 122 respondents' background who took part in this research. Section 4.3 shows the reliability of the questionnaire instrument. The frequency of digital technology usage and awareness towards digital adoption are discussed in Section 4.4 and Section 4.5 respectively. Section 4.6 discusses preparedness of digital adoption and its relationship with construction project performance. This chapter ends with a brief summary for the findings in this research in Section 4.7.

4.2 Respondents' Background

There were total of 122 sets of questionnaires received via social media such as Facebook (N=15), LinkedIn (N=104) and WhatsApp (N=3), where N denotes the number of respondents. The attributes of respondents are summarised in Table 4.1 below. Half of the respondents are working in consultancy firm (50%) and there is more than one-third of them are currently working in contractor firm (35.2%). Engineers are the highest professional group (36.1%), followed by quantity surveyors (29.5%) and architects (27.9%). Close to a third of the respondents (29.5%) have 'more than 2 years but lesser than 5 years' of working experience, a quarter of the respondents (25.4%) with 'more than 5 years but lesser than 10 years' of working experience. In addition, there are 13.1% of the respondents with 'more than 10 years' of experience.

Table 4.1: Respondents' Attributes (N=122).

General Information	Categories	Frequency	Percentage (%)
Nature of Business	Others	12	9.8
	Construction materials/equipment merchant	3	2.5
	Property development	3	2.5
	Consultancy	61	50
	Construction business	43	35.2
Profession	Others	8	6.6
	Quantity Surveyor	36	29.5
	Engineer	44	36.1
	Architect	34	27.9
Working Experience	Less than a year	9	7.4
	More than 1 year but lesser than 2 years	30	24.6
	More than 2 years but lesser than 5 years	36	29.5
	More than 5 years but lesser than 10 years	31	25.4
	More than 10 years	16	13.1

N= Total number of respondents

4.3 Reliability Analysis

Table 4.2 below shows the outcome of the reliability test. The reliability test shows that the computed Cronbach's coefficient alpha of all the four questions asked in Section A of the questionnaire are more than 0.95 which indicates a high consistency of the items included in each of the four questions asked. The assessment confirmed the reliability of the questionnaire instrument as described.

Table 4.2: Cronbach's Coefficient Value for Reliability Test

Questions	Cronbach's Coefficient Value
Utilisation of Digital Technologies in Day-to-Day Work (Number of items = 54)	0.977
Perception on Possible Applications of Digital Technologies in Construction Industry (Number of items = 54)	0.980
Perception on Usefulness of Digital Transformation (Number of items = 14)	0.953
Perception on Organisation's Current Practice in Preparation for the Adoption of Technologies (Number of items = 20)	0.962

4.4 Organisational Digital Practices in Daily Operations

(a) Frequency of Digital Technology Usage

Table 4.3 below shows the median, Chi-square and asymptotic level (*p*-value) of various digital technologies usage in their daily work operations. All the results obtained from Chi-Square tests are statistically significant which indicated the results are not likely to be due to chance. The computed median for usage of each digital technology is rearranged in descending order. A higher median value represents more frequently use.

Table 4.3: Digital Technology Usages (Number of Respondents = 122)

Statements	Median	Chi-Square	Asymp. Sig.
I use Smartphone in my organisation.	6	321.410	0.000
I use WhatsApp in my organisation.	6	250.984	0.000
I use Cloud Storage (e.g., Dropbox, OneDrive, iCloud Drive, Google Drive, etc.) in my organisation.	5	108.770	0.000

Remark: 0: Don't know what it is, 1: Never, 2: Rarely, 3: Sometimes, 4: Often, 5: Usually, 6: Always

Table 4.3 (Continued)

I use Cloud Meeting (e.g., Zoom Meetings, Microsoft Teams, etc.) in my organisation.	5	64.934	0.000
I use GPS in my organisation.	4	49.213	0.000
I use Video Surveillance Cameras in my organisation.	4	44.852	0.000
I use Building Information Modelling in my organisation.	4	36.361	0.000
I use LinkedIn in my organisation.	4	32.344	0.000
I use Facebook in my organisation.	4	30.738	0.000
I use Unmanned Aerial System (e.g., drone) in my organisation.	3	64.590	0.000
I use Barcode Scanner in my organisation.	3	45.770	0.000
I use Twitter in my organisation.	3	38.197	0.000
I use Temperature Sensor in my organisation.	3	35.672	0.000
I use Generative Design (e.g., Dynamo, Autodesk Fusion 360, Project Refinery Beta, etc.) in my organisation.	3	31.770	0.000
I use Electronic Distance Measurement in my organisation.	3	27.525	0.000
I use Time-lapse Cameras in my organisation.	3	27.180	0.000
I use QR Code Scanner in my organisation.	3	20.639	0.002
I use Ultrasonic Sensor in my organisation.	2	82.377	0.000
I use 3D Printing in my organisation.	2	82.033	0.000
I use Machine Learning (e.g., Construction IQ, etc.) in my organisation.	2	81.115	0.000
I use Laser Sensor in my organisation.	2	75.951	0.000

Remark: 0: Don’t know what it is, 1: Never, 2: Rarely, 3: Sometimes, 4: Often, 5: Usually, 6: Always

Table 4.3 (Continued)

I use Pressure Sensor in my organisation.	2	75.721	0.000
I use RFID Scanner in my organisation.	2	72.852	0.000
I use Light Sensor in my organisation.	2	72.623	0.000
I use Performance Analytics in my organisation.	2	70.557	0.000
I use Image Data Processing Algorithms in my organisation.	2	68.262	0.000
I use Virtual Reality (e.g., merging of BIM models and VR technologies, Iris VR, Fuzor VR, Worksite VR, etc.) in my organisation.	2	65.525	0.000
I use Motion Sensor in my organisation.	2	58.852	0.000
I use Wearable Devices (e.g., body cameras, head-mounted cameras, head-mounted cameras, etc.) in my organisation.	2	58.738	0.000
I use Supply Chain Management in my organisation.	2	57.246	0.000
I use Inventory Management in my organisation.	2	57.246	0.000
I use WeChat in my organisation.	2	56.213	0.000
I use Big data in my organisation.	2	49.098	0.000
I use Blog in my organisation.	2	44.279	0.000
I use Photogrammetry in my organisation.	2	41.869	0.000
I use Collaboration Software (e.g., Congrid, BIM360, etc.) in my organisation.	2	40.951	0.000
I use Video/image Analytics (e.g., Smartvid, etc.) in my organisation.	2	39.344	0.000
I use Facial Recognition in my organisation.	1	194.951	0.000

Remark: 0: Don’t know what it is, 1: Never, 2: Rarely, 3: Sometimes, 4: Often, 5: Usually, 6: Always

Table 4.3 (Continued)

I use Autonomous Equipment (e.g., self-driving excavators, etc.) in my organisation.	1	156.852	0.000
I use Smart Helmet in my organisation.	1	155.705	0.000
I use Artificial Intelligence in my organisation.	1	109.000	0.000
I use Speech Analytics in my organisation.	1	101.541	0.000
I use Mixed Reality (e.g., Microsoft HoloLens, etc.) in my organisation.	1	99.705	0.000
I use Augmented Reality (e.g., Morpholio AR Sketchwalk, Gamma AR, Arki, etc.) in my organisation.	1	99.016	0.000
I use Blockchain in my organisation.	1	90.754	0.000
I use Text Analytics in my organisation.	1	84.328	0.000
I use Data Mining in my organisation.	1	79.967	0.000
I use Risk Predictive Analytics in my organisation.	1	70.557	0.000
I use Digital Twin in my organisation.	1	67.918	0.000
I use Safety Behaviours Detection Algorithms in my organisation.	1	67.918	0.000
I use Light Detection-and-Ranging (lidar) technology in my organisation.	1	60.918	0.000

Remark: 0: Don’t know what it is, 1: Never, 2: Rarely, 3: Sometimes, 4: Often, 5: Usually, 6: Always

Based on Table 4.3, WhatsApp and Smartphone are ‘always’ (Median = 6) used as communication tools. However, Cloud Storage for storage of data on servers and Cloud Meeting Software to conduct virtual meetings are ‘usually’ (Median = 5) adopted by the respondents. Furthermore, most respondents answered that they ‘often’ (Median = 4) use Facebook, LinkedIn, Building Information Modelling software and Global Positioning System (GPS). Construction practitioners ‘sometimes’ (Median = 3) use Generative Design, Unmanned Aerial System, and Time-Lapse Camera in their organisation. Furthermore, 3D

Printing, Performance Analytics, Image/Video Analytics, Image Data Processing Algorithm, Machine Learning, Virtual Reality and Collaboration Software are ‘rarely’ (Median = 2) used digital technologies. In addition, Autonomous Equipment, Robotics, Digital Twin, Data Mining, Artificial Intelligence and Smart Helmet have ‘never’ (Median = 1) been used in the Malaysian construction industry.

The highest usage of WhatsApp and Smartphone among other digital technologies is concurred with the Construction Technology Report 2019 published by JBKnowledge (2019) which stated that Smartphone has obtained a 92.8% among the usage of mobile devices in construction and daily reporting is the most important purpose of using smartphone. Besides, the findings reveal that the usage of collaboration software such as BIM360 and Congrid remains unpopular among the local construction industry which concurred with the survey done by Kai et al. (2019) stating that the concept of cloud computing is still new and in infant stages of its development in Malaysian construction industry. However, there is a high usage of cloud storage and meetings among local construction community.

The findings show Building Information Modelling is often used by the Malaysian construction players is different from the survey done by CIDB (2019) which stated that the level of Building Information Modelling adoption in Malaysia is only 17%. The increase of usage may due to the mandatory use of Building Information Modelling for public projects as required by authority. Malaysian construction community sometimes deploy Unmanned Aerial Vehicle such as drone on construction site. It differed with the findings of Ayob (2017) who mentioned that there are only several construction companies which use drone in the industry. It is indicated that the adoption of drone technology has increased. Most respondents answered that they never use Artificial Intelligence, Machine Learning and Big Data and these concurred with the survey done by Aisyah et al. (2017) which found that only approximately 1% of the companies are mentioning Artificial Intelligence, Machine Learning and Big Data in their annual report.

(b) Significant Differences in Digital Technology Usage Among Professions

A Kruskal-Wallis non-parametric test was conducted to test for significant differences between respondents' profession in digital technology usage. The result of hypothesis testing on pairwise comparison across different professions in "frequency of digital technology usages" are reported in table 4.4. Only those statements successful in rejection ($p < 0.05$) of the relevant null hypothesis of the Krukal-Wallis Test are shown in table 4.4 with their respective asymptotic level.

Table 4.4: Rejected Null Hypothesis for Digital Technology Usages and Pairwise Comparison across Professions

Rejected Null Hypothesis	Mean Rank	Asymp. Sig.
"I use Electronic Distance Measurement in my organisation" are the same between		
Architect	71.47	0.024
Quantity Surveyor	47.60	
"I use Augmented Reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.) in my organisation" are the same between		
Architect	77.18	0.013
Quantity Surveyor	52.60	
Architect	77.18	0.025
Engineer	55.17	
"I use Mixed Reality (e.g., Microsoft HoloLens etc.) in my organisation" are the same between		
Architect	77.69	0.012
Quantity Surveyor	52.82	

Table 4.4 (Continued)

Architect	77.69	0.023
Engineer	55.52	
"I use Facebook in my organisation" are the same between		
Architect	76.66	0.018
Quantity Surveyor	52.07	
"I use LinkedIn in my organisation" are the same between		
Architect	76.16	0.010
Quantity Surveyor	50.14	
"I use 3D Printing in my organisation" are the same between		
Architect	73.69	0.031
Quantity Surveyor	50.94	

The results indicate that:

a) Architects are statistically significant in higher usage of digital technologies such as Augmented Reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.) and Mixed Reality (e.g., Microsoft HoloLens, etc.) than Engineer.

b) In addition to Augmented Reality and Mixed Reality as mentioned above, the Architects are also statistically significant in higher usage of Facebook, LinkedIn, 3D Printing and Electronic Distance Measurement than Quantity Surveyors.

Architects have higher usage of Electronic Distance Measurement than Quantity Surveyors as they are the initiator to kick-start any design; they need to work from the site plan. Electronic Distance Measurement is a more convenient and common way to prepare the site plan nowadays. There is significant higher usage in Augmented Reality and Mixed Reality for Architects as to provide in-depth visualisation of design to improve communication with client and therefore guide the design process more closely towards their desired result (Koutsogiannis, 2019).

4.5 Awareness on Digital Technologies

This section analyses the two questions of the survey instrument. The first question aims to determine respondents' extent of agreement towards the usage of digital technologies. The second question aims to assess respondents' perception towards the importance of digital transformation to their organisation.

4.5.1 Perception on Possible Applications of Digital Technologies in Construction Industry

(a) Extent of Agreement Towards the Usage of Digital Technologies

Table 4.5 below shows the median, Chi-square and asymptotic level (*p*-value) of respondents' extent of agreement towards digital adoption. All the results obtained from Chi-Square test are statistically significant which indicated that the results are not likely to be due to chance. The median value obtained for each digital tool are ranked in descending order. A higher median value simply represents stronger agreement.

Table 4.5: Extent of Agreement Towards the Usage of Digital Technologies (Number of Respondents = 122)

Statements	Median	Chi-Square	Asymp. Sig
I agree that Building Information Modelling should be provided in my organisation.	6	301.443	0.000
I agree that Smartphone should be provided in my organisation.	6	287.377	0.000

Remark: 0: Don't know what it is, 1: Strongly Disagree, 2: Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Agree, 6: Strongly Agree

Table 4.5 (Continued)

I agree that WhatsApp should be provided my organisation.	6	226.164	0.000
I agree that GPS should be provided in my organisation.	6	197.934	0.000
I agree that Cloud Storage (e.g., Dropbox, OneDrive, iCloud Drive, Google Drive, etc.) should be provided in my organisation.	6	174.557	0.000
I agree that Cloud Meeting (e.g., Zoom Meetings, Microsoft Teams, etc.) should be provided in my organisation.	6	174.557	0.000
I agree that Collaboration software (e.g., Congrid, BIM360, etc.) should be provided in my organisation.	5	148.131	0.000
I agree that Video Surveillance Cameras should be provided in my organisation.	5	143.082	0.000
I agree that Generative design (e.g., Dynamo, Autodesk Fusion 360, Project Refinery Beta, etc.) should be provided in my organisation.	5	117.377	0.000
I agree that LinkedIn should be provided in my organisation.	5	114.508	0.000
I agree that Electronic Distance Measurement should be provided in my organisation.	5	111.066	0.000
I agree that 3D Printing should be provided in my organisation.	5	110.033	0.000
I agree that Time-lapse cameras should be provided in my organisation.	5	107.852	0.000
I agree that Virtual reality (e.g., merging of BIM models and VR technologies, Iris VR, Fuzor VR, Worksite VR, etc.) should be provided in my organisation.	5	93.967	0.000
I agree that Inventory Management should be provided in my organisation.	5	92.475	0.000
I agree that Unmanned Aerial System (e.g., drone) should be provided in my organisation.	5	90.754	0.000
I agree that Photogrammetry should be provided in my organisation.	5	86.049	0.000

Remark: 0: Don’t know what it is, 1: Strongly Disagree, 2: Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Agree, 6: Strongly Agree

Table 4.5 (Continued)

I agree that Motion Sensor should be provided in my organisation.	5	82.492	0.000
I agree that Supply Chain Management should be provided in my organisation.	5	80.082	0.000
I agree that Machine Learning (e.g., Construction IQ, etc.) should be provided in my organisation.	5	78.361	0.000
I agree that Facebook should be provided in my organisation.	5	78.131	0.000
I agree that Laser Sensor should be provided in my organisation.	5	75.148	0.000
I agree that Augmented Reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.) should be provided in my organisation.	5	73.426	0.000
I agree that Temperature sensor should be provided in my organisation.	5	73.311	0.000
I agree that Risk Predictive Analytics should be provided in my organisation.	5	73.082	0.000
I agree that Light Sensor should be provided in my organisation.	5	68.951	0.000
I agree that Video/image Analytics (e.g., Smartvid, etc.) should be provided in my organisation.	5	66.311	0.000
I agree that Wearable Devices (e.g., body cameras, head-mounted cameras, etc.) should be provided in my organisation.	5	65.967	0.000
I agree that Performance Analytics should be provided in my organisation.	5	65.049	0.000
I agree that Light Detection-and-Ranging (lidar) technology should be provided in my organisation.	5	64.820	0.000
I agree that Pressure Sensor should be provided in my organisation.	5	62.639	0.000

Remark: 0: Don’t know what it is, 1: Strongly Disagree, 2: Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Agree, 6: Strongly Agree

Table 4.5 (Continued)

I agree that Mixed Reality (e.g., Microsoft HoloLens, etc.) should be provided in my organisation.	5	60.115	0.000
I agree that Smart Helmet should be provided in my organisation.	5	48.180	0.000
I agree that Barcode Scanner should be provided in my organisation.	4	71.810	0.000
I agree that Ultrasonic Sensor should be provided in my organisation.	4	60.230	0.000
I agree that Artificial Intelligence should be provided in my organisation.	4	55.525	0.000
I agree that Twitter should be provided in my organisation.	4	54.262	0.000
I agree that Autonomous Equipment (e.g., self-driving excavators, etc.) should be provided in my organisation.	4	53.344	0.000
I agree that RFID Scanner should be provided in my organisation.	4	52.541	0.000
I agree that Image Data Processing Algorithms should be provided in my organisation.	4	47.262	0.000
I agree that Exoskeleton (e.g., mounted arm support suit, arm support limb, whole-body suit, etc.) should be provided in my organisation.	4	45.885	0.000
I agree that Big Data should be provided in my organisation.	4	45.082	0.000
I agree that Digital Twin should be provided in my organisation.	4	42.328	0.000
I agree that Blog should be provided in my organisation.	4	41.984	0.000
I agree that Text Analytics should be provided in my organisation.	4	41.525	0.000
I agree that Line should be provided in my organisation.	4	37.852	0.000
I agree that Data Mining should be provided in my organisation.	4	36.934	0.000

Remark: 0: Don’t know what it is, 1: Strongly Disagree, 2: Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Agree, 6: Strongly Agree

Table 4.5 (Continued)

I agree that WeChat should be provided in my organisation.	4	36.361	0.000
I agree that Speech Analytics should be provided in my organisation.	4	34.066	0.000
I agree that Blockchain should be provided in my organisation.	4	32.344	0.000
I agree that Facial Recognition should be provided in my organisation.	4	26.148	0.000

Remark: 0: Don't know what it is, 1: Strongly Disagree, 2: Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Agree, 6: Strongly Agree

Based on Table 4.5, most of the respondents 'strongly agreed' (Median = 6) that Building Information Modelling, Cloud Computing, Global Positioning System (GPS) should be provided in the organisation to assist in their work. Besides, majorities of respondents 'agreed' (Median = 5) that Generative Design, 3D Printing, Unmanned Aerial System, Inventory Management, Supply Chain Management, Augmented Reality, Mixed Reality, Virtual Reality, Smart Helmet, Risk Predictive Analytics, Safety Behaviour Detection Algorithm and Light Detection-And-Ranging (LIDAR) should be provided in the workplace. Furthermore, construction practitioners 'slightly agreed' (Median = 4) to use Artificial Intelligence, Big Data, Blockchain Technology, Data Mining, Robotics and Autonomous Equipment in their workplace.

The local construction practitioners are willing and agree to use digital technologies at their workplace. There is higher extent of agreement towards the usage of Generative Design and Risk Predictive Analytics compared to Big Data and Artificial Intelligence. Big data has been described as a new oil and the algorithm used in the artificial intelligence. Both big data and artificial intelligence are the foundational elements for generative design and risk predictive analytics. Even though these are not reflected in the results of the survey conducted but it implies the knowledge of digital technology is not deep enough in the Malaysian construction industry.

(b) Significant Difference in Extent of Agreement Towards the Usage of Digital Technologies Among Different Profession

A Kruskal-Wallis non-parametric test was conducted to test for significant differences between respondents' profession in awareness towards digital technologies. The result of hypothesis testing on pairwise comparison across different professions in "extent of agreement towards digital adoption" are reported in table 4.6. Only those statements successful in rejection ($p < 0.05$) of the relevant null hypothesis of the Krukal-Wallis Test are shown in table 4.6 with their respective asymptotic level.

Table 4.6: Rejected Null Hypothesis for Extent of Agreement Towards the Usage of Digital Technologies and Pairwise Comparison across Professions

Rejected Null Hypothesis	Mean Rank	Asymp. Sig.
"I agree that GPS should be provided in my organisation" are the same between		
Architect	78.07	0.016
Quantity Surveyor	55.16	
Architect	78.07	0.015
Engineer	56.16	
"I agree that Photogrammetry should be provided in my organisation" are the same between		
Architect	76.07	0.041
Engineer	55.03	
"I agree that Light Detection-and-Ranging (LIDAR) technology should be provided in my organisation" are the same between		

Table 4.6 (Continued)

Architect	76.34	0.039
Engineer	55.00	
"I agree that Augmented Reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.) should be provided in my organisation" are the same between		
Architect	79.97	0.018
Quantity Surveyor	55.75	
Architect	79.97	0.001
Engineer	51.35	
"I agree that Mixed Reality (e.g., Microsoft HoloLens, etc.) should be provided in my organisation" are the same between		
Architect	76.88	0.028
Quantity Surveyor	53.61	
Architect	76.88	0.042
Engineer	55.74	
"I agree that Virtual reality (e.g., merging of BIM models and VR technologies, Iris VR, Fuzor VR, Worksite VR, etc.) should be provided in my organisation" are the same between		
Architect	75.85	0.018
Engineer	50.11	

Table 4.6 (Continued)

"I agree that Time Lapse Camera should be provided in my organisation" are the same between		
Architect	74.91	0.008
Engineer	50.27	
"I agree that Wearable Devices (e.g., body cameras, head-mounted cameras, etc.) should be provided in my organisation" are the same between		
Architect	74.12	0.042
Engineer	52.95	
"I agree that Facebook should be provided in my organisation" are the same between		
Architect	75.93	0.029
Engineer	53.90	
"I agree that Line should be provided in my organisation" are the same between		
Architect	75.65	0.009
Engineer	50.59	
"I agree that Twitter should be provided in my organisation" are the same between		
Architect	76.46	0.030
Engineer	54.32	
"I agree that 3D Printing should be provided in my organisation" are the same between		

Table 4.6 (Continued)

Architect	79.94	0.001
Engineer	51.26	
Architect	79.94	0.042
Quantity Surveyor	58.19	

The results indicate that:

a) Architects are statistically significant in higher agreement towards the usage of the GPS, Augmented Reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.), Mixed Reality (e.g., Microsoft HoloLens, etc.) and 3D Printing than Quantity Surveyors and Engineers.

b) Architects are also statistically significant in higher agreement towards the usage of Photogrammetry, Light Detection-And-Ranging (LIDAR) Technology, Time-Lapse Camera, Wearable Devices (e.g., body cameras, head-mounted cameras, etc.), Facebook, Line, Twitter than Engineers.

Architects have higher agreement towards the usage of Augmented Reality, Mixed Reality and 3D Printing than Quantity Surveyors and Engineers. Mixed reality techniques are specifically being employed to actively warn the workers of site hazards and to pre-emptively eliminate hazards during pre-construction planning (Moore and Gheisari, 2019). 3D Printers will be able to do most hazardous and dangerous works, minimising the wet construction processes (Sakin and Kiroglu, 2017). The adoption of these digital technologies can reduce the number of injuries and fatalities onsite. This is coherent to the findings mentioned at Section 4.5.1 which indicates that the Architect perceived that improve construction site safety is the top priority in digital transformation.

In addition, the higher agreement towards the usage of digital technologies from Architects can be further explained with the frequent use of social media applications such as LinkedIn and Facebook as mentioned in Section 4.4. Social media can enhance and upgrade the knowledge sharing process thus increase the awareness towards the need for digital transformation in the local construction industry.

(c) Significant Differences among Years of Working Experience

A Kruskal-Wallis non-parametric test was conducted to test for significant differences between respondents' years of working experience in awareness towards digital technologies. The result of hypothesis testing on pairwise comparison across different professions in "extent of agreement towards digital adoption" are reported in table 4.7. Only those statements successful in rejection ($p < 0.05$) of the relevant null hypothesis of the Krukal-Wallis Test are shown in table 4.7 with their respective asymptotic level.

Table 4.7: Rejected Null Hypothesis for Extent of Agreement Towards the Usage of Digital Technologies and Pairwise Comparison across Years of Working Experience

Rejected Null Hypothesis	Mean Rank	Asymp. Sig.
"I agree that Artificial Intelligence should be provided in my organisation" are the same between		
More than 2 years but lesser than 5 years	71.68	0.006
More than 5 years but lesser than 10 years	42.77	
"I agree that Facial Recognition should be provided in my organisation" are the same between		
More than 2 years but lesser than 5 years	72.28	0.004
More than 5 year but lesser than 10 years	42.34	
More than 1 year but lesser than 2 years	67.37	0.049
More than 5 year but lesser than 10 years	42.34	
"I agree that Risk predictive analytics should be provided in my organisation" are the same between		

Table 4.7 (Continued)

More than 2 years but lesser than 5 years	71.29	0.023
More than 5 years but lesser than 10 years	45.65	
"I agree that Exoskeleton (e.g., mounted arm support suit, arm support limb, whole-body suit, etc.) should be provided in my organisation" are the same between		
More than 2 years but lesser than 5 years	76.64	0.009
More than 5 years but lesser than 10 years	48.58	

The results indicate that:

a) Construction practitioners with working experience of 'more than 1 year but lesser than 2 years' is statistically significant in higher agreement towards the usage of Facial Recognition than construction practitioner with working experience of 'more than 5 years but lesser than 10 years'.

b) Construction practitioners with working experience of 'more than 2 years but lesser than 5 years' is statistically significant in higher agreement towards the usage of Facial Recognition, Artificial Intelligence, Risk Predictive Analytics, Exoskeleton (e.g., mounted arm support suit, arm support limb, whole-body suit, etc.) than those with working experience of 'more than 5 years but lesser than 10 years'.

The findings reveal that construction practitioners with working experience lesser than five years have greater extent of agreement towards the use of digital technologies. The estimated age of this group is below 30. This is concurred with the study of Meyer (2008) who found that workforce with age of 30 and below tend to have better acceptance towards new technologies. Exposure to the new curriculum content by the younger generation may also lead to this effect as course syllabus in recent years focused more on the application of digital technologies in the construction industry.

In addition, construction practitioners who have working experience of ‘more than five years but lesser than ten years’ have lower extent of agreement towards the use of digital technologies. This is concurred with the study of Kunze, Boehm and Bruch (2010) who presumes that older workers are less able to cope with changing environments. This happens as the traditional construction practice has become a norm for them.

4.5.2 Perception Towards the Importance of Digital Transformation

(a) Extent of Agreement Towards the Importance of Digital Transformation

Table 4.8 below shows mean rank, Chi-square and asymptotic level (*p*-value) of respondents’ extent of agreement towards the importance of digital transformation to their organisation. The results obtained from Chi-Square tests shows that the statements are statistically significant which indicated that the results are not likely to be due to chance. The computed mean rank for each of the statements is ranked in descending order. A higher mean rank simply indicates a stronger agreement.

Table 4.8: Extent of Agreement Towards the Importance of Digital Transformation (N=122)

Statements	Mean Rank			
	Overall	Quantity Surveyor	Engineer	Architect
Digital transformation is important to boost productivity.	8.69	8.99	8.28	9.06
Digital transformation is important to improve client experience (e.g., offering more channels of communication and information sharing).	8.55	9.24	8.70	7.66
Digital transformation is important to improve site safety.	8.52	7.67	8.80	9.21

Table 4.8 (Continued)

Digital transformation is important to improve collaboration for more efficient construction.	8.31	8.34	8.46	8.64
Digital transformation is important to innovate competitively.	8.28	8.33	8.45	7.71
Digital transformation is important to keep up with state-of-the-art technology.	7.89	8.40	7.64	7.50
Digital transformation is important to encourage employee engagement/satisfaction.	7.70	8.47	7.18	8.15
Digital transformation is important to sustain business growth.	7.36	7.14	7.48	7.21
Digital transformation is important to grow in revenue.	7.05	7.13	6.51	7.56
Digital transformation is important to ensure survival of the company.	6.77	6.43	6.89	7.12
Digital transformation is important to comply with environmental regulation.	6.63	6.15	7.13	6.84
Digital transformation is important to my organisation to reduce operating cost.	6.59	5.57	6.50	7.71
Digital transformation is important to increase profitability.	6.58	6.19	6.99	5.97
Digital transformation is important to adapt to unstable market conditions.	6.07	6.19	5.97	6.04
Chi-Square, $\chi 2$	151.690	80.036	64.092	45.707
Asymp. Sig.	.000	.000	.000	.000

Table 4.8 shows that as a whole, local construction practitioner perceived that the top three most important factor in digital transformation are to ‘boost productivity’ (Mean Rank = 8.69), ‘improve construction site safety’ (Mean Rank = 8.55), and ‘improve client experience through offering more channels of communication and information sharing’ (Mean Rank = 8.52). The least importance of digital transformation perceived by the respondents are ‘increase profitability (Mean Rank = 6.58) and ‘reduce operating cost’ (Mean Rank = 6.59) to the organisation.

Furthermore, both Architects and Engineers perceived that digital transformation is most important to improve construction site safety. Quantity Surveyor perceived digital transformation is most important in improving client experience through offering more channels of communication and information sharing.

The local construction practitioners are highly aware of the usefulness of digital technologies in boosting productivity, enhance site safety and engage client experience. The results also indicate the differences of perception on the importance of digital transformation. This is because of the different kinds of professional training and practices experienced or encountered by the different professionals. Although none of the professional value the importance of digital transformation in the increase of profitability, but the research done by McKinsey Global Institute (Koeleman et al., 2019) indicates that digital transformation can result in cost reductions of 4% to 6% of the entire project.

4.6 Strategies Executed in Preparation for Digital Transformation

(a) Extent of Agreement Towards the Strategy Executed in Preparation for Digital Transformation

Table 4.9 below shows the result of respondents’ perception on their organisation’s current practice in preparation for digital transformation. The statistically significant of the Chi-Square tests shows that the results ($\chi2$ = 106.938, p = .000) are not likely to be due to chance. Table 4.9 presented the strategy executed by the organisation in descending order. A higher mean rank simply indicates a stronger agreement to the strategy executed in the respondents' organisations.

Table 4.9: Organisation's Strategy in Preparation for Digital Transformation

Statements	Overall Mean Rank
My organisation enables easy access to information on digital transformation.	13.14
My organisation upgrades computer hardware once within five years.	12.45
My organisation has the capability in the execution of the planned strategy.	11.66
My organisation includes digital skills as new recruitment requirement.	11.65
My organisation has guidance in choosing the right technologies.	11.61
My organisation has commitment from the Chief Executive Officer in digital transformation.	11.57
My organisation provides digital skill training.	11.46
My organisation has well-defined success metrics/measurement for digital transformation.	11.36
My organisation has a culture that support change.	11.20
My organisation has collaboration across different functions group in the organisation.	11.14
My organisation has clear strategy from the top management	11.12
My organisation has adequate digital talent skills.	10.95
My organisation has awareness urgency of digital transformation by the top management.	10.27
My organisation established strategic alliances with software provider companies.	10.24
My organisation joins industry consortia focused on innovation technologies.	10.16
My organisation acquires or merges with software provider companies.	10.03

Table 4.9 (Continued)

My organisation sets up accelerator or incubator digital transformation programs.	9.95
My organisation has adequate funding in digital transformation.	9.83
My organisation employs consultants to guide the digital transformation.	9.45
My organisation employs digital experts in the field aggressively.	8.68

Based on Table 4.9, the top 3 strategies adopted by organisation are ‘enable easy access of information on digital transformation’ (Mean Rank = 13.14), ‘upgrade computer hardware once within five years’ (Mean Rank = 12.45) and ‘have capability in the execution of the planned strategy’ (Mean Rank = 11.66). However, the strategies least practiced by organisation are ‘employ digital experts in the field aggressively’ (Mean Rank = 8.68), ‘employ consultants to guide the digital transformation’ (Mean Rank = 9.45) and ‘have adequate funding’ (Mean Rank = 9.83).

As a whole, the construction practitioners most agreed on their organisation in ‘enabling easy access to information on digital transformation’ and ‘ensuring that their computer hardware is up to date’. These strategies do not overcome the hurdles as found out by Institution of Civil Engineers and BlueBeam (2019). These hurdles include ‘lack of expertise in implementing change (55%)’, ‘lack of understanding of new technology (46%)’ and ‘inadequate funding (39%)’. In addition, their survey also found that inadequate training (52%) and poor implementation strategy (48%) are the main reasons that the respondents feel the technology has failed after the implementation. In fact, organisations should focus on digital skills development for existing employees and hire new digital talents to overcome these challenges.

However, the findings revealed that most organisations ‘do not employ digital experts in the field aggressively’ to cope with the digital transformation, ‘do not have adequate funding’ and ‘do not employ consultants to guide the digital technology implementation’. These indicates a reluctance of the organisations to invest in digital talents and digital infrastructure.

(b) Significant Differences in Organisation's Strategies in Preparation for Digital Transformation Among Professions

A Kruskal-Wallis non-parametric test was conducted to test for significant differences between respondents' profession in assessing the strategies adopted in preparation for digital transformation. The results of hypothesis testing on pairwise comparison across different professions in "extent of agreement towards strategies adopted in digital transformation" are reported in table 4.10. Only those statements successful in rejection ($p < 0.05$) of the relevant null hypothesis of the Krukal-Wallis Test are shown in table 4.10 with their respective asymptotic level.

Table 4.10: Rejected Null Hypothesis for Strategies Adopted by Organisation in Preparation for Digital Transformation across Professions

Rejected Null Hypothesis	Mean Rank	Asymp. Sig.
"My organisation employs digital experts in the field aggressively" are the same between		
Architect	74.50	0.010
Quantity Surveyor	48.22	
"My organisation enables easy access to information on digital transformation" are the same between		
Architect	78.31	0.007
Engineer	52.68	
Architect	78.31	0.027
Quantity Surveyor	54.81	
"My organisation includes digital skills as new recruitment requirement" are the same between		

Table 4.10 (Continued)

Architect	79.76	0.002
Engineer	50.81	
Architect	79.76	0.011
Quantity Surveyor	53.83	
"My organisation provides digital skill training" are the same between		
Architect	77.84	0.003
Engineer	50.14	
"My organisation sets up accelerator or incubator digital transformation programs" are the same between		
Architect	75.46	0.010
Engineer	54.11	
"My organisation upgrades computer hardware once within five years" are the same between		
Architect	71.66	0.042
Engineer	50.34	

The results indicate that:

a) Architects are statistically significant agreed that their organisation has executed strategies of 'employs digital experts in the field aggressively', 'enables easy access to information on digital transformation' and 'includes digital skills as new recruitment requirement' more than Quantity Surveyors in digital transformation.

b) Architects are statistically significant agreed that their organisation has executed strategies of ‘enable easy access to information on digital transformation’, ‘includes digital skills as new recruitment requirement’, ‘provides digital skill training’, ‘sets up accelerator or incubator digital transformation programs’ and ‘upgrades computer hardware once within five years’ more than Engineer in digital transformation.

Architects have higher significance in employing digital experts in the field aggressively and including digital skills as new recruitment requirement provision of digital skills training due to digital skills shortage. These outcomes coincide with the earlier findings that Architects have adopted more digital technologies such as 3D Printing and Electronic Distance Measurement as compared to Engineers and Quantity Surveyors. In addition, architecture firm is significantly frequent in upgrading their computer hardware at least once within five years. The higher usage of Augmented Reality and Mixed Reality as identified in Section 4.4 will expect a higher performance computer capability to be in used.

4.6.1 Relationship Between Preparedness in Digital Technology Adoption and Current Project Performance

This section intends to find out any associations between organisation’s strategies and their current project performance. Spearman Correlation test is conducted to validate their relationship. The current project performance is assessed by the performance in time, cost and quality. 17 out of 60 significant correlated coefficients extracted in Table 4.11 indicate positive relationships between the associate variables according to Table 3.2 (Corder and Foreman, 2014).

Table 4.11: Spearman Correlation Coefficient between Strategies Executed by Organisation in Preparation for Digital Transformation and Project Performance in Construction Project (N=122).

Statements	Time Performance		Cost Performance		Quality Performance	
	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)	Correlation Coefficient	Sig. (2-tailed)
My organisation has adequate digital talent skills in the organisation.	0.351	0.000			0.350	0.000
My organisation has adequate funding in digital transformation.	0.413	0.000				
My organisation has the capability in execution of the digital transformation strategy.	0.464	0.000	0.374	0.000	0.371	0.000
My organisation has clear digital transformation strategy from the top management.	0.405	0.000			0.360	0.000
My organisation has commitment from the Chief Executive Officer in digital transformation.	0.393	0.000				
My organisation has guidance in choosing the right technologies.	0.495	0.000	0.427	0.000	0.495	0.000
My organisation's culture support change.	0.421	0.000			0.375	0.000
My organisation has well-defined success metrics/measurement for digital transformation.	0.452	0.000	0.365	0.000	0.428	0.000

Table 4.11 reveals that organisations that have ‘capability in execution of the planned digital transformation strategy’, ‘guidance in choosing the right technologies’ and ‘well-defined success metrics for digital transformation’ will have better time, cost and quality performance in a construction project.

In addition, organisations that have ‘adequate digital skills in the organisation’, ‘clear digital transformation strategy from the top management’, ‘change supporting culture’ will have better time and quality performance in current construction project. Finally, organisations that ‘have adequate funding in digital transformation’ and ‘commitment from the Chief Executive Officer in digital transformation’ will have better time performance in current construction project.

The positive correlations between the highlighted strategies and project time, cost and quality performance shown that these strategies are consistent with the strategies proposed by Project Management Institute in the Thought Leadership Series Report (PMI, 2018) which is aim to ensure successful digital transformation in project management.

4.7 Summary

In a nutshell, the findings of this research identify the following:

4.7.1 Adoption of Digital Technology in the Construction Industry

a) The digital technologies which are the most frequently used by the construction industry practitioners are WhatsApp, Smartphone, Cloud Meeting and Cloud Storage.

b) The digital technologies which are least frequently used by the construction industry practitioners are Artificial Intelligence, Big Data and Machine Learning.

c) There is an increase in the adoption of Building Information Modelling and Unmanned Aerial Vehicle (e.g., drone) as compared to the literature reviewed.

d) Architects are statistically significant in higher usage of digital technologies such as Augmented Reality and Mixed Reality than Engineers and Quantity Surveyors.

e) Architects are statistically significant in higher usage of digital technologies such as Facebook, LinkedIn, 3D Printing and Electronic Distance Measurement than Quantity Surveyors.

4.7.2 Awareness of Construction Practitioners Towards the Adoption of Digital Technology

a) Construction practitioners agree and willing to use digital technology but their knowledge on digital technology need to be improved.
b) Respondents with working experience of two to five years are statistically significant in higher agreement towards the use of Facial Recognition, Artificial Intelligence, Risk Predictive Analytics, Exoskeletons than those with working experience of five to ten years.
c) Architects tend to agreed more usage of GPS, Augmented Reality, Mixed Reality and 3D Printing than Quantity Surveyor and Engineer; Architect also tends to agreed more usage of Photogrammetry, Light-Detection-and-Ranging (LIDAR) Technology, Time-Lapse Camera, Wearable Devices, Facebook, Line and Twitter than Engineer.
d) The most important factors perceived in digital transformation are to boost productivity, improve client experience and improve site safety.
e) The least important factors perceived in digital transformation are to increase profitability and reduce operating cost.
f) Architects and Engineers agreed that improve site safety is the most important factor in digital transformation while Quantity Surveyors perceived that improve client experience is the most important factor.

4.7.3 Strategies Implemented to Ensure Successful Digital Transformation

a) The most popular strategies adopted are to enable easy access to information on digital transformation and upgrade computer hardware once within five years.
b) Most organisations did not employ consultant to guide the transformation, employ digital experts in the field and have adequate funding.

c) Architects have adopted strategies of employing digital experts in the field aggressively, enable easy access to information on digital transformation and include digital skills as new recruitment requirement more than Quantity Surveyors.

d) Architects have adopted strategies to enable easy access to information on digital transformation, includes digital skills as new recruitment requirement, provides digital skill training, sets up accelerator or incubator digital transformation programs and upgrades computer hardware once within five years more than Engineers.

4.7.4 Relationship between Preparedness in Digital Technology Adoption and Construction Project Performance

a) There are positive correlations between some of the strategies to ensure successful digital transformation and their current project performance.

b) It is revealed that organisations that have the capability in execution of the planned digital transformation strategy, guidance in choosing the right technologies and well-defined success metrics for digital transformation will have better time, cost and quality performanc

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The accomplishment of research objectives is summarised in Section 5.2. The implications of this research to the industry, the regulators and academics are highlighted in the Section 5.3. Section 5.4 reflected the research by identifying some of the limitations in this research. Section 5.5 provides recommendations to overcome the limitation in the upcoming similar research.

5.2 Accomplishment on Research Objectives

This research is aimed to explore the preparedness in digital adoption in construction project management in Malaysia as mentioned in Section 1.3. There are three research objectives to be accomplished. They are (1) to discover the adoption of digital technology in the construction industry; (2) to explore the awareness of construction practitioners towards digital adoption; and (3) to analyse the preparedness in digital adoption and its relationship with construction project performance. The achievement of the research aim and objectives are reviewed in the following paragraphs.

5.2.1 To Explore the Adoption of Digital Technology in the Construction Industry

The significant findings on the digital technology are highlighted in Section 4.7.1. In summary, this research found that the construction community frequently use data generating tools such as smartphone and social media applications (i.e. WhatsApp) for communication. The cloud storage is used for information sharing and cloud meetings are being used for project management purposes. However, the emerging technology such as Artificial Intelligence, Big Data and Blockchain have not been adopted by the industry. Besides, there is a gradual increase in the usage of Building Information Modelling. In addition, drones are being more commonly used by the industry for video recording of the construction progress at site. Architects have higher usage of digital technologies such as Augmented Reality, Mixed Reality and Electronic Distance Measurement.

5.2.2 To Assess the Awareness of Construction Practitioners Towards Digital Adoptions

In short, the adoption of digital technology is agreed by the construction community. Architects and the younger generation of construction practitioners are significant tend to be more aware of the emerging technology as highlighted in Section 4.7.2. This reflects the need of the professional practices and exposure to the digital technology knowledge playing an important role in driving the perceptions of the construction practitioners in their favours to the digital transformation.

5.2.3 To Analyse the Preparedness in Digital Technology Adoption

Section 4.7.3 revealed that most organisations did not hire for digital experts and provide sufficient funding in digital transformation. Digital skills shortage and insufficient funding are the main hurdles for organisation to digitally transform. Architecture firms are more prepared in the digital adoption as they actively provide digital skill training and employ digital experts in the field aggressively. Besides, this research also found that organisations which are more prepared in the digital transformation tend to perform better in all the three important project performance metrics e.g. time, cost and quality. construction project in respect of time, cost and quality.

In conclusion, the Malaysian construction industry has adopted digital technology that were mainly used for data generation (i.e. communications) at real time but is yet to unleash the potentials of digital technologies for higher and more complex digital transformation. The generalisable findings identified from this study are depicted in the following Figure 5.1.

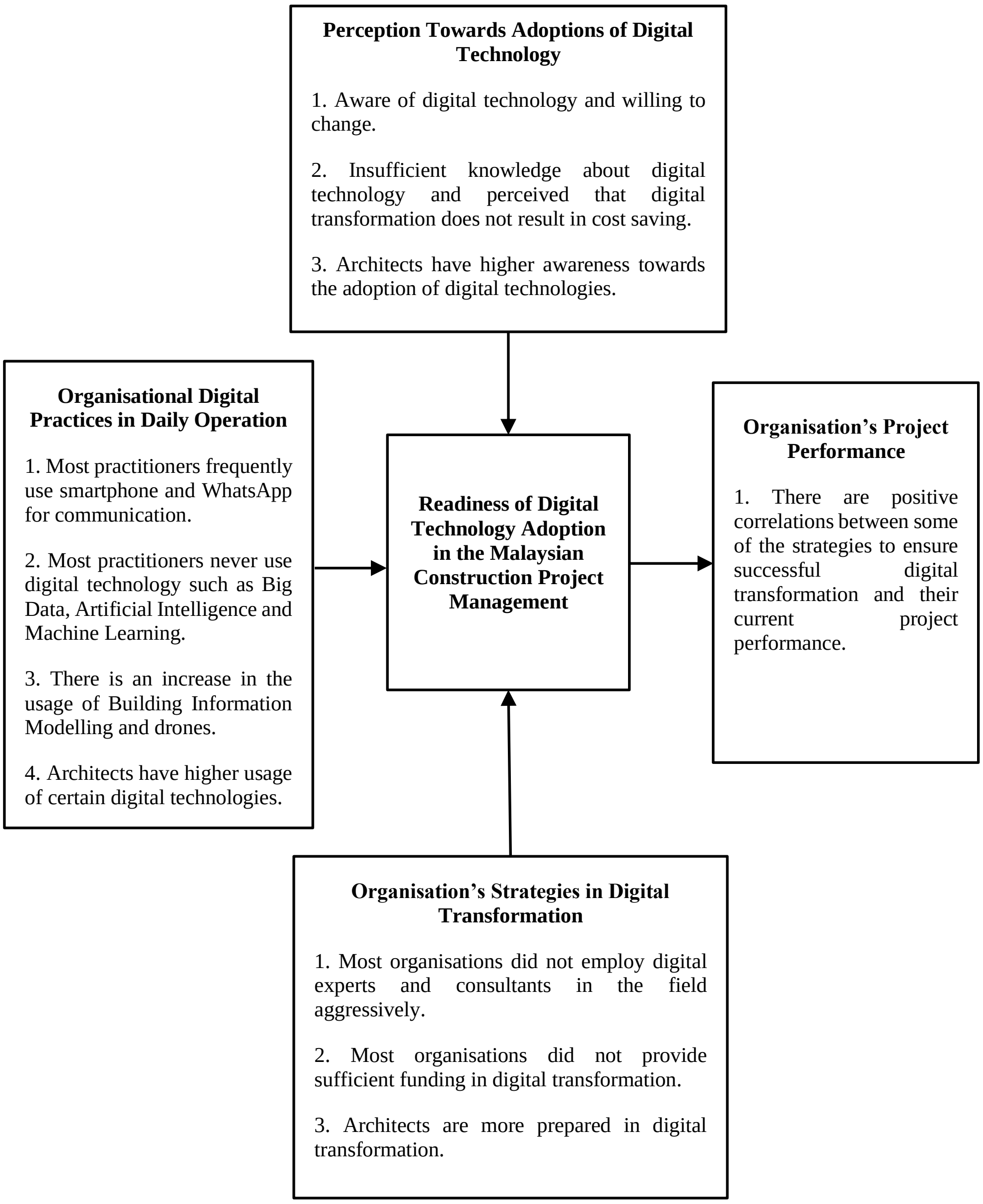

Figure 5.1: Summary of Key Findings

5.3 Research Implications

This research enables the construction community to apprehend the status quo of digitalisation of the industry in Malaysia. It points the directions for the industry to prepare for the digitalisation era. In fact, the construction industry should nurture digital talents by encourage upskilling of their employees and invest in the digital infrastructures in order to unleash the full potential of the construction industry.

The construction industry is slow in digital transformation as compared with other industry. Those with power and authority in regulating the industry can help to speed up the digital transformation of the industry. For examples, more policies to incentivise the willingness of digital transformation such as providing tax exemption and other incentive measures for pioneer companies in adopting emerging and innovative technology. In addition, professional regulatory body such as Board of Engineers Malaysia (BEM), Board of Quantity Surveyors Malaysia (BQSM) and Lembaga Arkitek Malaysia (LAM) are playing an important role to enhance the digital knowledge and skills of the construction professionals.

Education sector has the responsibility to implant digital culture among the younger generations. Professors and lecturers in the higher education institutions need to keep abreast with the innovative digital technologies in order to equip the students with sufficient knowledge before entry to the fast-changing working environment. Digital construction embraces more than Building Information Modelling. In addition, digital skill is not sufficient to be taught as a stand-alone course, it shall be embedded in all the courses taught in the higher education institutions wherever appropriate.

The exploratory nature of this research provides clues for further research areas to the researchers who are interested to contribute to the digitalisation of the construction industry in the digital economy which already arrives.

5.4 Research Limitations

As a reflection of this research, it is undeniable that there are small number of property developer, construction materials merchant and senior executives with more than ten years of experience participated in the questionnaire survey although much efforts had been tried to solicit their participation. As a result, they have been excluded in the pairwise comparison analysis. It may have some implications to the final conclusion of this study.

5.5 Research Recommendations

The future research of similar topic shall aware the limitation of sample mix highlighted in the previous section. In addition, the correlations of different digital technologies and the project performance have not been fully addressed in this research. These are the potential areas for the growing of body of knowledge in the digital construction.

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APPENDICES

APPENDIX A: Survey Questionnaire

Readiness of Digital Technology Adoption in the Malaysian Construction Project Management

Dear Sir/ Madam,

I am a final year undergraduate student pursuing Bachelor of Science (Hons) Quantity Surveying in University Tunku Abdul Rahman (UTAR). I am currently conducting a research on "Readiness of Construction Project Management in the Digital Age". It would be appreciated if you could spare 15-30 minutes to answer the following questionnaire survey. You are being assured that all the information collected are treated as private and confidential and will be strictly used for this research only. Should you have any further queries, please do not hesitate to contact me at jiunrenong97@1utar.my.

Thank you.

Yours faithfully,

Ong Jiun Ren

Section A - Readiness of Digital Technology Adoption in the Malaysian Construction Project Management

1. How frequent do you use the following digital technologies in your organisation?

	Always	Usually	Often	Sometimes	Rarely	Never	I don't know what it is
Big data							
Blockchain							
Artificial intelligence							
Data mining							
Digital twin							
Facial recognition							
Generative design (e.g., Dynamo, Autodesk Fusion 360, Project Refinery Beta, etc.)							
Image data processing algorithms							
Machine learning (e.g., Construction IQ, etc.)							
Safety behaviours detection algorithms							
Performance analytics							

Risk predictive analytics							
Speech analytics							
Text analytics							
Video/image analytics (e.g., Smartvid, etc.)							
Inventory management							
Supply chain management							
Electronic distance measurement							
GPS							
Photogrammetry							
Light detection-and-ranging (lidar) technology							
Autonomous equipment (e.g., self-driving, excavators, etc.)							
Robotics (e.g., brick laying robot, demolition robot, etc.)							
Unmanned aerial system (e.g., drone)							
Augmented reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.)							
Mixed reality (e.g., Microsoft HoloLens, etc.)							

Virtual reality (e.g., merging of BIM models and VR technologies, Iris VR, Fuzor VR, Worksite VR, etc.)							
Collaboration software (e.g., Congrid, BIM360, etc.)							
Cloud meeting (e.g., Zoom Meetings, Microsoft Teams, etc.)							
Cloud storage (e.g., Dropbox, OneDrive, iCloud Drive, Google Drive, etc.)							
Barcode scanner							
QR code scanner							
RFID scanner							
Laser sensor							
Light sensor							
Motion sensor							
Pressure sensor							
Temperature sensor							
Ultrasonic sensor							

Smartphone							
Time-lapse cameras							
Video surveillance cameras							
Wearable devices (e.g., body cameras, head-mounted, cameras, etc.)							
Exoskeleton (e.g., mounted arm support suit, arm support limb, whole-body suit, etc.)							
Smart helmet							
Blog							
Facebook							
Line							
LinkedIn							
Twitter							
WeChat							
WhatsApp							
Building information modelling							
3D printing							

2. Do you agree that the following digital technologies should be provided in your organisation?

	Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	Strongly Disagree	I don't know what it is
Big data							
Blockchain							
Artificial intelligence							
Data mining							
Digital twin							
Facial recognition							
Generative design (e.g., Dynamo, Autodesk Fusion 360, Project Refinery Beta, etc.)							
Image data processing algorithms							
Machine learning (e.g., Construction IQ, etc.)							
Safety behaviours detection algorithms							
Performance analytics							
Risk predictive analytics							

Speech analytics							
Text analytics							
Video/image analytics (e.g., Smartvid, etc.)							
Inventory management							
Supply chain management							
Electronic distance measurement							
GPS							
Photogrammetry							
Light detection-and-ranging (lidar) technology							
Autonomous equipment (e.g., self-driving, excavators, etc.)							
Robotics (e.g., brick laying robot, demolition robot, etc.)							
Unmanned aerial system (e.g., drone)							
Augmented reality (e.g., Morpholio AR Sketchwalk, Gamma AR, ARki, etc.)							
Mixed reality (e.g., Microsoft HoloLens, etc.)							

Virtual reality (e.g., merging of BIM models and VR technologies, Iris VR, Fuzor VR, Worksite VR, etc.)							
Collaboration software (e.g., Congrid, BIM360, etc.)							
Cloud meeting (e.g., Zoom Meetings, Microsoft Teams, etc.)							
Cloud storage (e.g., Dropbox, OneDrive, iCloud Drive, Google Drive, etc.)							
Barcode scanner							
QR code scanner							
RFID scanner							
Laser sensor							
Light sensor							
Motion sensor							
Pressure sensor							
Temperature sensor							
Ultrasonic sensor							

Smartphone							
Time-lapse cameras							
Video surveillance cameras							
Wearable devices (e.g., body cameras, head-mounted, cameras, etc.)							
Exoskeleton (e.g., mounted arm support suit, arm support limb, whole-body suit, etc.)							
Smart helmet							
Blog							
Facebook							
Line							
LinkedIn							
Twitter							
WeChat							
WhatsApp							
Building information modelling							
3D printing							

3. Why digital transformation is important to your organisation?

	Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	Strongly Disagree	I don’t know what it is
Adapt to unstable market conditions							
Boost productivity							
Comply with environmental regulation							
Encourage employee engagement/satisfaction							
Ensure survival of the company							
Grow in revenue							
Improve client experience (e.g., offering more channels of communication and information sharing)							
Improve collaboration for more efficient construction							
Improve site safety							
Increase profitability							
Innovate competitively							
Keep up with state-of-the-art technology							

Reduce operating cost							
Sustain business growth							

4. Are the following being practiced in your organisation?

	Always	Usually	Often	Sometimes	Rarely	Never	I don't know what it is
Acquire or merge with software provider companies							
Employ consultants to guide the digital transformation							
Employ digital experts in the field aggressively							
Enable easy access to the information							
Establish strategic alliances with software provider companies							
Include digital skills as new recruitment requirement							
Join industry consortia focused on innovation technologies							
Provide digital skill training							

Set up accelerator or incubator digital transformation programs							
Upgrade computer hardware once within 5years							
Adequate digital talent skills in the organisation							
Adequate funding in digital transformation							
Awareness urgency of digital transformation by the top management							
Capability in the execution of the strategy							
Clear strategy from the top management							
Collaboration across different functions group in the organisation							
Commitment from the Chief Executive Officer							
Guidance in choosing the right technologies							
Organisation's culture support change							
Well-defined success metrics/measurement for digital transformation							

5. How do you rate the time performance of your current project?

	1	2	3	4	5	6	7	8	9	10	
Completely out of control	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Ahead of schedule

6. How do you rate the cost control of your current project?

	1	2	3	4	5	6	7	8	9	10	
Completely out of budget	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Always within budget

7. How do you rate the quality performance of your current project?

	1	2	3	4	5	6	7	8	9	10	
Completely not meeting the client’s expectation	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Beyond the client's expectation

Section B- About Yourself

1. Email

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2. How long have you been involved in the construction industry?

- ◯ Less than 1 year
- ◯ More than 1 year but lesser than 2 years
- ◯ More than 2 years but lesser than 5 years

- More than 5 years but lesser than 10 years
- More than 10 years

3. How long have you been in the current position?

- Less than 1 year
- More than 1 year but lesser than 2 years
- More than 2 years but lesser than 5 years
- More than 5 years but lesser than 10 years
- More than 10 years

4. Which of the following best describe your current position?

- CEO/Board of directors
- Senior manager/General manager
- Department manager
- Executive
- Others

5. Which of the following best describe your profession?

- Architect
- Engineer
- Quantity Surveyor
- Accountant
- Others

6. Which of the following best describe the nature of business of your organisation?

- Construction business
- Consultancy
- Property development
- Construction materials/equipment merchant
- Others