EXAMINE DIGITAL TRANSFORMATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) 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 **"EXAMINE DIGITAL TRANSFORMATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY"** was prepared by **TAN KAI WEN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

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ABSTRACT

The Malaysian construction industry is a vital component of the country's economy. As technology advances, digital transformation has become a necessity for continued development and competitiveness of the industry. This research examines the digital maturity of the Malaysian construction industry. A questionnaire survey was conducted, comprising both open-ended and close-ended questions. The survey included 24 close-ended questionnaires' statements covering digital tools and software to appraise the availability of digital infrastructure in construction organizations. Another 25 statements were employed to assess the digital maturity of the construction organization. Furthermore, two open-ended questions sought respondents' opinions regarding encountered challenges and the reasons necessitating digital transformation. The data collected from 202 respondents were subjected to reliability analysis, Friedman test, and Kruskal-Wallis H test. The study found that the overall degree of digital maturity for Malaysian construction industry stands at 60%. Software applications were found to be more prevalent in construction organizations, with data dimension exhibiting the highest level of maturity. The study identified three biggest challenges currently hindering the construction industry: high technology cost, resistance to change, and lack of knowledge and skills. The findings alert industry practitioners as a wake-up call, regulators to develop strategies, and academia to conduct future research on specific areas.

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LIST OF SYMBOLS / ABBREVIATIONS

GDP	Gross Domestic Product
NCP 2030	National Construction Policy 2030
BIM	Building Information Modelling
RICS	Royal Institution of Chartered Surveyors
AI	Artificial Intelligence
IoT	Internet of Things
ICT	Information and Communications Technology
AR	Virtual Reality
VR	Augmented Reality
UAV	Unmanned Aerial Vehicle
GPS	Global Positioning System
LiDAR	Light Detection and Ranging
LADAR	Laser Distance and Ranging
CIDB	Construction Industry Deveolopment Board
SMEs	Small and Midsize Enterprises
DMM	Digital Maturity Model
SPSS	Statistical Package for Social Sciences
SAM	Semi-Automated Mason

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CHAPTER 1

INTRODUCTION

1.1 Background

Construction industry is one of the pillar industry in a country's economy. It has a strong linkage with the other economic sectors such as manufacturing, services and etc in bothways interactions. The construction sector serves as a backbone to the country's economy and contributes significantly to the Gross Domestic Product (GDP) of the country. Malaysia Productivity Corporation (2022) reviewed that the share of construction sector has contributed approximately 5% of the nation’s economy activity. It further reported that in order to accelerate the performance of the construction industry, significant changes need to be imposed by infusing new digital technology, materials and advanced automation.

Digital transformation has changed the way the construction industry performs their works and tasks. It causes disruption which is unavoidable. Instead of being threatened by the change in business model and process, industry players need to be aware of the potential that the incoming technologies can bring to their role (RICS, 2020). The industry needs to embrace new ways of conducting business with emerging disruptive technologies, practice new mechanisms and working procedures in order for them to stay competitively in the world market (Ministry of Works, 2021).

In year 2021, Ministry of Works launched a new construction policy, “National Construction Policy 2030 (NCP 2030)” which lead the continued reinvention and revitalisation in the Malaysian construction industry to achieve inclusive, sustainable national development in the year 2030. It is a 10-year policy with six policy thrusts established under NCP 2030 that will be implemented by the Ministry of Works. From the policy, the construction industry needs to focus on advanced knowledge and skills enhancement of their future workforces from technological advancement through reskilling and upskilling in order to be well-competitive and viable in the future of construction sector. With the theme ‘Digitalising the Construction Sector’, NCP 2030 aims to facilitate the adoption and adaption of the emerging technology, data systems, digital innovation and automation throughout every phase of construction including pre-, during and post-construction phase (Ministry of Works, 2021).

1.2 Problem Statement

The digital transformation journey under the construction industry is regarded as slow in its starting phase as compared to other industries. Around the world, the construction sector is ranked second to the last among the other industry sectors under the digitisation index according to a McKinsey report (Talamo and Bonanomi, 2019). Based on the Productivity Report 2022 by Malaysia Productivity Corporation, the construction industry tends to have a much lower adoption rate of digital tools, new materials, construction methods and technologies. 90% of the industry remains at the category of conventional and newcomer, indicates with a minimum intention to pursue for digitalisation. According to the analysis, the overall Malaysian industry has recorded decrease performance in terms of digital infrastructure, with a poor mobile download speed of 24.56 Mbps, even behind our neighboring country, Singapore (63.41 Mbps) and Thailand (31.91 Mbps) (Malaysia Productivity Corporation, 2022).

Apart from that, even though BIM technology has becoming an industry norm, the momentum is still relatively slow as according to RICS (2020) where 22% of respondents are unlikely to adopt BIM in their industry practice from the survey in Malaysia. Globally, approximately USD1.8 trillion were allocated for digital transformation in 2022 in business practice, products and organisation, which increased by 17.6% as compared to 2021. According to International Data Corporation (IDC) (2022), it is forecast that such spending will even grow at an annual compound rate of 16.6% until the year 2025. Although a huge amount of money has been invested towards the effort of transformation into digital business, it is revealed by Harry Robinson in McKinsey report that 70% of the transformation process fails, resulting in wasting of money invested (Jordan, 2022). A true transformation is often difficult to reach. Most of the company fails due to not having necessary skills and capabilities needed to drive transformation of their organisation, absence of change-management infrastructure, and no initiative or unwillingness from the organisation to look into transformative change (McKinsey & Company, 2019).

Thus, it raises a doubt whether the construction industry is ready for the disruption. Another study by Chia et al. (2021) revealed that digital transformation is yet to be achieved by construction industry as digital technologies are rarely incorporated into construction stage. Next, there remains a knowledge gap concerning the maturity in terms of digital capabilities necessary for the construction organisation towards digitalised process as mentioned in the study by Aghimien et al. (2021). Thus, have the construction industry equipped with neccesary digital technology and leverage their potential use ? Are they digitally matured enough in preparing to coup with the change ? Are they aware of the need of transformational change within their industry ? This research will address the above questions.

1.3 Research Aim

This research aims to assess the maturity of the Malaysian construction industry in the industry's preparedness of digital transformation.

1.4 Research Objectives

The following research objectives have been set up to achieve the above research aim:

1. To establish the landscape of digital technology in the construction industry.
2. To evaluate the current state of digital technology adoption in the construction industry.
3. To infer the digital maturity to digital transformation of the construction industry in Malaysia.

1.5 Research Method

This research has delved into the digital maturity of the Malaysian construction organisation using an exploratory approach to assess the maturity of the Malaysian construction industry in the preparedness of digital transformation. Exploratory study approach is utilised as to explore the current readiness and maturity of the construction industry towards the digital transformation journey. Online questionnaire survey was adopted that included both open-ended and close-ended questions. The results were analysed descriptively and inferentially through Cronbach's alpha reliability test, Friedman test, and Kruskal-Wallis H test (Section 4.3 - 4.6). Figure 1.1 illustrated the framework of research plan.

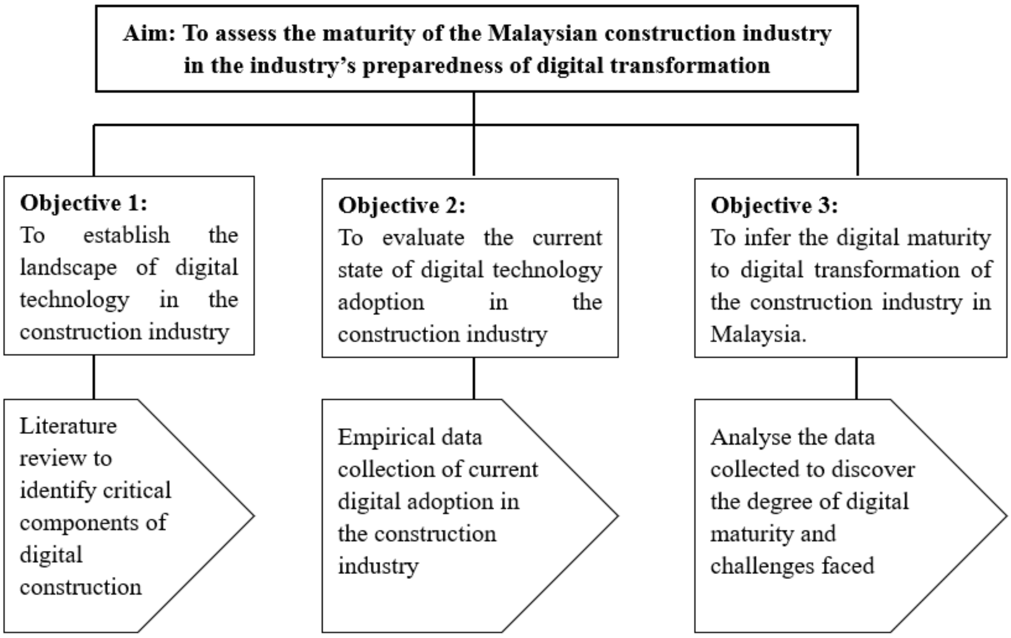

Figure 1.1: Research Plan

1.6 Research Scope

This research was conducted in Malaysia. The empirical data were collected from local construction practitioners. There is no specific limitation on the qualification of the respondents other than the participants must be involved in construction sector.

1.7 Report Structure

Chapter 1 introduces the background of digital construction and some associated issue towards digital transformation in the construction industry. The research aim and objectives are outlined and research method is illustrated as Figure 1.1. The target scope has been narrowed down to only construction practitioners in Malaysia.

Chapter 2 defines digitisation, digitalisation and digital transformation from business context. Next, it reviewed the published literature on four critical components pertaining to digital construction, followed by processes of Construction 4.0 and its challenges. The penultimate section of this chapter introduced the five digital maturity dimensions. A conceptual framework is established at the end of this chapter

Chapter 3 explains both qualitative and quantitative research methodology used in this research. It justifies with the rationale of questionnaire design and its structure covering both close-ended and open-ended questions and summarises in Figure 3.1. Convenience sampling approach is adopted. Sufficiency of sample size is accounted for with Central Limit Theorem. Next, data analysis methods used including Cronbach Alpha Reliability test, Friedman Test, and Kruskal-Wallis H Test are highlighted with their applications in the results reported in Chapter 4. The last section of this chapter reported research ethical issues addressed in the data collection.

Chapter 4 starts with the introduction of background of total 202 respondents. The reliability of the questionnaire is tested. The availability of digital infrastructure and digital maturity of the construction organisation were compared across different respondent's business activities, professions, and years of experience through inferential test. The last section presents the findings compared against the literature review.

Chapter 5 concludes that software application is more widespread in construction organisation and data dimension was most matured in the construction organisation, with overall degree of digital maturity at 60%. Accomplishment of all research objectives and research aim were discussed. Moreover, this chapter presents the research's implication towards industry practitioners as a wake-up call, regulators to develop strategies, academias to conduct future research on specifc areas. It ends with a reflections of research's limitation followed by recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Digital transformation assists in driving the construction industry towards the 4th Industrial revolution, which reshape the process and business model of the industry. This chapter briefly defines the concept between digitisation, digitalisation, and digital transformation. The subsequent section discussed the four critical components towards digital construction, followed by how digital transformation is related to Construction 4.0. Challenges towards digitalisation and digital maturity in five major dimension is then highlighted next. This chapter ends with a proposed conceptual framework of digital transformation.

2.2 Digitisation, Digitalisation, Digital Transformation

A successful digital transformation in an organisation or industry involves 3 different phases, digitisation, digitalisation, and digital transformation respectively. Digitisation means converting an analogue information into digital representation of physical objects that the new information can be processed by computer technology (Olanipekun and Sutrisna, 2021). It serves as a foundation to integrate a combination of products, services, and data to reformulate the value proportion of a company (Sebastian et al., 2017).

Secondly, digitalisation refers to the utilizing of digital technologies and digitized data into the current process to improve the process in terms of efficiency and productivity (Olanipekun and Sutrisna, 2021). Construction digitalisation only improves the current construction process, for instance, process from human-driven into software-driven, without transforming or changing the whole construction process into a new model (Gupta, 2020).

Additionally, digital transformation is a complex process that requires major changing and transforming in the current business process to a new business process and model enabled by digitalization. It involves the restructuring of the business model, organization structure, construction production process, the way the workers work and more (Gamage, 2021). For example, the on-site control of the physical construction process is shifted to a new practice of remote controlling and monitoring of the site process by using mobile digital technology considered as part of the digital transformation in the construction industry. A successful digital transformation aims to benefit the construction industry in a more efficient, productive and profitable way of their new business model (Gamage, 2021). In fact, digitisation, digitalisation, digital transformation are in progression, where digitisation and digitalisation is prior needed to attain digital transformation (Olanipekun and Sutrisna, 2021).

2.3 Digital Construction

Digital construction means the adoption of digital technologies and tools to enhance the the process of delivering and operating of the built environment. It can be simplified as the process of creating the delivery, operation and renewal of the building towards a safer, more efficient and collaborative environment (Chia et al., 2019). The trend of digital construction is unavoidable and we have no choice to it but adapt to the trend (LetsBuild, 2019). It alters the way in which the construction professional works and brings them into digitised solutions. The digital technologies, particularly in the BIM adoption has turned the construction industry into a new way of working that demands a highly collaborative culture (Mills, 2016). Most of the construction professionals often rely on such technology for better collaboration (Alfresco, 2015).

The term “Digital construction” does not have a fixed definition. Different people might define it in a different ways. Digital construction is regarded to involve the entire life cycle of the construction building rather than only the physical construction process on site (Radley, 2019), where different core technologies can be integrated differently throughout the life cycle of the building.

2.3.1 Critical Components towards Digital Construction

Construction process and works can be done digitally in various forms (Mills, 2016). It can be in the form of simple messaging tools and video conferencing system, automation in manufacturing process, enhancement in plant or materials, filing system and cloud-based computing or software through adoption of basic or advance technologies (Mills, 2016). In order to fully engage in the fundamental of digital construction (D), component A (Algorithm), B (Big Data) and C (Computational Power) are essential towards the process, where A + B + C = D as cited by Chia (2019). Besides, another c (Connectivity) is critical in contributing to digital construction, forming a new digital construction's framework as proposed in Figure 2.1.

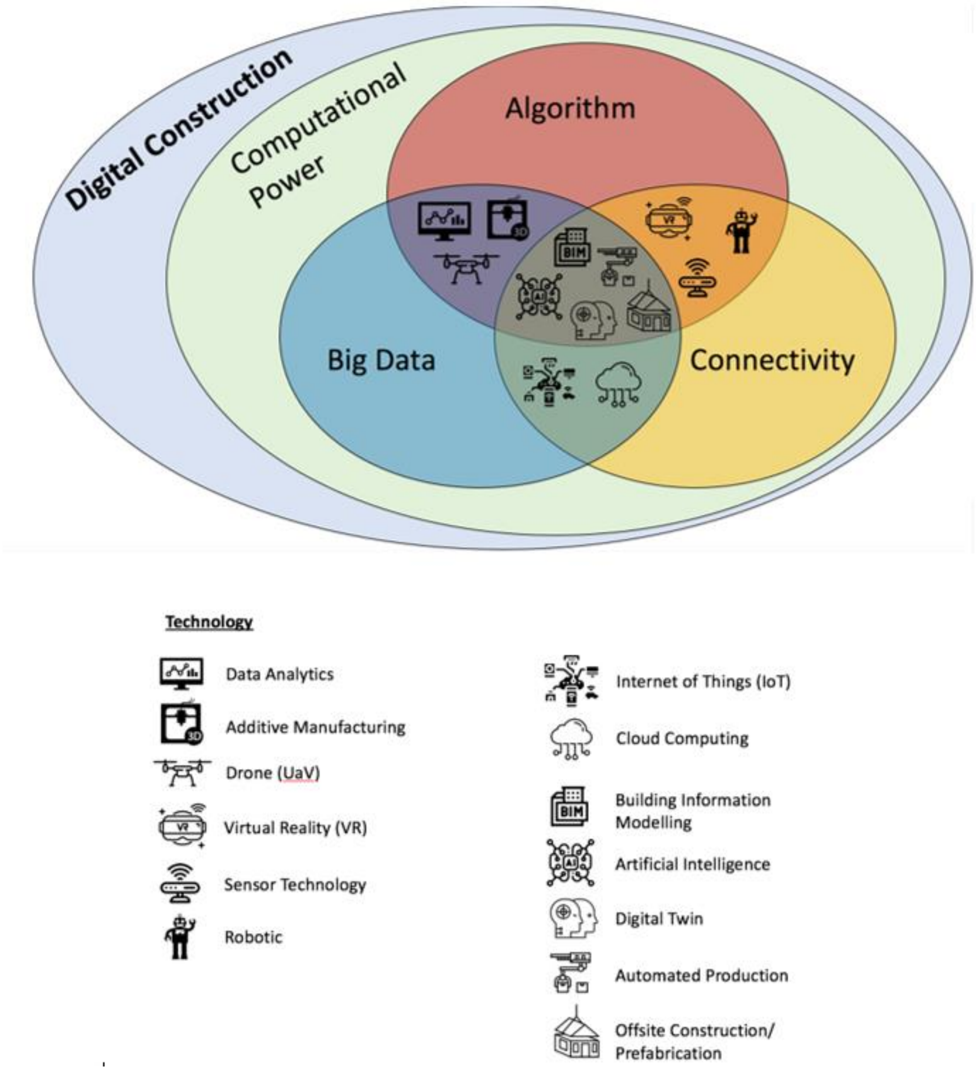

Figure 2.1: Digital Construction's Framework

(a) Algorithm (A)

An algorithm is defined as a program to carry out a computational function or solve a problem (Gillis, 2022). Algorithm normally begin with initial input and command which specific a certain computation to execute and eventually produce an output. Algorithms are essential to make up the technology of Artificial Intelligence (AI) as machine learning techniques used in AI depend on algorithms to predict outcomes (Gillis, 2022). It acts as a methodology for

AI to function that allows the machines to imitate human intelligence to perform the works normally done by humans. For instance, the AI machines report problems that occur on the site through the algorithm as they can recognize various buildings based on their size, location and shape (LetsBuild, 2019). In other words, the AI program could collect the data from the current project, so that it can identify the issue occurring and provide rapid suggestions to resolve the similar issue (Culbert, 2019). Machine learning is the branch of Artificial Intelligence that studies algorithm and techniques in automating solutions towards complicated problems which are difficult to program using traditional programming methods (CIDB, 2020). One of the applications that rely on algorithms and use AI is generative design. It is a concept to design exploration processes to develop highly sophisticated design alternatives rapidly (Aparaschivei, 2021). Generative design is revolutionising the way human design by using algorithms together with its outcome beyond what humans have imagined (Keane, 2018). Algorithms within the generative design software have their significant function in generating a wide range of possible design alternatives based on each parameter input at the design stage or the pre-construction stage (Aparaschivei, 2021).

For machine learning, few different techniques can be applied, which are supervised learning, unsupervised learning, and reinforcement learning (Wakefield, 2022). In supervised learning, both input and output of the algorithm are specified in which humans supply the labeled training dataset to the algorithm with desired input and the algorithm accesses the way and relationship to reach the output (Gillis, 2022); in unsupervised learning require no human instruction, the algorithm will study and analyse large data set available to identify the pattern for data grouping in cluster; while in reinforcement learning, trial and error is being practiced and algorithm will explore various possibilities to reach an optimal result through evaluation (Wakefield, 2022). Table 2.1 shows several machine learning algorithms available for each of the techniques.

Table 2.1: Examples of Machine Learning Algorithms

Machine Learning techniques	Algorithms Used
Supervised Learning	Naïve Bayes Classifier Algorithm
	Support Vector Machine Algorithm
	Logistic Regression
	Linear Regression
	Random Forests
	Decision Trees
	K-Nearest-Neighbour algorithm
Unsupervised Learning	K Means Clustering Algorithm
Reinforcement Learning	Artificial Neural Networks

(b) Big Data (B)

The term of 'Big Data' has arised since early 1990s, and made popular by John R. Mashey which known as the 'father of big data' (Firican, 2022). Big data is defined as an increasing volume of unstructured, semi-structured, and structured data that comes in with a higher velocity which is hard to be managed by conventional software and database techniques (Oracle, 2022). Volume of data generated throughout the construction life cycle starting from design to completion is huge and increasing rapidly (Woodhead et al., 2018). Due to the technology improvement, digital storage of data is more cost-effective than physical storing of data on paper traditionally in which this enhance the storing, analysing, interpreting and realising of big data for its potential value. According to a McKinsey & Company study, large volume of data has been produced from 30,000 sensors at oil platform, but only less than 1% of the data has been exploited for its potential value. It further supported by Massey (2021) that huge amount of data generated are often loosely organised, especially by the contracting firm. However, the practices by consulting firm is different in which the consulting firms has develop strategic framework around the big data to coup with data explosion (Tras, 2015).

The significant consideration to enable digital construction is the availability of data to be move from one technology to another, between different phase of construction and even from the real physical site to the virtual world. For instance, the collected data through the sensors embedded in the structural element on the site is vital to be transmitted and reflected in real-time in the BIM model (Team, 2022). This allows the construction professional to exploit potential value from the real-time data for data-insight decision making (Glodon, 2022). According to a McKinsey report, the real time analysis of collected data can significantly improve the productivity in construction (Rao, 2019).

However, the transmission of huge amount of real-time data is hard to achieve without the strong wireless telecommunication network (5G). According to Lundblad (2018), 5G network improves the process of data conveying through a high speed of transmission. This improved the potential of data analysis by using advanced analytics in construction that results in smart operation and smart decision making (Olanipekun and Sutrisna, 2021). According to BuildOps (2022), such predictive data analytics has gained much interest among the construction industry for decision making purpose. The data has closely related to the computational power and work together with digital tools and digital concept of algorithm with the support of strong connectivity.

Morover, big data can be referred to the high volume of data which are collected from machinery or equipment that includes performance, engine output, hours of operation, maintenance and others (Johnson, 2019). For example, the concept of machine learning rely on big data as revealed by Oracle (2022) in using the data available to teach the machine rather than only giving commands to them. Additionally, maintenance required for equipment could be better predicted from the analysis of various data collected in the form of warning signs to the possible issues before it occurs, which resulted in prolonging the lifetime of equipment and optimising their maintenance cost (Oracle, 2022).

Not only that, BIM data acts to assist in making a better decision for building materials and fittings, and to inform the maintenance schedule after construction completed in order to keep the project’s cost within budget (Rhumbix, 2021).

(c) Computational Power (C)

A computing system with high computational power results in certain benefits such as minimising latency, preventing downtime and enabling timely responses to be made (Technology, 2022). A high capability of the computational power results in enhancing the implementation of cobots (Collaborative robots) to perform the tasks or activities in collaboration with humans in the construction industry (Olanipekun and Sutrisna, 2021). A high computational power enables the computational workloads to run across various different commodity servers all together through a high speed networking link. As a result, organisations tend to solve their computational problems at lower cost. The high computing power must be able to deal in the extent with complex data processing.

Besides, digital construction will only be effective through the wide exchange of information and data which originates from digital sensors together with a strong computing power of the system that is able to process the vast amount of data received. A low computational power or incompatible platform for data exchange causes a substantial loss in the value of the project data (Olanipekun and Sutrisna, 2021). A high computational power can be closely linked to the required level of 5G network connectivity. It allows a high speed transmission of huge data to optimise the performance of computing technology (Lundblad, 2018). Smooth and rapid data exchange between the automation system such as Light management helps the system to facilitate the energy performance of the building by analysing the surrounding data (Technology, 2022).

A strong computational power is insufficient to attain the maximum potential from digital construction, in which it is necessary come together with a great storage capacity. Data centric computational storage need to undergo a rapid development in order to coup with the scenario of data blooming. According to Werdmuller (2020), the volume of data is estimated to reach 175 zettabytes in 2025 as compared to 33 zettabytes in 2018. This also means that optimum data storage solutions and effective digital structure is required for the construction firms to better manage the increasing inflow of data. However, the traditional way of data storing is carried out in hard-disk drive and solid-state drive which require the data later to be transferred in huge amounts to the external server system for processing and generating data insights. Computational storage which is a storage system that consists of various processors able to solve this problem by having data processing on the storage controllers to allow direct generation of value from the data (Pritchard, 2020). As a result, it helps to reduce latency, enhance data security and energy-savings (Werdmuller, 2020). Hence, computational storage offers a great data storage solution in handling big data.

(d) Connectivity (c)

Connectivity or networks focus on linking and synchronizing different activities for example, 3D model development and simulation of energy under the BIM platform, as well as connecting physical-to-digital-to-physical in construction through sensors, and other digital technologies (Olanipekun and Sutrisna, 2021). 5G networks has significantly improved the mobile broadband speed, making it more faster, reliable, and efficient as compared to the existing 4G connectivity (UK Connect, 2021). The substantial increase in the speed of 5G allows the industry to better handle big data in rapid data transmission, support more advanced automation systems and connect various IoT devices effectively. This will also ensure all the connected devices are having the peak performance through the transmission of real-time data with minimum lagging for immediate reporting and reduce the amount of energy use.

Besides, there will be greater potential by integrating 5G network with robotics technology which help the construction industry propel towards digital transformation and enhance their productivity. It is reported by Sweet (2022) that the robots mounted with 3D laser scanners which have connected to 5G mobile networks provide an alternative way of tracking the site progress remotely. Due to the capability of the 5G network, the real-time transmission of massive data collected from robot technology for live-processing is made possible. The BIM model will then be automatically keep updated from the 3D scanning data collected. However, the current situation of poor ICT infrastructure hinders the up-take of robotics that require high capacity performance and low latency in network connectivity at the construction sites (GSMA, 2022). Next, the incorporation of the 5G network with AR technology could provide a transformational effect by enabling real-time quality control on building installation (Singtel, 2021). This combination of technology provides the supervisors and workers to visualise how the intended construction activities will be carried out on the site and identify any possible issues before real-construction begins.

2.3.2 Digital Application

(a) Unmanned-Aerial-Vehicle (UAV) & Drone

Unmanned Aerial Vehicle (UAV) or so called drone, a technology generally made up of a flying platform being controlled remotely by a pilot flight software, onboard sensor and even GPS that normally will be attached together with cameras system, LIDAR technology and so on (Rebuilding Humanity, 2021). Real time data is collected through digital technology of UAV with mounted sensors, and followed by analysis work from advanced analytic software which incorporate the algorithm. The well-organised real time data contribute to a smart monitoring system which involves better management of operations, planning and adjustment (Anwar et al., 2018). Besides, the adoption of UAV or drones technology changes significantly in terms of the way the site supervisor or construction manager carried out their works. Smart monitoring allows the respective person to monitor the whole site condition remotely from anywhere and anytime that removes accessibility constraints, with the internet connection available (Liu et al., 2014).

(b) 3D Printing

Printing a 3D house in the construction industry is made possible by the advanced technology of 3D printers. Digitalisation of the construction process through the implementation of 3D Printing technology provides the benefits of greater flexibility, reducing costs and labors (Patel, 2019). The adoption of 3D printing technology will change the construction process as more components are capable of being produced by 3D printers such as building wall structure (Ellis, 2020). By this way, the end product will be printed in a faster and more sustainable way. Besides, 3D printing allow the clients to have a better visual representation of the project by its potential of creating a model faster (RICS, 2020). Although the construction industry is still at some distance to capture the full potential of implementing 3D Printing technology, however, the wave will be reaching in near time.

(c) Augmented Reality (AR)/ Virtual Reality (VR)

VR is normally used for worker training purpose, while AR technologies are implemented for better identifying of possible safety risks on the site. Real-time communication is enabled by exploiting the AR technologies and the mobile connectivity, which also provide the workers with more on-site information. All the data generated from AR technologies will only be transferred in real-time with the existence of high speed network. Development in VR technologies allow the clients as well as the users to be engaged with along the life cycle of the building assets. The virtual model of a complete building can be created and provide the clients and other stakeholders in visualising the space of the project and examine for its fitness before actual construction start (RICS, 2020). However, these simulation technologies have not been fully embraced by the contractor on site (LetsBuild, 2019). One of the reasons is high cost implementation where the augmented reality headgear is very expensive to engage by firms which having water-thin profit margin (Radley, 2019). In respect of safety, AR can improve the abilities to recognise safety hazards accurately in the process of inspection, supervision and strategising (Li et al., 2018).

(d) Robots

Adopting robotics technology allows the construction work process to be carried out more efficiently by the automation system and in a high quality of work (Manzoor et al., 2021). It makes the construction process work faster, safer and more productive with a lesser workforce needed. Robots that handle repetitive tasks throughout the process are able to perform highly productive work with quality. The robots able to perform their tasks from the algorithm that being developed for the automated workflow. For instance, "Hadrian X", a brick-laying robot, is applied in the construction process to lay 1000 bricks within half an hour, which proves to be much faster than human labours (Jones, 2022). Moreover, by having a strong connectivity, Volvo has revealed the use of autonomous vehicles around construction sites in transporting tools and materials. It is believed that more and more construction specialised tasks are going to be taken over by advanced robotics technologies (Knight, 2020). In terms of safety, robotics can be applied in wearable technologies to minimize workers' safety risk. For instance, an upper body exoskeleton known as EskoVest allows the workers to carry heavy objects while protecting them from getting hurt (Edirisinghe, 2019).

(e) Building Information Modelling (BIM)

BIM is the virtual model which shows real-time extraction or development of fully valued parametric building components (Korte, 2022). BIM can be used to create and manage the data in the stage of design, construction and operating stages of the building. It enhances the real-time collaboration between parties as the digital model created from the integration of multi-disciplinary data which are then managed in the open cloud (Autodesk, 2022). This is made possible due to the advancement of computational power, incorporating the algorithm for the BIM software, present of high speed data and existence of strong connectivity.

Application of BIM process with associated technologies is found to have a huge impact towards the construction industry. Through the adoption of BIM technology, it helps the quantity surveyor particularly in terms of cost estimating and planning, to generate a more reliable budget (Moses, 2020). It enables generating of automatic quantification at a high speed and higher accuracy of data by establishing quicker estimates. In term of planning, it gives the estimators a more well understanding on the likely cost and schedule impacts of various design decisions as any proposed changes made to design are reflected to the costing and scheduling programme instantly. This is crucial as time is money in construction industry. It permits the construction team to analyse the risks earlier and make better decision. The integration of BIM with Augmented Reality (AR) and Virtual Reality (VR) technologies further enhance the sustainability and efficiency of the designing and construction works (Radley, 2019). According to Li et al. (2022), adoption of BIM also helps the construction industry towards well-decision making, for instance, in selection of most suitable tenderer at the tendering stage as BIM is able to minimize information asymmetry.

2.4 Digital Transformation as Construction 4.0 in Malaysia

In Malaysia, digital transformation in construction industry is often refered to as Construction 4.0. The term of ‘Construction 4.0’, is a process of digitising the construction industry as well as the supply chain by implementation of new digital technologies. It targets to drive the construction industry towards the Fourth Industrial Revolution, from automation to a higher level of digitalisation, or known as “smart construction” that are less workforce dependency (CIDB, 2020). The term Construction 4.0 originates from the term Industry 4.0, where the concept of Construction 4.0 involved 2 components, digitalisation of the construction industry and industrialisation of the construction process (Kozlovska et al., 2021). However, Industry 4.0 is classified as stage of industrial revolution connected to the advancement of digital tehcnologies. According to Zabidin et al. (2020), majority of study are focusing on application of Industry 4.0 in manufacturing industry, engineering sectors, business management, social science and others rather than in the construction sector, which pointed out that Construction 4.0 is still in the process of formation and further investigation is required. The convetional data-handling approach in delivering a construction project will result to shift towards a more innovative approach that incorporating with new tehcnologies allow for automated analysation (The Star, 2021). The trend of smart construction will form the future of the industry. The connection between the cyberspace and physical space becomes decentralised through widespread connectivity in Construction 4.0 (Building Transformations, 2022). The effect of digital transformation in the era of IR 4.0 towards the construction sector is strong, but it is in a slow progress (CIDB, 2020). According to research from McKinsey Global Institute, digital transformation can improve productivity by 14-15 %, and cost reduction up to 45% (Koutsogiannis, 2019).

In the context of Construction 4.0, technologies such as BIM has made the connection between the physical world and cyberspace possible, in which an entire numerical model of a construction project is possible to be generated and 2-way interconnection between the model and the construction site can be created (Building Transformations, 2022). The role of humans will gradually be replaced by new technologies which result in a decrease in human intervention. Besides, Construction 4.0 also results in actions of industrial off-site production instead of building one-by-one on the site using conventional methods, implementation of computing tehcnologies and cybersystem where the sensors is embeded into building structures for data exchange through the Internet to have a real-time monitoring on their performances(Team, 2022).

However, the conventional practice of the Malaysian construction industry by using the traditional construction method has caused a low performance and development growth. Recently, the construction industry even encountered huge percentage changes in the overall GDP in the first quarter of year 2020 due to the lockdown periods imposed by the government as a result of the outbreak of Covid-19 (Alaloul et al., 2021). Things are getting worse due to the prolonged lockdown period and significantly affect the stability of the country’s economy. It further revealed by Webster (2021) that the conventional low bid model as practiced by current contractor impede the technological investment for digitally innovated construction process. In order to achieve the concept of digital transformation, the country have to shift from a conventional construction to a more digitized, modern construction approach by involving the advanced construction technologies to the daily progress as what is being practiced by Hong Kong, United Kingdom and Singapore (Hamid and Kamar, 2012).

2.5 Challenges Ahead of Digital Construction

According to Radley (2019), the subsequent 5 years are crucial for the construction industry to fully leverage its potential through the process of digital transformation. Even though the construction industry is considered fast to recognise its potential as compared to other sectors, it could not be too confident on how the speed of construction digitalisation can solve the challenges or obstacles encountered, due to the reason that the construction industry nearly missed out on 3rd Industry Revolution. According to McKinsey report, the construction sector has been placed within the least digitised sector (Talamo and Bonanomi, 2019). The study by Jacobsson and Linderoth (2021) revealed that a lack of time for the construction participants which might due to tight margins of works, continuous inflow of unanticipated events causing them having insufficient time to adapt and employ to the new digital technologies and working methods. Besides, the transformational effect of digitalisation creates a huge amount of data which needs to be gathered, processed and stored. This has caused a significant impact in terms of the cost for data processing, and the operational cost in the data center that eventually affect the firm's decision to implement the new digital technology and applications (Sivarajah et al., 2017). The nature of sharing information and data between organisations in the digitalised construction environment also raises problems such as data security and ownership of data as some data produced are highly confidential (Lee, 2018; Aghimien et al., 2020).

In addition, the high upfront investment cost to adopt technologies in construction industry was ranked as top barrier in a study by Nnaji and Karakhan (2020), in which the BIM application, robotics, automation and even AI technology required the procurement of necessary hardware and software components. Although the use of such technologies will be cost-effective in the long run, however, the main concern is that most of the construction organisation in particular SMEs firms are having the limited capabilities in their capital investments and low profit-margin (Oesterreich and Teuteberg, 2016; Radley, 2019). Other than the initial purchase cost, the true cost of operating the new technologies and its maintenance cost presents as another cost barriers (Yap et al., 2021). According to Manzoor et al. (2021), over 80% of cost in utilizing the new technology is likely to incur after the initial purchase.

Despite some of the large construction firms having the financial capabilities to invest in digitalisation, there might be a problem of lack of skilled personnel to exploit it (Radley, 2019). According to Yahya et al. (2019), 93% of workers in the Malaysian Construction Industry are classified in the category of low-skilled workforce. The absence of relevant and necessary skills to handle digital tools caused the employers, contractors and designers facing difficulties in moving towards a higher level of digitalisation in construction (Lee, 2018). For example, study done by Li et al. (2018) indicated that visual literacy skills needed to be further enhanced within the construction personnel in order to perform better when managing visualised object through AR/VR technologies. Immersive or extra training is needed to attain the required skills and educate the workforce to handle different technologies throughout the process of digital transformation. The cost implication from such training restricts the use of on-site digital technologies (Nnaji and Karakhan, 2020).

Construction industry is known to have a poor digital culture (Aghimien et al., 2022). Resistant to changes from the social and human perspective is the other major challenges in digital transformation in the construction industry. Resistance to change from employees' perspective mainly arise from their poor understanding concerning the inherent benefits in adopting digital technologies (Gamage, 2021; Aghimien et al., 2022). This is supported by Heponiemi (2022) that older group of employees are less likely to appreciate the benefits of emerging digital technology. Apart from that, fear of job loss as they might be replaced by computer technologies, robotics and machines gave the employees a strong resistance to the changes in their current working methods (Oesterreich and Teuteberg, 2016). This is supported by Meno (2020) that construction workers tend to remain what they had practiced and afraid of the unknown.

2.6 Digital Maturity

Digital maturity measures on the ability of an organisation to react quickly to the evolving trends of digital technology (BCG, 2023). The focus is to create values better towards the organisation both internally and externally by leveraging the new technology.

According to Digital Maturity Model (DMM) introduced by Deloitte in 2018, an organisation's digital maturity is measured in few different dimensions, which are customer, strategy, technology, operations, organisation's culture and lastly data (Dieffenbacher, 2022). It acts as a tool to access the maturity level of an organisation in term of their digital capability. Company or organisation having high level of digital maturity could results in better advantages than their rivals in the aspect of cost efficiency, quality of the products, income growth, time to market and customer satisfaction (BCG, 2023). However, company with low digital maturity level will be struggling behind these advantages.

The first core dimension mentioned in the DMM by Deloitte is "Customer". It provides an output where the organisation is viewed by the customers as their digital partners that assist them in controlling their connected future through their preferred methods of interaction. Second dimension, "Strategy" mentioned on the ways the organisation transforms and operates its business through digital initiatives as outlined in the organisation's overall business strategy. By having digital strategy, there will be a clear direction for the organisation to transform their processes or operations digitally, eventually improve their competitive advantage (Dieffenbacher, 2022).

Apart from that, digital maturity is accessed from the "Technology" dimension to evaluate how success the organisation leverage the use of new technology in dealing with different data so as to target the customer needs, while reducing cost and overheads. It is important to have an integrated tools and systems within the organisation to ensure a smooth customer experience. For "Operations", an organisation is defined as mature providing there is technology-driven process that runs across the organisation to drive their business effectively and efficiently. The activities are carrying out and evolving with the incorporation of digital technologies (Dieffenbacher, 2022).

The next dimension in DMM is about "Organisation's Culture", that determine the company's culture including governance practices and talent processes by targeting to support transformation progress along the digital maturity curve. It mainly affected by the culture of working, behaving, receiving and responding to changes from the organisation's employees. The last dimension is about "Data" maturity, which evaluate on the capability of the organisation in handling and dealing with the use of data on different level to maximise their value as revealed by Deloitte in DMM.

2.7 Conceptual Framework

From literature review, a conceptual framework is proposed as shown in Figure 2.2. It is assumed that the degree of digital maturity of the Malaysian construction industry could be affected by the adoption of digital infrastructure in the organisation. Nevertheless, the encountered challenges have contingent effect on the maturity of the construction industry in the preparedness of digital transformation.

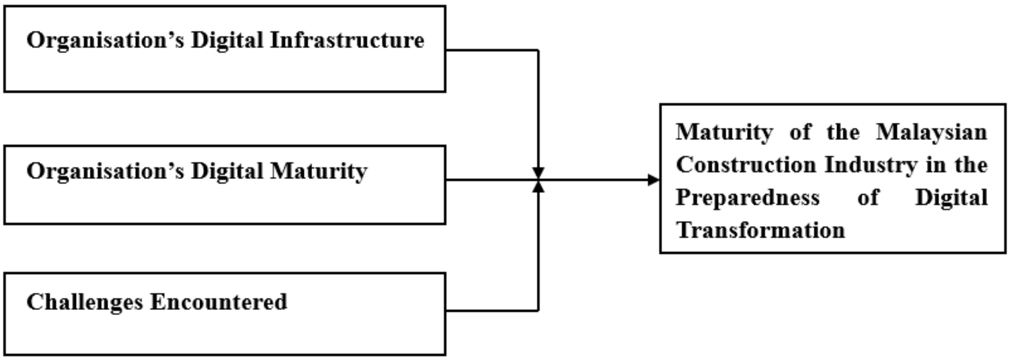

Figure 2.2: Conceptual Framework of Digital Transformation in the Construction Industry

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter outlines the research approach under section 3.2, followed by section 3.3 on formulation of both open-ended and close-ended questions under the questionnaire design. In section 3.4, sampling approach is explained, followed by the determination of the sample size and also the targeted respondents for this study. Furthermore, the data analysis section 3.5 will be discussed on the analysis methods and tests being used in this study. Digital ethics is explained at the end of this chapter.

3.2 Research Approach

Exploratory study approach was applied in this study to identify various key components contributing to construction digitalisation through literature review, while assessed the digital maturity of the Malaysian construction industry in five different dimensions. This approach was conducted as to explore the current readiness and maturity of the construction industry towards the process of digital transformation.

3.3 Research Strategies

In this study, primary data from the construction industry practitioners were collected through questionnaire survey, which comprises of both multiple choice questions and open-ended questions. Quantitative analysis and qualitative analysis were used in analysing of the multiple choice questions and open ended questions respectively. Invitation to the questionnaire survey was sent via Google Link through different platform such as Whatsapp, email, LinkedIn and etc. The questionnaire was available in the Google Form from 11/2/2023 to 19/3/2023. Further details regarding the design and structure of the questionnaire is explained in the following section.

3.3.1 Questionnaire Design

The questionnaire survey used in this research comprised close-ended questions on Section A, B and D and open-ended questions on Section C . The structure of the questionnaire comprised of four primary sections. Section A is aim to explore the current digital infrastructure available in the Malaysian construction industry. Section B aims to assess the maturity of the Malaysian construction industry in five different dimensions which are strategy, culture, operations, data, and technology. Next, Section C aims to uncover the significant challenge towards digital transformation in Malaysian construction industry. The last section will be on demographic information. Figure 3.1 illustrated the questionnaire's layout.

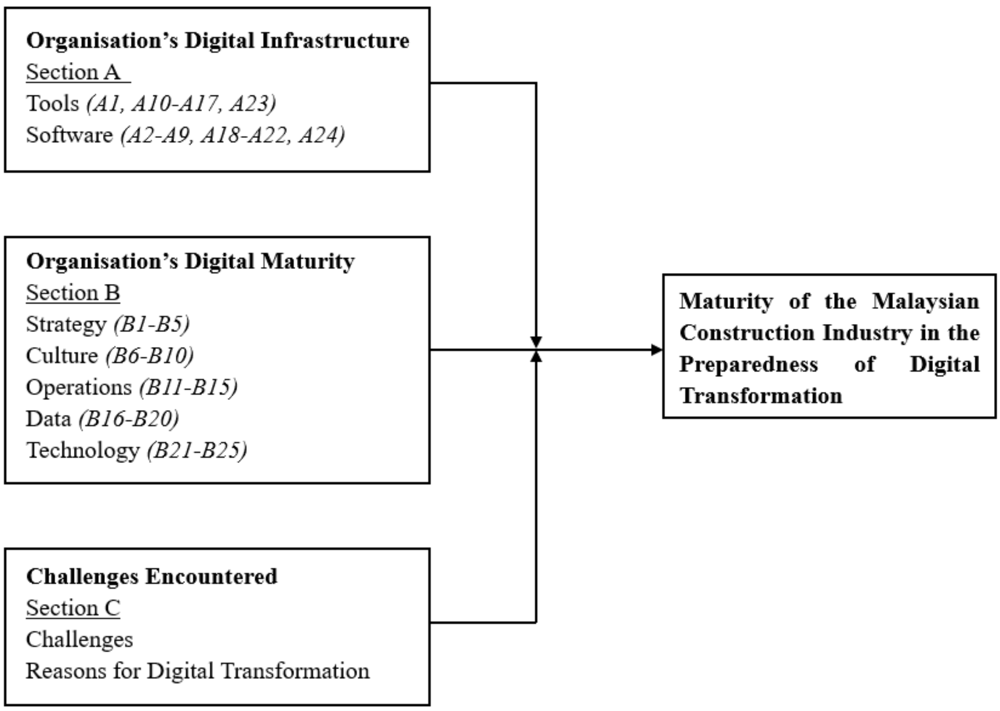

Figure 3.1: Questionnaire's Design

(a) Availability of Digital Infrastructure in Malaysian Construction Organisation

Section A focus on the digital tools or softwares currently provided by the construction organisation. List of digital infrastructure prepared is mainly based on the digital technology found under the paper "The Future of BIM" by RICS (2020). Five-points Likert scale is adopted to collect the feedbacks from the respondents pertaining to their current state of digital application. It comprises the options of ‘Don’t know’, ‘Never use’, ‘Expect to use in 5 years’, ‘Expect to use in 3 years’, and ‘Use it now’ to a given questions. Breakdown of infrastructure into two categories are shown in Table 3.1.

Table 3.1: Statement Summary for Section A

Categories	No. of Statement	Reference
Tools	10	RICS, 2020 Chia et al., 2021 World Economic Forum, 2016
Software Application	14	

(b) Digital Maturity of the Construction Organisation

Section B was designed based on the digital maturity assessment published by Digital Leadership Ltd. (2023) and the questions from this section have been classified into the five major dimensions mentioned by Deloitte under the Digital Maturity Model (Dieffenbacher, 2022). Five-points Likert scale is adopted in Section B to assess the degree of maturity in different aspects possessed by the construction organisation. It comprises the options of ‘strongly disagree’, ‘disagree’, ‘neutral’, ‘agree’, and ‘strongly agree’ to a given questions. Breakdown of statements into five key dimensions are shown in Table 3.2. A reversing approach is adopted in statements B1, B6, B11, B16, B21, and B22 in which the reversed worded statements is used in the survey. The rating provided by the respondents on such statements were reversed, for instance, rating 5 will be subsequently converted into 1, 4 into 2 and so on.

Table 3.2: Statement Summary for Section B

Dimensions	No. of Statement	Reference
Strategy	5	Dieffenbacher, 2022 Digital Leadership Ltd., 2023
Culture	5	
Operations	5	
Data	5	
Technology	5	

(c) Challenge Encountered

Section C was designed as open-ended question for the respondent to share their opinions on an optional basis. This section consisted of two questions as shown in Table 3.3.

Table 3.3: Summary of Questions for Section C

Ref. Code	Questions
C1	What is the biggest challenge for your organisation to digitise the construction process?
C2	Do you think digital transformation is necessary in the construction industry? Why?

(d) Demographic Information

Section D comprised of 3 questions to collect the demographic data of the respondents, which was summarised in Table 3.4.

Table 3.4: Summary of Demographic Data for Section D

Ref. Code	Respondent's Demographic data
D1	Company's Business Activities
D2	Professions
D3	Years of Working Experience

3.4 Sampling Design

The sample frame of this research is the community of the Malaysian construction industry. The sampling approach, sample size and targeted respondents are discussed in detail in the following subsections.

3.4.1 Sampling Approach

This research used convenience sampling to obtain data randomly from the construction practitioners in Malaysian construction industry. The only qualification for respondents is that they must be involved in construction industry.

3.4.2 Sample Size

Central Limit Theorem (CLT) was adopted to justify the sufficiency of the sample size in this study. A minimum of 30 sample size acts as a benchmark for any categories or groups for the CLT to hold true (McLeod, 2023). A minimum of 30 sample size for each categories' group is sufficient to represent the mean value for the group. In this research, there are a total of 202 responses received and all the variables' categories have received more than 30 responses which meet the benchmark of CTL.

3.4.3 Targeted Respondents

The targeted respondents for this research includes the construction practitioners in Malaysia who were involved in any business in the construction industry, and pocess construction related professions and without minimum and maximum working experience in the construction industry.

3.5 Data Analysis

In this research, data obtained from the questionnaire is analysed through Statistical Package for Social Sciences (SPSS) software. Qualitative and quantitative analysis are used for open-ended question and close-ended question respectively. The Cronbach's Alpha Reliability Tests is used to ensure the consistency and reliability of the questions in each sections. The findings from the data is analysed through the descriptive and inferential statistics.

3.5.1 Reliability Test

Cronbach's Alpha Reliability Test is used to determine the amount of internal consistency. The alpha coefficient ranges in value from 0 to 1, in which when the value is equal to or greater than 0.7, indicates the questionnaire design is consistent and reliable.

3.5.2 Descriptive Statistic

In this research, frequency distribution was used in organising the demograpic data into a systematic data form. Besides, Friedman's test was adopted to test the differences between two groups of digital infrastructure and between five dimensions of digital maturity. From the test, the highest and lowest ranked digital infrastructure and digital maturity's dimension were reported.

3.5.3 Inferential Statistic

In this research, Kruskal-Wallis H test was adopted to compare various independent groups to develop generalisable outcomes that can represent the large population group.

(a) Kruskal-Wallis H Test

This K-independent sample test is applied to test the existence of statistically significant differences between two or more groups of one independent variable on the ordinal variables with p-value less than 0.05. This test is adopted to compare between groups on the variables of respondent's business activities, professions, and years of experience.

3.6 Research Ethics

In this research, the feedbacks from the respondents were kept confidential without disclose to any thrid party and all the data collected was strictly used for research purpose. Besides, the participation in this survey was totally voluntary and the participants was allowed to withdraw at any time. It is presumed that the particpants agreed with UTAR privacy notice before submiting the survey form, and any related enquiries can be reached to the researcher or UTAR Research Ethics Officers through phone or email.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The online questionnaire elucidated in Chapter 3 was posted in Google Form from 10/2/2023 to 20/3/2023. The questionnaire survey were send out through Whatsapp, Linked-In, and Email. Until 19/3/2023, a total of 202 valid responses were collected. Summary of respondents' demographic is presented under Section 4.2. Details of results for reliability test is further reported in Section 4.3. Section 4.4 presents the availability of digital infrastructure in the construction organisation, while Section 4.5 analyses the digital maturity of the construction organisation. The responses from open-ended questions regarding the chellenges encountered and reasons necessary for digital transformation are summarised under Section 4.6. Lastly, the key findings of this study in the context of published literatures are covered under Section 4.7.

4.2 Respondents' Background

A total of 202 responses of the questionnaire survey were collected over a period of one month through whatsapp, email, and LinkedIn. The repondents' demographic data are summarised in Table 4.1, the main business activities is contracting (40.1%), followed by consultancy service (28.7%). Different professionals are almost represented by one-fifth (19%-21%) of the respondents; Quantity Surveyors is marginally higher in this research. Lastly, more than 70% of the respondents have more than 2 years experience in the construction industry.

Table 4.1: Demographic Data of Respondents (N=202)

Attributes	**Categories**	**Frequency**	**Percentage**
Company's Business Activities	Property Development	32	15.8
	Contracting Business	48	23.8
	Consultancy Service	58	28.7
	Sub-Contracting	33	16.3

	Supplying Business	31	15.3
Profession	Architect	38	18.8
	Quantity Surveyor	43	21.3
	Civil or Structural Engineer	37	18.3
	Mechanical or Electrical Engineer	36	17.8
	Chartered Builder	39	19.3
	Other	9	4.5
Years of Working Experience	Less than 2 years	60	29.7
	2 – 5 years	48	23.8
	6 – 10 years	40	19.8
	11 – 20 years	33	16.3
	More than 20 years	21	10.4

N= Total number of respondents

4.3 Reliability Analysis

Table 4.2 shows the results of reliability for section A (Digital Infrastructure) and section B (Digital Maturity) in the questionnaire. Section A and section B, and all subcategories under both section achieve the Cronbach's Alpha value of above 0.80, indicates the questions designed in each section are constructed with internally consistency.

Table 4.2: Cronbach's Alpha Reliability Test

Sections	Number of Items	Cronbach's Alpha Value
Section A: Digital Infrastructure	**24**	**0.921**
Tools (A1, A10-A17, A23)	10	0.882
Software (A2-A9, A18-A22, A24)	14	0.891
Section B: Digital Maturity	**25**	**0.955**
Strategy (B1-B5)	5	0.853
Culture (B6-B10)	5	0.837

Operations (B11-B15)	5	0.820
Data (B16-B20)	5	0.842
Technology (B21-B25)	5	0.849

4.4 Availability of Digital Infrastructure in the Construction Organisation

The availability of ‘Software’ is more than ‘Tools’ in the organisation. The results is statistically significant indicated by the results of Friedman test (χ^2 (1) = 49.25, p = 0.00) (Table 4.3).

Table 4.3: Digital Infrastructure Available in the Construction Organisation

Digital Infrastructure	**Mean Rank**	**Chi-Square**	**Asymp. Sig.**
Software (A2-A9, A18-A22, A24)	1.75	49.251	0.000
Tools (A1, A10-A17, A23)	1.25		

Complete results of all 24 digital infrastructure of this survey are available in Appendix B.

(A) Software

Table 4.4 extracted the three most available and three least provided software by the organisation. The collaboration software (mean rank = 10.62) and data analyst softwares (mean rank = 10.26) are widely used in the organisation. Besides, the application of cloud-based storage (mean rank = 9.28) was also frequently used. However, virtual reality (mean rank = 5.48), augmented reality (mean rank = 5.35), and digital twins application (mean rank = 4.64) were seldom available in the organisation. The results is statistically significant indicated by the results of Friedman test (χ^2 (13) = 607.06, p = 0.00)

Table 4.4: Top three and least three software application available in Construction Organisation (N=202, df = 13)

Ref Code	Digital Infrastructure	Mean Rank	Chi-Square	Asymp. Sig.
	Software (A2-A9, A18-A22, A24)			
A6	Collaboration Tools (eg. Microsoft Team/ Zoom)	10.62	607.064	0.000
A7	Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)	10.26		
A20	Cloud-based Storage (eg. Google Drive)	9.28		
A19	Virtual Reality (VR)	5.48		
A18	Augmented Reality (AR)	5.35		
A24	Digital Twins (eg. Digital replica of building)	4.64		

Note: N = number of respondents; df = degree of freedom

(B) Tools

Table 4.5 extracted the three most available and two least provided tools by the organisation. Majority of the organisation are using the mobile technology (mean rank =9.15), semi-autonomous robot (mean rank = 5.97) and unmanned aerial vehicle or drone (mean rank = 5.90). However, the wearable technology (mean rank = 4.27) and 360-degree on-site monitoring tool (mean rank = 4.24) are least provided and used in the organisation. The results is statistically significant indicated by the results of Friedman test (χ^2 (9) = 556.36, p = 0.00)

Table 4.5: Top three and least two digital tools available in Construction Organisation (N=202, df = 9)

Ref Code	Digital Infrastructure	Mean Rank	Chi-Square	Asymp. Sig.
	Tools (A1, A10-A17, A23)			
A1	Mobile Technology (eg. Laptop/Tablet)	9.15	556.355	0.000

A15	Semi-Autonomous Robot (eg. SAM)	5.97
A17	Unmanned Aerial Vehicle/Drone	5.90
A11	Wearable Technology (eg. Smart Glasses)	4.27
A12	360-degree On-Site Monitoring Tool	4.24

Note: N = number of respondents; df = degree of freedom

4.4.1 More Digital Softwares are available for Consultancy Service in term of Business's Activities

Consultants are available with "Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)", "Estimation Software (eg. CostX)", and "Building Information Modelling (BIM) technology". Meanwhile, the sub-contractor are least available with "Estimation Software (eg. CostX)", and "Building Information Modelling (BIM) technology". Appendix D presented further significant digital software available among the business's activities. These results are supported by Kruskal-Wallis H test with $p<.05$ as shown in Table 4.6.

Table 4.6: Differences of Digital Infrastructure Available in The Organisation According to Business's Activities

No	Null Hypothesis	Mean Rank					Sig.
		Property Development	Contracting Business	Consultancy Service	Sub-Contracting	Supplying Business	
A7	Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)	108.53	79.18	114.62	100.76	105.05	0.004
A9	Estimation Software (eg. CostX)	109.00	87.46	121.65	76.12	104.82	0.001
A21	Building Information Modelling (BIM) technology	97.34	96.82	125.26	77.95	93.65	0.001

4.4.2 More Digital Softwares are available to Quantity Surveyor in term of Professions

Quantity surveyors are available with “Estimation Software (eg. CostX)”, and “Building Information Modelling (BIM) technology”. However, Architect, Quantity Surveyor and M&E Engineer have quite similar availabilities on “Project Management Software (eg. Primavera/ Microsoft Project” provided by the organisation. Appendix E presented further significant digital software available among the professions. These results are supported by Kruskal-Wallis H test with $p<.05$ as shown in Table 4.7.

Table 4.7: Differences of Digital Infrastructure Available in The Organisation According to Professions

No	Null Hypothesis	Mean Rank					Sig.
		Architect	Quantity Surveyor	C & S Engineer	M & E Engineer	Chartered Builder	
A8	Project Management Software (eg. Primavera/ Microsoft Project)	114.32	112.88	87.15	111.29	90.22	0.020
A9	Estimation Software (eg. CostX)	105.12	125.30	91.11	113.82	83.18	0.000
A21	Building Information Modelling (BIM) technology	104.54	128.59	87.23	95.26	97.29	0.002

4.5 Digital Maturity of Construction Organisation

Among the digital maturity dimension, ‘Data’ has the highest maturity. It follows by ‘Culture’ and ‘Operations’. Meanwhile, the lowest digital maturity went to ‘Technology’ aspect. The results of Friedman test indicates there is a significant difference between the mean ranks of the organisation’s digital maturity, χ^2 (4) = 50.13, p = 0.00 (Table 4.8).

Table 4.8: Digital Maturity of the Construction Organisation

Digital Maturity	**Mean Rank**	**Chi-Square**	**Asymp. Sig.**
Data (B16-B20)	3.32	50.131	0.000
Culture (B6-B10)	3.24		
Operations (B11-B15)	3.05		
Strategy (B1-B5)	3.00		
Technology (B21-B25)	2.38		

Complete results of all 25 statements under the five major dimension of digital maturity are shown in Appendix C.

(A) Highest Rank: Data

Table 4.9 presents detailed anaysis of the data maturity of the organisation. Based on the table, there is a significant difference between the mean ranks of the data maturity, χ^2 (4) = 104.97, p = 0.00. Majority of the organisation has improved the quality and use of data (mean rank=3.36). Also, they have established a clear policy in managing over the data (mean rank=3.32) .

Table 4.9: Two Most Agreed Data Maturity Statements by the Construction Organisation (N = 202, df = 4)

Ref Code	Statements	Mean Rank	Chi-Square	Asymp. Sig.
	Data			
B17	Quality and use of data in the organisation is improving in some areas	3.36	104.967	0.000
B18	There's a clear policy for data management (eg. Data is integrated and analysed)	3.32		

Note: N = number of respondents; df = degree of freedom

(B) Lowest Rank: Technology

Table 4.10 presents detailed anaysis of the digital maturity of the organisation in term of technology. Based on the table, there is a significant difference between the mean ranks of the technology maturity, $\chi^2(4) = 152.42$, $p = 0.00$. The tools and systems in majority of the organisation are stable and for basic operations purposes (mean rank=3.58). The technologies used by the organisation are also getting effective (mean rank=3.42).

Table 4.10: Two Most Agreed Technology Maturity Statements by the Construction Organisation (N = 202, df = 4)

Ref Code	Statements	Mean Rank	Chi-Square	Asymp. Sig.
	Technology			
B23	Systems are stable and enable basic operations	3.58	152.416	0.000
B24	Tools and systems are delivering improvements in effectiveness	3.42		

Note: N = number of respondents; df = degree of freedom

4.5.1 Overall Score for Digital Maturity of Malaysian Construction Organisation is 60%

Based on Table 4.8, the total average score for digital maturity across five major dimension is 2.998 out of 5, which is approximately 60%.

4.5.2 Consultancy Service has The Highest Digital Maturity while Contracting Business has The Lowest Digital Maturity

Consultants have most agreed on statements under each of the maturity dimensions, inferring the consultant is more matured than others in terms of strategy, culture, operations, data and technology dimensions. The degree of maturity for supplying business come after next except in the aspect of culture maturity. However, the contractor is least agreed on all the statements in Table 4.11, inferring the contractor is the least digitally matured. Appendix F presented further significant statements among the business's activities. These results are supported by Kruskal-Wallis H test with $p<.05$ as shown in Table 4.11.

Table 4.11: Differences of Digital Maturity According to Business's Activities

No	Null Hypothesis	Mean Rank					Sig.
		Property Development	Contracting Business	Consultancy Service	Sub-Contracting	Supplying Business	
B5	Digital is an integral part of the overall strategy and digital leadership is present at all levels	95.28	78.81	125.24	90.89	109.92	0.001
B8	My organisation understand the value of digital and wants to learn more	106.55	80.69	119.68	102.44	93.50	0.010
B15	Agile principles of digital project management are consistently used in all projects	95.16	75.35	123.72	98.11	110.56	0.000
B19	My organisation use quality, integrated data across the company	99.86	82.71	122.80	88.59	106.18	0.004
B25	Interconnected tools and systems provide a smooth internal and external user experience	97.91	81.07	123.06	89.71	109.05	0.002

4.5.3 Quantity Surveyor has The Highest Digital Maturity while Chartered Builder has The Lowest Digital Maturity

Quantity surveyors have most agreed on statements under each of the maturity dimensions, inferring the quantity surveyor is more digitally matured than others in terms of culture, operations, data and technology dimension. Besides, the architect, C&S engineer and M&E engineer have almost the same agreeement towards the maturity statements, except for chartered builder. The chartered builder is least agreed on all the statements in Table 4.12, inferring this chartered builder is the least digitally matured. Appendix G presented further significant statements among the professions. These results are supported by Kruskal-Wallis H test with $p<.05$ as shown in Table 4.12.

Table 4.12: Differences of Digital Maturity According to Professions

No	Null Hypothesis	Mean Rank					Sig.
		Architect	Quantity Surveyor	C & S Engineer	M & E Engineer	Chartered Builder	
B10	Digital is the principal way to achieve company's mission	106.47	119.05	100.69	111.17	78.08	0.006
B15	Agile principles of digital project management are consistently used in all projects	102.50	124.79	101.86	110.57	71.81	0.001
B20	My organisation use live data to shape decisions and performance	103.50	122.14	100.57	102.06	88.94	0.011
B25	Interconnected tools and systems provide a smooth internal and external user experience	95.16	128.51	100.04	102.89	86.24	0.005

4.5.4 Construction Practitioners with More Than 20 years Working Experience are More Matured in Digital Operations

Construction practitioners with more than 20 years working experiences are most agreed on the statements under the operations dimension, inferring that this group of people have higher digital maturity in terms of operations. However, those with 6 to 10 years experience showing the least agreement on the same statements, indicating with the lowest maturity level on the digital operations. These results are supported by Kruskal-Wallis H test with $p<.05$ as shown in Table 4.13.

Table 4.13: Differences of Operations Maturity According to Years of Working Experience

No	Null Hypothesis	Mean Rank					Sig.
		Less than 2 years	2-5 years	6-10 years	11-20 years	More than 20 years	
B13	Projects are managed through a structured but often lengthy process	105.59	99.05	78.18	114.35	119.64	0.027
B14	Agile project management principles and practice are used. There is a launch, test and improve approach	112.83	96.30	82.74	96.80	124.12	0.030
B15	Agile principles of digital project management are consistently used in all projects	112.53	102.27	73.58	105.00	115.90	0.009

4.6 Challenge Encountered

4.6.1 Challenges to Digitalise Construction Process

There is a total of 94 responses received on the open-ended question pertaining to challenges encountered. Among the responses, the high cost (26.60%) was considered as the biggest challenge, followed by resistance to change (17.02%) and lack of knowledge and skills (15.96%) (Figure 4.1).

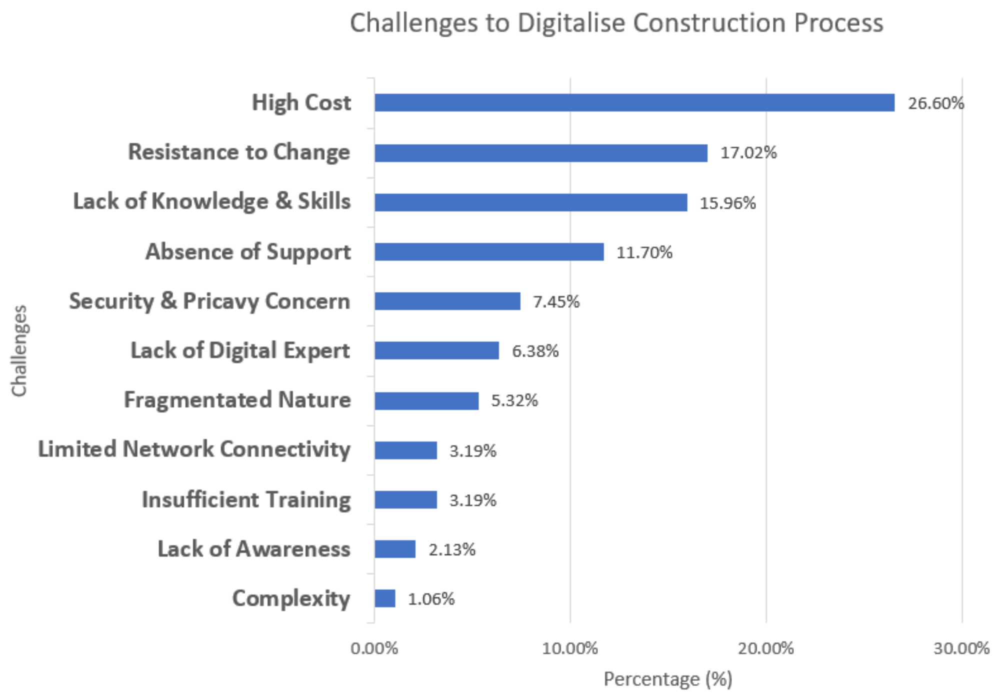

Figure 4.1: Top 11 Challenges to Digitalise Construction Process

4.6.2 Reasons Necessary For Digital Transformation in Malaysian Construction Industry

All 94 responses agreed that digital transformation is necessary. Among the reasons for digital transformation, speed up work process and improve productivity (36%) was the most vital reason, followed by improve collaboration (13.33%) and enhance safety (12.00%) (Figure 4.2).

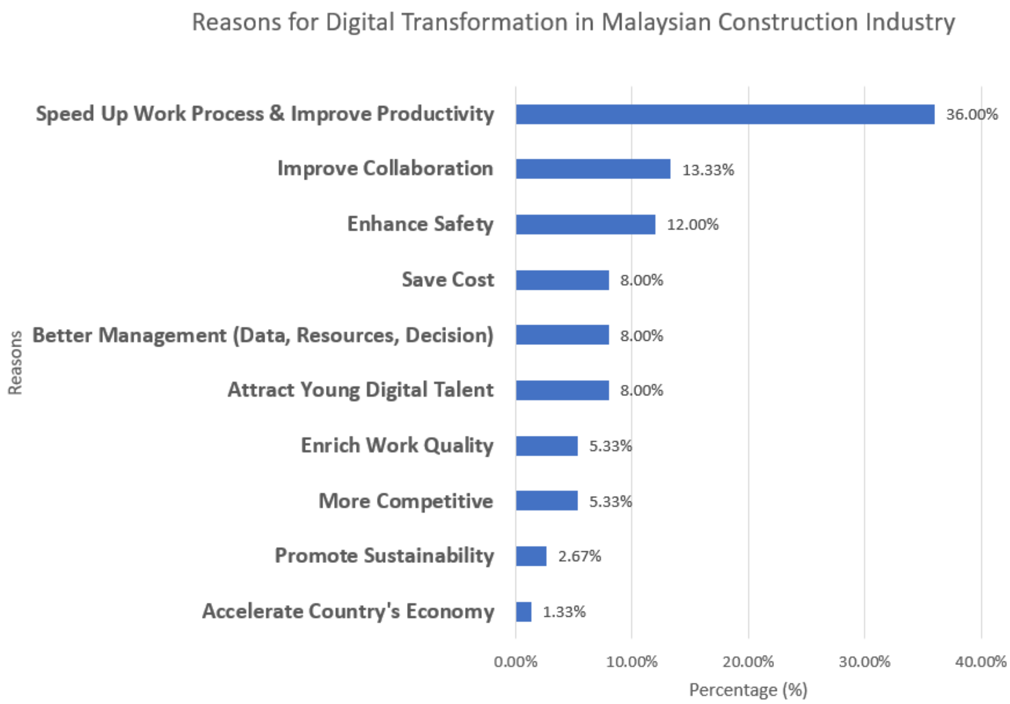

Figure 4.2: Top 10 Reasons for Digital Transformation in Malaysian Construction Industry

4.7 Discussion

In short, there are seven generalisable findings can be derived from the survey results. One finding from availability of digital infrastructure in construction organisation, four findings from digital maturity and another two are from the saturated findings summarised in open-ended questions.

4.7.1 Digital Infrastructure Available in the Construction Organisation

(a) Collaboration Tools and Data Analyst Tools are Mostly Available in Construction Organisations

The most common software application were "Collaboration Tools (eg. Microsoft Team/ Zoom)" and "Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)", inferring that the staffs are collaborating digitally and analysing the data through software. These digital software application are highly provided across the consultancy service and quantity surveyor prefessions. It is in line with Alfresco's Report as reviewed in Section 2.3, whereby 83% of the professionals relies on the technology to collaborate (Alfresco, 2015). While 71% of the construction professionals are having great interest and using predictive data analytics towards the data-driven decision (BuildOps, 2022) as mentioned in Section 2.3.1 aligns with the above findings.

4.7.2 Digital Maturity of the Construction Organisation

(a) Overall Construction Organisation's Digital Maturity Score is 60%

Section 4.5.1 reveals the overall digital score by 60%, slightly more than half. It infer that the construction organisation has taken initiatives in moving towards digitalised process, but is yet to achieve digitalisation entirely. This is a significant finding which different from the McKinsey's Report in 2017 as literature reviewed in Section 2.5 whereby the construction sector is ranked second as the least digitised sector (Talamo and Bonanomi, 2019). In reality, most of the constuction industry has started their digital journey, but still is not up to the status readily for transformation.

(b) Consultancy Service has The Highest Data Maturity

Section 4.5 reveals that out of the five major dimension related to digital maturity, data maturity falls under the the highest rank-ordered maturity for an organisation (Table 4.6). The consultancy sevices have shown the highest mean rank towards "my organisation use quality, integrated data across the company". This indicates that consultancy business excel in managing data within organisation. This aligns with Tras's (2015) finding in Section 2.3.1 where consulting firms have shaped their strategies and construct framework primarily focused on big data and agile analytical solutions.

However, it was found that the contracting business and chartered builder was less proficient in using the real-time data for decision making. The live data generated from machinery on-site is never employed. Moreover, they seldom having data management policy, in which all their data are not well-organised in a systematic structure. This support the claim made by Massey (2021) as literature reviewed in Section 2.3.1 that almost 80% of the data was left unstructured by contractors and sub-contractors, where information is frequently stored in dispered spreadsheet and documents.

(c) Contracting Business has The Lowest Technology Maturity

From Table 4.11, respondents' responses to statements under technology maturity such as "Systems are stable and enable basic operations" and "Tools and systems are delivering improvements in effectiveness" indicates that the organation does not practice the full integration of tools and systems instead these system are only applicable for basic function purposes.

The findings discovered that the level of maturity in terms of technology used in the construction organisation is still poor, and the construction industry requires more effort to enhance interconnection between digital technology. Furthermore, with regards to business's activities, , the respondents involved in contracting business shown the lowest mean rank towards "interconnected tools and systems provide a smooth internal and external user experience". These findings are consistent with the report from Webster (2021) in Section 2.4, which emphasis on contractors still having long way to matured in terms of technology adoption as the low bid model commonly practiced by the contractor inhibits digital innovation or investment towards new technologies.

(d) Quantity Surveyor has The Highest Digital Maturity by Profession

Finding from section 4.5.2 shows that quantity surveyors are deemed to be more digitally matured in term of culture, operation, and data. They have practiced digital culture, where the works or projects are managed and operated through digital way. This is coincide with the The Star (2021)'s report desmonstrated in Section 2.4, in which majority of the past manual paper-documentation process has now been shifted to computers for automated surveying analyses, highlighting the digital proficiency of the quantity surveyor in dealing with digitally. Furthermore, quantity surveyors is digitally compent in data-driven decision making. This finding corroborated with Glodon (2022)'s observation where quantity surveyors tend to evolve from merely managing data to extracting value from the data in real-time as literature reviewed in Section 2.3.1. Integration of predictive cost data instead of historic cost data alone results in better decision making. Based on Section 4.5.3 (Table 4.13), those practitioners with more than 20 years working experiences was more matured in using digital way of project management throughout the projects. However, this is opposed to the findings from Heponiemi (2022) in Section 2.5 where higher working-age group was associated with lower digital competence as lower likelihood to adopt new technology. They are less likely to capture the value of new digital technology. Since there is inadequate representation of respondents with over 20 years of working experience, this impact the obtained result against the findings found in published literature.

4.7.3 Challenge Encountered

(a) High Costing is the Biggest Challenge to Digitalise Construction Process

Findings from Figure 4.1 revealed the high investment cost and resistance to change to be the major challenge for an organisation to shift towards digitalisation. This concurred with literature review Section 2.5 stating that technology application are costly and some even required the procurement of various software and hardware which presents as a hidden cost (Nnaji and Karakhan, 2020)

Besides, most of the employees perfered to remain in conventional style of working under their comfort zone. It is recognised by Meno (2020) as in literature review Section 2.5 that the employees afraid of the uncertainty and tends to remain in their current working style. This keep them challenging to explore the opportunities brought by new technology, while still holding on to the outdated conventional working style.

(b) Digital Transformation in Malaysian Construction Industry is Necessary to Speed Up Work Process and Improve Productivity

Digital transformation process is most necessary as it accelerate the work process and improve prodcutivity. This findings aligneed with McKinsey’s research with the productivity increase of 15% through digital adoption as literature reviewed in Section 2.4 (Koutsogiannis, 2019). It enable great reduction of construction time with highly productive works.

Furthermore, digital transformation is required to enhance collaboration within construction industry as second reason. It helps digitally collaborate the construction practitioners for better connection and avoid them from ‘working in silo’. This findings supported by Olanipekun and Sutrisna (2021) in literature review Section 2.3.1 where collaboration between human and robotics is made possible through strong computational power.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In summary, digital infrastructure provided by construction organisation is more focused on software application rather than digital tools and the construction organisation is more digitally matured in data dimension than other maturity dimension, with overall digital maturity score of 60%. The following Section 5.2 and 5.3 elaborate more on this conclusion. Besides, the implication of this research to the construction industry, regulatory bodies, and academia are identified in Section 5.4. Reflection of this entire research is highlighted in limitations under Section 5.5 and recommendations for future research are made in last section based on insights gained.

5.2 Accomplishments

Objective 1- To establish the landscape of digital technology in the construction industry

The four key components namely Algorithm, Big Data, Connectivity, and Computational Power are identified through literature reviews, standard documents and organisational reports as the drivers of the process in digital construction. To fully digitalised the construction process, this four key components are important to be integrated for technology-used throughout the project lifecycle. It forms the landscape of digital technology for the purpose of digital construction as shown in Figure 2.1.

Objective 2- To evaluate the current state of digital technology adoption in the construction industry

The currently available digital infrastructure in the construction organisation are collaboration software (Microsoft Team and Zoom), data analyst software (Microsoft Excal and Apache Spark). However, digital twin is rarely provided.

Consultant has the highest digital maturity among the five dimensions, and the lowest digital maturity business is contracting service. Quantity surveyors are more digitally matured in data handling, business operations and culture. Also, workers with more than 20 years working experience are more matured in digital way of working.

Objective 3- To infer the digital maturity to digital transformation of the construction industry in Malaysia

The output drawn from research objective 1 and 2 are enriched through evaluating the respondents' response towards the different digital maturity's dimension and challenges encountered in digitalisation. Data maturity is the highest in the construction organisation, inferring with a strong capability in data processing and handling procedure. This align with the findings from Section 4.7.1 where data analyst software are commonly adopted by the construction organisation, which make them digitally capable in managing over the data. Digital transformation is considered important and necessary. However, the main issue revealed from the findings in Section 4.7.3 are high costing for technology and resistance to change. This support the same finding outcome from section 4.7.2 in which technology dimension is having the least digital maturity, inferring the construction organisation are yet to prepare themselves in applying and integrating with the new technologies, and fully transform into digital way of working.

5.3 Conclusion

In short, fulfilment of all research objectives justified the accomplishment of the research aim: maturity of the Malaysian construction industry in the industry's preparedness of digital transformation. The overall average of digital maturity for Malaysian construction industry is approximately 3 out of 5 or 60%. There is yet a long way to go to acheive digital transformation in the Malaysian construction industry, especially in the aspect of technology with the least maturity which required integration and strong interconnectivity between digital tools and systems. The issue of high costing, resistance to change and lack of knowledge and skills are crucial to be addressed.

5.4 Research Implications

The research's findings indicated that Malaysian construction industry has yet to transform into fully digital business context, despite the awareness of the need to change. From the findings, the consultant quantity surveyors outperform all other professions in terms of digital practice across their organisation. Perhaps this finding will wake up other professions in Malaysia such as architects, engineers, and chartered builders in getting ready to coup with the digital business trend. It also alert the construction practitioners to know clearly the main issue of digitalisation and eventually turn the challenges into opportunities.

Besides, this findings allow the regulatory bodies to develop long term digital strategies that ensure successful implementation of National Construction Policy 2030. It can act as motivations to accelerate digital transformation of the industry by understanding and removing critical issues faced by the construction practitioners.

Lastly, the findings from this research, particularly on current state of overall digital infrastructure available in Malaysian construction industry can inspire other academic researches in narrowing down the research scope to explore on more specific technology areas like artificial intelligence and blockchain in the construction industry, to know more in-depth details on such technology.

5.5 Research Limitations

The sample size for each categories of attributes has attained beyond the minimum requirement of the Central Limit Theorem, except for the group of 'More than 20 years' under the working experience's attribute with only 21 respondents, presented as the limitation of this research. Besides, since this study is only focused in Malaysia, hence the conclusion findings can only be applicable to Malaysian construction industry.

Furthermore, it was unable to prove that there is a significant difference of digital infrastructure available in the organisation among respondents with different years of experience, as the p value is greater than 0.05. Lastly, as the fast-paced nature of digital business makes it difficult to keep up-to-date, this questionnaire design may not encompass the newly developed digital approaches and technologies.

5.6 Research Recommendation

In future research, the sample size limitation can be addressed through expanding the number of respondents in the underrepresented group and reconfiguring the demographic infromation, to enable meaningful comparison between groups that results in stronger statistical analysis.

Moreover, future research may expand the scope of participants beyond Malaysia, allowing the research to be applied in other countries and foster a broader generalisation of the research findings. Additionally, the statements in questionnaire survey should be carefully designed and examined when it involves the respondents' years of experience as demographic data in future research, to ensure valueble comparison resulted in generalisable findings. Lastly, the researcher is recommended to engage with digital communities in the future research. This provides an online platform to keep one updated on the latest trend and technologies through the insights sharing from digital experts.

REFERENCES

Aghimien, D., Aigbavboa, C., Meno, T. and Ikuabe, M. 2021. "Unravelling the risks of construction digitalisation in developing countries", *Construction Innovation*, [e-journal] 21(3), pp. 456-475. https://doi-org.libezp2.utar.edu.my/10.1108/CI-02-2020-0026.

Aghimien, D., Aigbavboa, C., Oke, A., Thwala, W., 2021. *Construction Digitalisation: A Capability Maturity Model for Construction Organisations*. [e-book] Routledge, 2021. Available at: Google Books < https://books.google.com.my/books?id=RK0xEAAAQBAJ&dq=digital+maturity+of+construction+organisation&lr=&source=gbs_navlinks_s> [Accessed 24 April 2023].

Aghimien, D., Aigbavboa, C., Oke, A., Thwala, W., and Moripe, P., 2020. Digitalization of Construction Organisations - a Case for Digital Partnering. *International Journal of Construction Management*, [e-journal] 1–10. doi:10.1080/15623599.2020.1745134

Aghimien, D., Ngcobo, N., Aigbavboa, C., Dixit, S., Vatin, N. I., Kampani, S., and Khera, G. S., 2022. Barriers to Digital Technology Deployment in Value Management Practice. *Buildings*, 12(731) pp. 1-14.

Alaloul, W., Musarat, M. A., Rabbani, M. B. A., Iqbal, Q., Maqsoom, A., and Farooq, W., 2021. Construction Sector Contribution to Economic Stability: Malaysian GDP Distribution, *Sustainability*, 13(9).

Alfresco, 2015. *COLLABORATION TRENDS AND TECHNOLOGY A SURVEY OF KNOWLEDGE WORKERS.* [online] Available at: <https://www.alfresco.com/sites/www.alfresco.com/files/dimesional-research-collab-survey-findings-report-082415.pdf> [Accessed 3 April 2023].

Anwar, N., Izhar, M. A., Najam, F. A., 2018. Construction Monitoring and Reporting using Drones and Unmanned Aerial Vehicle (UAVs). *Proc. of The Tenth International Conference on Construction in the 21st Century (CITC-10),* July 2nd-4th, 2018.

Aparaschivei, L., 2021. *What Is Generative Design? A Full Guide.* [Online] Available at: <https://www.vectornator.io/blog/generative-design/> [Accessed 12 July 2022].

Autodesk, 2022. *What are the benefits of BIM?* [online] Available at: < https://www.autodesk.com/industry/aec/bim/benefits-of-bim> [Accessed 18 July 2022].

BCG, 2023. *DIGITAL, TECHNOLOGY, AND DATA*. [online] Available at: <https://www.bcg.com/capabilities/digital-technology-data/digital-maturity> [Accessed 15 February 2023].

BERGER,R., 2016.Digitization in the Construction Industry, Think Act,1-16.

Bigelow, S. J., 2022. *What is edge computing? Everything you need to know*. [Online] Available at: <https://www.techtarget.com/searchdatacenter/definition/edge-computing> [Accessed 9 July 2022].

Bilal, M., L. O. Oyedele, J. Qadir, K. Munir, S. O. Ajayi, O. O. Akinade, H. A. Owolabi, H. A. Alaka, and M. Pasha. 2016. “Big data in the construction industry: A review of present status, opportunities, and future trends.” *Advanced Engineering Informatics.* [e-journal] 30 (3), pp. 500–521. https://doi.org/10.1016/j.aei.2016 .07.001.

Building Transformation, 2022. *Construction 4.0.* [online] Available at: < https://www.buildingtransformations.org/articles/construction-4-0> [Accessed 7 July 2022].

BuildOps, 2022. *Activate Your Data，The Most Popular Analytics, Business Intelligence, & Insights Tools in 2022.* [online] Available at: <https://21610950.fs1.hubspotusercontent-na1.net/hubfs/21610950/BuildOps-The-Most-Popular-Analytics-BI-and-Insights-Tools-in-2022.pdf> [Accessed 3 April 2023].

Chia, F. C., 2019. *2.4 Digital Consturction*. Lecture Slide.

Chia, F. C., Tung, Y. H., Felicia Yong, Y. Y., 2021. EXPLORING THE USAGE OF DIGITAL TECHNOLOGIES FOR CONSTRUCTION PROJECT MANAGEMENT. *Journal of the Malaysian Institute of Planners.* 19(3), pp. 13-22. https://doi.org/10.21837/pm.v19i17.983

Chu, J., 2021. *New Algorithm Trains Drones to Fly Around Obstacles at High Speeds.* [online] Available at: <https://scitechdaily.com/new-algorithm-trains-drones-to-fly-around-obstacles-at-high-speeds/> [Accessed 18 July 2022].

CIDB, 2020. *Construction 4.0 Strategic Plan (2021-2025).* [online] Available at:<https://www.cream.my/my/media/com_eshop/attachments/Construction%204.0%20Strategic%20Plan%202021-2025.pdf> [Accessed 7 July 2022].

Culbert, D., 2019. *How advancing technology will affect construction workers.* [Online] Available at: <https://www.pbctoday.co.uk/news/planning-construction-%20news/technology-construction-workers/54967/> [Accessed 11 July 2022].

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

Dieffenbacher, S. F., 2022. *What is Digital Maturity, How to Measure, Tools & Models*. [online] Available at: <https://digitalleadership.com/blog/digital-maturity/> [Accessed 15 February 2023].

Digital Leadership Ltd., 2023. *Making the most of digital* [online] Available at: < https://digitalmaturity.org/> [Accessed 16 April 2023].

Edirisinghe,R., 2019. Digital skin of the construction site: Smart sensor technologies towards the future smart construction site. *Engineering, Construction and Architectural Management*, [e-journal] 26(2), pp. 184–223. https://doi.org/10.1108/ECAM-04-2017-0066

Ellis, G., 2020. *3D Printing in Construction: Growth, Benefits, and Challenges*. [online] Available at: https://constructionblog.autodesk.com/3d-printing-construction/ [Accessed 18 July 2022].

Fedorov, V. F. and Stolyar, V. L., 2022. Digital Transformation is a Way to Increase the Effectiveness of Personal Telemedicine. *24th International Conference on Digital Signal Processing and its Applications (DSPA), :1-6 Mar, 2022.*

Firican, G., 2022. *The history of big data*. [online] Available at: <https://www.lightsondata.com/the-history-of-big-data/> [Accessed 18 July 2022].

Galloway, A., 2005. *Non-Probability Sampling*. [online] Available at: <https://www.sciencedirect.com/topics/computer-science/convenience-sampling> [Accessed 18 August 2022].

Gamage, A. N. K. K. 2021. Study of Challenges in Implementing Digital Transformation in Construction Projects.*International Journal of Progressive Sciences and Technologies (IJPSAT)*. 30 (Dec): 350-363.

Gillis, A. S., 2022. *Algorithm*. [Online] Available at: <https://www.techtarget.com/whatis/definition/algorithm> [Accessed 11 July 2022].
GSMA, 2022. *How 5G could help transform construction*. [online] Available at: <https://www.gsma.com/5GHub/construction> [Accessed 4 July 2022].

Glodon, 2022. *The Evolving Role of Quantity Surveyors in the Digital Age.* [onlien] Available at: <https://www.glodon.com/en/articles/The-Evolving-Role-of-Quantity-Surveyors-in-the-Digital-Age-267> [Accessed 10 April 2023].

Gupta, M. S., 2020. *What is Digitization, Digitalization, and Digital Transformation?* [online] Available at : <https://www.arcweb.com/blog/what-digitization-digitalization-digital-transformation> [Accessed 17 June 2022].

Hamid, Z. A., and Kamar, K. A. M., 2012. *Modernising the Malaysian Construction Industry*. [online] Available at: <https://www.irbnet.de/daten/iconda/CIB_DC24217.pdf> [Accessed 17 June 2022].

Heponiemi, T., Kaihlanen, A. M., Kouvonen, A., Leemann, L. Taipale, S., and Gluschkoff, K., 2022. The role of age and digital competence on the use of online health and social care services: A cross-sectional population-based survey. *Digital Health*. U.S. National Library of Medicine. Available at: https://doi.org/10.1177/20552076221074485 [Accessed10 April 2023].

IBM, 2020. *What is edge computing?* [Online] Available at: <https://www.ibm.com/cloud/what-is-edge-computing> [Accessed 9 July 2022].

Ibrahim, F.S.B., Ebekozien, A., Khan, P.A.M., Aigbedion, M., Ogbaini, I.F. and Amadi, G.C., 2022. Appraising fourth industrial revolution technologies role in the construction sector: how prepared is the construction consultants?, *Facilities*, 40(7/8), pp. 515-532.

IDC, 2022. *Worldwide Digital Transformation Investments Forecast to Reach $1.8 Trillion in 2022, According to New IDC Spending Guide.* [online] Available at: <https://www.idc.com/getdoc.jsp?containerId=prUS49114722> [Accessed 13 August 2022].

Ismail, N., 2019. *Digital transformation in the construction industry: is an AI revolution on the way?*. [online] Available at: <https://www.information-age.com/digital-transformation-construction-industry-123484133/> [Accessed 18 June 2022].

Jacobsson, M., and Linderoth, H. C. J., 2021. Newly graduated students' role as ambassadors for digitalisation in construction firms, *Construction Management and Economics*, [e-journal] 39(9), pp. 759-772, DOI: 10.1080/01446193.2021.1955398

Johnson, A., 2019. Impact of big data on construction equipment. [Online] Available at: <https://www.pbctoday.co.uk/news/digital-construction/bim-news/big-data-construction-equipment/58173/> [Accessed 8 July 2022].

Jones, K. 2022. *Robots Are Coming to the Construction Site.* [online] Available at: https://www.constructconnect.com/blog/construction-robotics [Accessed 17 July 2022].

Jordan, A., 2022. *Are You Truly Transforming Digitally…or Just Digitizing?* [online] Available at: <https://www.projectmanagement.com/articles/796648/are-you-truly-transforming-digitally-or-just-digitizing-?PMIwelcome=1&regComplete=1> [Accessed 13 August 2022].

Jordan, A., 2022. *Digital Ethics and the Project Manager.* [online] Available at: <https://www.projectmanagement.com/articles/796652/digital-ethics-and-the-project-manager> [Accessed 13 August 2022].

Kalichman, M., 2010. *Introduction: What is Research Ethics?* [online] Available at: <https://onlineethics.org/cases/resources-research-ethics-education/introduction-what-research-ethics> [Accessed 18 August 2022].

Keane, P., 2018. *Generative Design: The Road to Production*. [Online] Available at: <https://www.engineering.com/story/generative-design-the-road-to-production> [Accessed 12 July 2022].

Khan, R. A., Liew, M. S., and Ghazali, Z. B., 2014. *Malaysian Construction Sector and Malaysia Vision 2020: Developed Nation Status.* [online] Available at:<https://www.sciencedirect.com/science/article/pii/S1877042813051306?via%3Dihub> [Accessed 16 June 2022].

Knight, W., 2020. *Robots Invade the Construction Site.* [online] Available at: https://www.wired.com/story/robots-invade-construction-site/ [Accessed 17 July 2022].

Koeleman, J.,Ribeirinho, M. J.,Rockhill, D., Sjödin, E. and Strube, G., 2019. *Decoding digital transformation in construction*. [online] Available at: <https://www.mckinsey.com/business-functions/operations/our-insights/decoding-digital-transformation-in-construction> [Accessed 28 June 2022].

Koutsogiannis, A., 2019. Online assessment measures digital maturity of construction businesses. [Online] Available at: <http://www.bimplus.co.uk/analysis/online-assessment-measures- digital-maturity-constr/> [Accessed 27 July 2022].

Kozlovska, M., Klosova, D., and Strukova, Z., 2021. Impact of Industry 4.0 Platform on the Formation of Construction 4.0 Concept: A Literature Review, *Sustainability*, [e-journal] 13(5), pp. 2683. https://doi.org/10.3390/su13052683

Lazaro-Aleman, W., Manrique-Galdos, F., Ramirez-Valdivia, C., Raymundo-Ibañez, C., and Moguerza, J. M. 2020. "Digital Transformation Model for the Reduction of Time Taken for Document Management with a Technology Adoption Approach for Construction SMEs," *2020 9th International Conference on Industrial Technology and Management (ICITM)*, pp. 1-5, doi: 10.1109/ICITM48982.2020.9080390.

Lee, P., 2018. *The Future of Construction - Embracing Technology and Innovation*. [online] Available at: <https://www.lexology.com/library/detail.aspx?g=146ad57e-cc21-45c3-8c97-0696bab98d77> [Accessed 27 June 2022].

LetsBuild, 2019. *How digital technology is changing the construction industry.* [Online] Available at: <https://www.letsbuild.com/blog/how-digital-technology-is-changing-the-construction-industry> [Accessed 10 July 2022].

Li, X., W. Yi, H.-L. Chi, X. Wang, and A. P. C. Chan. 2018. "A critical review of virtual and augmented reality (VR/AR) applications in construction safety." *Automation in Construction.* [e-journal] 86 (Feb): pp. 150–162. https://doi.org/10 .1016/j.autcon.2017.11.003.

Li, Y., Sun, H., Li, D., Song, J., and Ding, R., 2022. Effects of Digital Technology Adoption on Sustainability Performance in Construction Projects: The Mediating Role of Stakeholder Collaboration, *Journal of Management in Engineering*, 38(3), pp. 1-12.

Liu, P., Chen, A. Y., Huang, Y. N., Han, J. Y., Lai, J. S., Kang,S.C., 2014. A Review of Rotorcraft Unmanned Aerial Vehicle (UAV) Developments and Applications in Civil Engineering. *Smart Structures and Systems*, 13(6), pp. 1065–1094.

Lundblad, P., 2018. *How 5G will Transform Construction Machines*. [Online] Available at: <https://www.machinedesign.com/industrial-automation/how-5g-will-transform-construction-machines> [Accessed 8 July 2022].

Malaysia Productivity Corporation, 2022. *Productivity Report 2022.* [online] Available at: <https://www.mpc.gov.my/static_files/media_manager/37/PRODUCTIVITY%20REPORT%202022.pdf> [Accessed 5 August 2022].

Manzoor, B., Othman, I., and Pomares, J.C., 2021. Digital Technologies in the Architecture, Engineering and Construction (AEC) Industry-A Bibliometric-Qualitative Literature Review of Research Activities, *International journal of environmental research and public health*, 18(11), pp. 6135.

Massey, L., 2021. *Common Challenges in Construction Data Management and How to Overcome Them.* [online] Available at: <https://www.structionsite.com/blog/challenges-in-construction-data-management> [Accessed 10 April 2023].

McKinsey & Company, 2019. *Why do most transformations fail? A conversation with Harry Robinson.* [online] Available at: <https://www.mckinsey.com/business-functions/transformation/our-insights/why-do-most-transformations-fail-a-conversation-with-harry-robinson> [Accessed 13 August 2022].

McKinsey & Company, 2020. *The next normal in construction*. [online] Available at: <https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/The%20next%20normal%20in%20construction/The-next-normal-in-construction.pdf> [Accessed 22 June 2022].

Mcleod, S., 2023. *What Is The Central Limit Theorem In Statistics*? [online] Available at: <https://simplypsychology.org/central-limit-theorem.html> [Accessed 20 March 2023].

Meno, T., 2020. A*N ASSESSMENT OF RISK ASSOCIATED WITH DIGITALISATION IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY*. [online] Available at: <DISSERTATION o Attribution - COPYRIGHT AND CITATION ...https://ujcontent.uj.ac.za › Download › SOURCE1> [Accessed 27 June 2022].

Mertiri, S., 2018. *Digital Transformation in the IT Solutions sector*. [online] Available at: <https://www.diva-portal.org/smash/get/diva2:1266387/FULLTEXT01.pdf> [Accessed 7 August 2022].

Michel, K., 2021. *Building A Better Future with Edge Computing.* [Online] Available at: <https://www.ccr-mag.com/building-a-better-future-with-edge-computing/> [Accessed 9 July 2022].

Mills, F. (2016). *What is Digital Construction*. [Online] Available at: <https://www.theb1m.com/video/what-is-digital-construction> [Accessed 10 July 2022].

Ministry of Works, 2021. National Construction Policy 2030. [online] Available at: <https://www.kkr.gov.my/public/Dasar%20Pembinaan%20Negara%20NCP2030.pdf> [Accessed 18 July 2022].

Miorandi, D., Sicari, S., De Pellegrini, F., and Chlamtac, I., 2012. Internet of things: Vision, applications and research challenges, *Ad Hoc Networks*, [e-journal] 10(7), pp. 1497-1516. https://doi.org/10.1016/j.adhoc.2012.02.016

Moses, T., Heesom, D. and Oloke, D., 2020. Implementing 5D BIM on construction projects: contractor perspectives from the UK construction sector. *Journal of Engineering, Design and Technology,* [e-journal] 18(6), pp. 1867-1888. https://doi-org.libezp2.utar.edu.my/10.1108/JEDT-01-2020-0007

Musarat, M. A., Hameed, N., Altaf, M., Alaloul, W. S., Salaheen, M. A., Alawag, A. M., 2021. Digital Transformation of the Construction Industry: A Review. *2021 International Conference on Decision Aid Sciences and Application (DASA)*, 897-902 Dec, 2021.

Nnaji, C., and Karakhan, A. A., 2020. Technologies for safety and health management in construction: Current use, implemen- tation benefits and limitations, and adoption barriers. *Journal of Building Engineering*, *29*, 101212.

Olanipekun, A., Sutrisna, M., Facilitating Digital Transformation in Construction—A Systematic Review of the Current State of the Art. *Frontiers in Built Environment*, Vol 7 (2021).

Oesterreich, T. D., and Teuteberg. F., 2016. “Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangu- lation approach and elements of a research agenda for the construction industry.” *Computers in Industry*. [e-journal] 83 (Dec), pp. 121–139. 10.1016/j.compind.2016.09.006.

Olawumi, T.O., Chan, D.W., Wong, J.K., and Chan, A.P., 2018. Barriers to the integration of BIM and sustainability practices in **construction** projects: A Delphi survey of international experts, *Journal of Building Engineering*, 20, pp. 60-71.

Oracle, 2022. *What is Big Data?* [Online] Available at: <https://www.oracle.com/my/big-data/what-is-big-data/> [Accessed 8 July 2022].

Osunsanmi, T. O., Aigbavboa, C. & Oke, A., 2018. Construction 4.0: The Future of the Construction. World Academy of Science, Engineering and Technology, 12(3), p. 206.

Parusheva, S., 2019. *Digitalization and Digital Transformation in Construction – Benefits and Challenges*. INFORMATION AND COMMUNICATION TECHNOLOGIES BUSINESS AND EDUCATION Proceedings of the International Conference dedicated to the 50th anniversary of the Department of Informatics. Varna, Bulgaria, October 2019. Vrana: University of Economics.

Patel, P., 2019. *How 3-D Printing Could Break into the Building Industry*. [Online] Available at: <https://www.scientificamerican.com/article/how-3d-printing-could-break-into-the-building-industry/> [Accessed 22 June 2022].

Pritchard, S., 2020. Computational storage: What is it and what are its key use cases? [online] Available at: https://www.computerweekly.com/feature/Computational-storage-What-is-it-and-what-are-its-key-use-cases [Accessed 17 July 2022].

Radley, S., 2019. *Digitalisation in construction: The path ahead*. [Online] Available at: <https://www.pbctoday.co.uk/news/planning-construction-news/digitalisation-in-construction/56536/> [Accessed 27 June 2022].

Rao, S., 2019. The Benefits of AI In Construction. [Online] Available at: <https://constructible.trimble.com/construction-industry/the-benefits-of-ai-in-construction> [Accessed 8 July 2022].

Rausch, C., Sanchez, B., Esfahani, M. E., and Haas, C., 2020. *Computational Algorithms for Digital Twin Support in Construction*. [Online] Available at: <https://www.researchgate.net/publication/343083751_Computational_Algorithms_for_Digital_Twin_Support_in_Construction> [Accessed 12 July 2022].

Rebuilding Humanity, 2021. *Drones in Construction: What does it mean for the Industry?* [online] Available at: <https://27.group/drones-in-construction-what-does-it-mean-for-the-industry-2/> [Accessed 22 June 2022].

Rhumbix, 2021. *How Technology in Construction is Revolutionizing the Industry*. [Online] Available at: <https://www.rhumbix.com/how-technology-in-construction-is-revolutionizing-the-industry/> [Accessed 22 June 2022].

RICS, 2020. *The future of BIM: Digital transformation in the UK construction and infrastructure sector.* [online] Available at: <https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/construction/future-of-bim_1st-edition.pdf> [Accessed 12 August 2022].

Saunders, M., 2016. Research Methods for Business Students, ed. 2016. Italy: Pearson. pp. 162-166.

Sebastian, I.M., Ross, J.W., Beath, C., Mocker, M. , Moloney, K.G., Fo nstad, N.O., 2017. How Big Old Companies Navigate Digital Transformation, *MIS Quarterly Executive,* 16(3), pp. 197-213.

Singtel, 2021. *First batch of public sector 5G trials at Sentosa underway.* [online] Available at: <https://www.singtel.com/about-us/media-centre/news-releases/first-batch-of-public-sector-5g-trials-at-sentosa-underway> [Accessed 4 July 2022].

Sivarajah, U., M. M. Kamal, Z. Irani, and V. Weerakkody. 2017. "Critical analysis of big data challenges and analytical methods." *Journal of Business Research*. [e-journal] 70 (Jan): pp.263–286. https://doi.org/10.1016/j.jbusres.2016.08.001.

Sommer, A., 2021. *What is Construction 4.0 and is the industry ready ?* [online] Available at: < https://blogs.oracle.com/construction-engineering/post/what-is-construction-40-and-is-the-industry-ready> [Accessed 30 July 2022].

Sweet, R., 2022. *What could we do with bigger data pipes? Singapore tests a 5G construction site*. [online] Available at: <https://www.globalconstructionreview.com/what-could-we-do-with-bigger-data-pipes-singapore-tests-a-5g-construction-site/> [Accessed 4 July 2022].

Talamo, C., and Bonanomi, M. M., 2019. *The Impact of Digitalization on Processes and Organizational Structures of Architecture and Engineering Firms*. [online] Available at: <https://link.springer.com/chapter/10.1007/978-3-030-33570-0_16> [Accessed 7 August 2022].

Team, G.C., 2022. *What is Construction 4.0?* [online] Available at: <https://www.goconstruct.org/why-choose-construction/whats-happening-in-construction/what-is-construction-40/> [Accessed 7 July 2022].

Technology, H., 2022. *Computing power for smart building*. [Online] Available at: <https://www.hattelandtechnology.com/blog/computing-power-for-smart-building> [Accessed 9 July 2022].

The Star, 2021. *Digital-savvy Quantity Surveyors*. [online] Available at: < https://cdn.thestar.com.my/Content/StarPicks/Issues/CE757AD9-3851-457E-8B1E-221D5C772620.pdf> [Accessed 10 April 2023].

Tras, P., 2015. *Effective use of Big data analysis in consulting business*. [online] Available at: < https://www.linkedin.com/pulse/effective-use-big-data-analysis-consulting-business-priyanka-tras/> [Accessed 5 April 2023].

Turner, D. P., 2020. *Sampling Methods in Research Design*. [online] Available at: <https://headachejournal.onlinelibrary.wiley.com/doi/abs/10.1111/head.13707> [Accessed 18 August 2022].

UK Connect, 2021. *How 5G is helping digital transformation in the construction sector*.[Online] Available at: https://ukconnect.com/5g-helping-digital-transformation-in-the-construction-sector/ [Accessed 15 July 2022].

Wade, A., 2018. *Digital builds: The technology taking construction to the next level.* [Online] Available at: <https://www.theengineer.co.uk/digital-construction-technology/> [Accessed 30 July 2022].

Wakefield, K., 2022. *A guide to the types of machine learning algorithms and their applications*. [Online] Available at: <https://www.sas.com/en_gb/insights/articles/analytics/machine-learning-algorithms.html> [Accessed 12 July 2022].

Webster, G.A., 2021. *Construction in a Digital World, KPMG.* Available at: <https://kpmg.com/ca/en/home/insights/2021/05/construction-in-a-digital-world.html> [Accessed 5 April 2023].

Werdmuller, N., 2020. *Computational Storage is bringing processing closer to the data.* [online] Available at: https://community.arm.com/arm-community-blogs/b/internet-of-things-blog/posts/computational-storage-is-bringing-processing-closer-to-the-data [Accessed 15 July 2022].

Woodhead, R., Stephenson, P. and Morrey, D., 2018. "Digital construction: From point solutions to IoT ecosystem," *Automation in Construction*, vol. 93, pp. 35-46.

World Economic Forum, 2016. *Shaping the Future of Construction A Breakthrough in Mindset and Technology.* [Online] Available at: <https://www3.weforum.org/docs/WEF_Shaping_the_Future_of_Construction_full_report__.pdf> [Accessed 11 July 2022].

Yahya, M. Y. Bin, Yin, L. H.., Yassin, A. M., Omar,R., Robin, R. O. A., and Kasim,N., 2019. The challenges of the implementation of construction robotics technologies in the construction. In *International Conference on Built Environment and Engineering 2018 – "Enhancing Construction Industry through IR4.0" (IConBEE 2018)*, MATEC Web of Conferences, Johor, Malaysia, 05012.

Yap, J. B. H., Lam, C. G. Y., Skitmore, M., and Talebian, M., 2021. BARRIERS TO THE ADOPTION OF NEW SAFETY TECHNOLOGIES IN CONSTRUCTION: A DEVELOPING COUNTRY CONTEXT, *Journal of Civil Engineering and Management,* 28(2), pp. 120-133.

Zabidin, N.S., Belayutham, S., and Ibrahim, K.I., 2020. A Bibliometric and scientometric mapping of Industry 4.0 in construction, *Journal of Information Technology in Construction*, [e-journal] 25, pp. 287–307. https://dx.doi.org/10.36680/j.itcon.2020.017

APPENDICES

APPENDIX A: Questionnaire

Examine Digital Transformation in the Malaysian Construction Industry

Dear Sir/Madam/Mr/Ms,

Good day !

I'm a final year student from Bachelor of Science (Hons) Quantity Surveying in Universiti Tunku Abdul Rahman (UTAR). I wish to invite you to participate in my final year project entitled "Examine Digital Transformation in the Malaysian Construction Industry".

This questionnaire consists of 4 sections which may take you 10-15 minutes to complete.
Section A: Digital Infrastructure
Section B: Digital Maturity
Section C: Challenge Encountered
Section D: Demographic data

Your contribution to this research is much appreciated. Thank you very much for your time to fill up this questionnaire as every single contribution would greatly mean a lot to this study. All the information that provided will be strictly keep private and confidential, without reveal to any third parties without consent. The information which includes personal information will be only used for this research study. Participant is voluntary participate in this research study, and you are allowed to withdraw your participation from this research study anytime. Participant may be contacted through the email provided if the information given has certain errors or issues.

Lastly, a copy of response will be delivered to the email that you provided.

If you have any inquiries, please do not hesitate to contact me at kaiwen883281@1utar.my.

Thank you.

Yours faithfully,

Tan Kai Wen

Bachelor of Science (Hons) Quantity Surveying

Universiti Tunku Abdul Rahman (UTAR) Sungai Long Campus

Section A: Digital Infrastructure

Do you use the following digital technology in your organisation?

Please find the indicator of each scale as follow:

1 - Don't know

2 - Never use

3 - Expect to use in 5 years

4 - Expect to use in 3 years

5 - Use it now

	1	2	3	4	5
Mobile Technology (eg. Laptop/Tablet)					
QR Code System					
Barcode System					
Fingerprint Detection					
Face ID Recognition					
Collaboration Tools (eg. Microsoft Team/ Zoom)					
Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)					
Project Management Software (eg. Primavera/ Microsoft Project)					
Estimation Software (eg. CostX)					
Sensing Technology (eg. IoT Sensor)					
Wearable Technology (eg. Smart Glasses)					
360-degree On-Site Monitoring Tool					
3-D scanners or laser distance and ranging (LADAR)					
Light detection and ranging (LiDAR)					
Semi-Autonomous Robot (eg. SAM)					
Additive Manufacturing (eg. 3D printing)					

Unmanned Aerial Vehicle/Drone	
Augmented Reality (AR)	
Virtual Reality (VR)	
Cloud-based Storage (eg. Google Drive)	
Building Information Modelling (BIM) technology	
Artificial Intelligence Technology (eg. AI-powered generative design for design purpose)	
Artificial Intelligence Technology (eg. AI-powered robots equipped with cameras for site operation)	
Digital Twins (eg. Digital replica of building)	

Section B: Digital Maturity

To what extent do you agree with the following statements?

Please find the indicator of each scale as follow:

1 - Strongly Disagree

2 - Disagree

3 - Neutral

4 - Agree

5 - Strongly Agree

	1	2	3	4	5
There's no clear digital leadership at any level					
The digital lead is confined to a mostly tactical role					
The digital lead is encouraged to be strategic, when time allows					
A senior digital lead exists, and digital leadership is actively invested in					
Digital is an integral part of the overall strategy and digital leadership is present at all levels					
Staff are wary of digital and try to avoid it					
Staff are happy that specialists are dealing with digital					
My organisation understand the value of digital and wants to learn more					
Digital is seen as key to success and incorporated into everything					
Digital is the principal way to achieve company's mission					

Project management is done differently for different projects	
Some common project management principles are used	
Projects are managed through a structured but often lengthy process	
Agile project management principles and practice are used. There is a launch, test and improve approach	
Agile principles of digital project management are consistently used in all projects	
Data in the organisation is scattered and mainly about offline activity	
Quality and use of data in the organisation is improving in some areas	
There’s a clear policy for data management (eg. Data is integrated and analysed)	
My organisation use quality, integrated data across the company	
My organisation use live data to shape decisions and performance	
Systems are limited in scope and aren’t integrated	
Systems aren’t keeping up with the needs of the organisation	
Systems are stable and enable basic operations	
Tools and systems are delivering improvements in effectiveness	

Interconnected tools and systems provide a smooth internal and external user experience	

Section C: Challenge Encountered

Digital transformation process involves major shifting in the business model, structure, and process with the integration of digital technology. However, the process of digitalisation throughout the construction sector is still relatively slow.

Please share your ideas/ experience in the following questions.

C1) What is the biggest challenge for your organisation to digitise the construction process?

C2) Do you think digital transformation is necessary in the construction industry? Why?

Section D: Demographic Information

In this section, your personal information will be collected.

Please choose only 1 answer that most suit you from each question in this section.

D1) Which of the following best describes your company's business activities?

- Developer
- Contractor
- Consultant
- Sub-Contractor
- Supplier
- Other:

D2) Which of the following best described your profession?

- Architect

- Quantity Surveyor
- Civil or Structural Engineer
- Mechanical or Electrical Engineer
- Chartered Builder
- Other:

D3) For how many years have you been working in construction industry?

- Less than 2 years
- 2-5 years
- 6-10 years
- 11-20 years
- More than 20 years

Consent of Participation

By clicking submit of the online questionnaire, you are indicating that:

1) You understand that if you have any additional questions, you can contact kaiwen883281@1utar.my

2) You understand that Privacy Notice of UTAR is available at https://www2.utar.edu.my/PrivacyNotice_English.jsp

3) You understand that you can contact the Research Ethics Officers at +603 9086 0288 or aswini@utar.edu.my

4) You agree to participate in this survey voluntarily

APPENDIX B: Friedman Test of Digital Infrastructure Available in the Construction Organization

Ref Code	Digital Infrastructure	Mean Rank	Chi-Square	Asymp. Sig.
	Tools			
A1	Mobile Technology (eg. Laptop/Tablet)	9.15	556.355	0.000
A15	Semi-Autonomous Robot (eg. SAM)	5.97		
A17	Unmanned Aerial Vehicle/Drone	5.90		
A16	Additive Manufacturing (eg. 3D printing)	5.79		
A10	Sensing Technology (eg. IoT Sensor)	5.64		
A13	3-D scanners or laser distance and ranging (LADAR)	4.80		
A14	Light detection and ranging (LiDAR)	4.71		
A23	Artificial Intelligence Technology (eg. AI-powered robots equipped with cameras for site operation)	4.52		
A11	Wearable Technology (eg. Smart Glasses)	4.27		
A12	360-degree On-Site Monitoring Tool	4.24		
	Software			
A6	Collaboration Tools (eg. Microsoft Team/ Zoom)	10.62	607.064	0.000
A7	Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)	10.26		
A20	Cloud-based Storage (eg. Google Drive)	9.28		
A21	Building Information Modelling (BIM) technology	8.58		
A4	Fingerprint Detection	8.13		
A8	Project Management Software (eg. Primavera/ Microsoft Project)	7.64		

A2	QR Code System	7.38
A9	Estimation Software (eg. CostX)	7.23
A5	Face ID Recognition	7.02
A22	Artificial Intelligence Technology (eg. AI-powered generative design for design purpose)	6.91
A3	Barcode System	6.49
A19	Virtual Reality (VR)	5.48
A18	Augmented Reality (AR)	5.35
A24	Digital Twins (eg. Digital replica of building)	4.64

APPENDIX C: Friedman Test of Digital Maturity of the Construction Organisation

Ref Code	Statements	Mean Rank	Chi-Square	Asymp. Sig.
	Strategy			
B2	The digital lead is confined to a mostly tactical role	3.42	130.535	0.000
B3	The digital lead is encouraged to be strategic, when time allows	3.35		
B4	A senior digital lead exists, and digital leadership is actively invested in	3.09		
B5	Digital is an integral part of the overall strategy and digital leadership is present at all levels	2.97		
B1	There's no clear digital leadership at any level	2.17		
	Culture			
B7	Staff are happy that specialists are dealing with digital	3.56	159.841	0.000
B8	My organisation understand the value of digital and wants to learn more	3.40		
B10	Digital is the principal way to achieve company's mission	2.99		
B9	Digital is seen as key to success and incorporated into everything	2.96		
B6	Staff are wary of digital and try to avoid it	2.08		
	Operations			
B12	Some common project management principles are used	3.63	116.265	0.000

B13	Projects are managed through a structured but often lengthy process	3.28		
B14	Agile project management principles and practice are used. There is a launch, test and improve approach	3.03		
B15	Agile principles of digital project management are consistently used in all projects	2.69		
B11	Project management is done differently for different projects	2.36		
	Data			
B17	Quality and use of data in the organisation is improving in some areas	3.36	104.967	0.000
B18	There’s a clear policy for data management (eg. Data is integrated and analysed)	3.32		
B19	My organisation use quality, integrated data across the company	3.12		
B20	My organisation use live data to shape decisions and performance	2.99		
B16	Data in the organisation is scattered and mainly about offline activity	2.21		
	Technology			
B23	Systems are stable and enable basic operations	3.58	152.416	0.000
B24	Tools and systems are delivering improvements in effectiveness	3.42		
B25	Interconnected tools and systems provide a smooth internal and external user experience	3.21		

B21	Systems are limited in scope and aren’t integrated	2.48
B22	Systems aren’t keeping up with the needs of the organisation	2.32

APPENDIX D: Differences of Digital Infrastructure Available in The Organisation According to Business's Activities

No	Null Hypothesis	Mean Rank					Sig.
		Property Development	**Contracting Business**	**Consultancy Service**	**Sub-Contracting**	**Supplying Business**	
A4	Fingerprint Detection	115.00	96.81	115.21	75.27	97.10	0.010
A6	Collaboration Tools (eg. Microsoft Team/ Zoom)	112.08	91.58	112.75	93.27	93.65	0.043
A7	Data Analyst Tools/Software (eg. Microsoft Excel/ Apache Spark)	108.53	79.18	114.62	100.76	105.05	0.004
A8	Project Management Software (eg. Primavera/ Microsoft Project)	114.03	93.65	117.26	76.23	98.15	0.008
A9	Estimation Software (eg. CostX)	109.00	87.46	121.65	76.12	104.82	0.001
A18	Augmented Reality (AR)	92.84	96.27	123.67	82.41	97.37	0.005
A19	Virtual Reality (VR)	100.64	93.56	123.84	83.85	91.68	0.005
A20	Cloud-based Storage (eg. Google Drive)	107.88	96.13	115.22	73.95	106.89	0.006
A21	Building Information Modelling (BIM) technology	97.34	96.82	125.26	77.95	93.65	0.001

A22	Artificial Intelligence Technology (eg. AI-powered generative design for design purpose)	104.34	95.23	119.78	80.38	96.55	0.020
A24	Digital Twins (eg. Digital replica of building)	98.39	93.54	119.93	83.29	101.94	0.028

APPENDIX E: Differences of Digital Infrastructure Available in The Organisation According to Professions

No	**Null Hypothesis**	**Mean Rank**					**Sig.**
		Architect	**Quantity Surveyor**	**C & S Engineer**	**M & E Engineer**	**Chartered Builder**	
A2	QR Code System	107.26	112.36	98.92	106.54	95.79	0.017
A3	Barcode System	106.34	115.63	97.61	108.25	91.96	0.010
A4	Fingerprint Detection	110.50	120.98	90.81	99.75	92.41	0.018
A8	Project Management Software (eg. Primavera/ Microsoft Project)	114.32	112.88	87.15	111.29	90.22	0.020
A9	Estimation Software (eg. CostX)	105.12	125.30	91.11	113.82	83.18	0.000
A18	Augmented Reality (AR)	122.64	114.57	93.92	105.07	80.21	0.001
A19	Virtual Reality (VR)	115.26	115.29	93.23	107.60	85.82	0.005
A21	Building Information Modelling (BIM) technology	104.54	128.59	87.23	95.26	97.29	0.002
A22	Artificial Intelligence Technology (eg. AI-powered generative design for design purpose)	118.89	110.51	96.70	99.28	96.08	0.004
A24	Digital Twins (eg. Digital replica of building)	119.26	117.21	92.30	101.08	86.05	0.005

APPENDIX F: Differences of Digital Maturity According to Business's Activities

No	Null Hypothesis	Mean Rank					Sig.
		Property Development	Contracting Business	Consultancy Service	Sub-Contracting	Supplying Business	
B1	There's no clear digital leadership at any level	109.28	78.23	119.18	88.95	109.77	0.002
B3	The digital lead is encouraged to be strategic, when time allows	102.02	80.57	120.91	95.32	103.63	0.008
B4	A senior digital lead exists, and digital leadership is actively invested in	103.66	75.50	121.05	92.08	112.98	0.001
B5	Digital is an integral part of the overall strategy and digital leadership is present at all levels	95.28	78.81	125.24	90.89	109.92	0.001
B6	Staff are wary of digital and try to avoid it	92.66	81.39	118.34	85.92	126.84	0.000
B7	Staff are happy that specialists are dealing with digital	117.66	88.86	109.99	111.42	77.94	0.011
B8	My organisation understand the value of digital and wants to learn more	106.55	80.69	119.68	102.44	93.50	0.010
B9	Digital is seen as key to success and incorporated into everything	90.77	84.34	119.82	95.48	111.27	0.013

B10	Digital is the principal way to achieve company's mission	102.25	80.78	121.93	91.86	104.84	0.005
B11	Project management is done differently for different projects	100.92	82.55	113.08	87.23	124.97	0.005
B13	Projects are managed through a structured but often lengthy process	89.98	82.69	123.79	100.98	101.35	0.004
B14	Agile project management principles and practice are used. There is a launch, test and improve approach	94.70	76.56	129.57	91.52	105.24	0.000
B15	Agile principles of digital project management are consistently used in all projects	95.16	75.35	123.72	98.11	110.56	0.000
B16	Data in the organisation is scattered and mainly about offline activity	89.89	85.53	123.66	89.82	109.19	0.003
B18	There's a clear policy for data management (eg. Data is integrated and analysed)	99.53	84.88	117.21	86.32	116.05	0.011
B19	My organisation use quality, integrated data across the company	99.86	82.71	122.80	88.59	106.18	0.004

B20	My organisation use live data to shape decisions and performance	101.17	88.98	121.11	83.85	103.32	0.015
B21	Systems are limited in scope and aren't integrated	99.27	76.38	117.59	86.89	128.15	0.000
B22	Systems aren't keeping up with the needs of the organisation	102.34	77.80	112.24	95.97	123.11	0.004
B23	Systems are stable and enable basic operations	94.16	83.16	118.10	108.03	99.47	0.026
B24	Tools and systems are delivering improvements in effectiveness	94.41	77.19	127.43	86.30	114.13	0.000
B25	Interconnected tools and systems provide a smooth internal and external user experience	97.91	81.07	123.06	89.71	109.05	0.002

APPENDIX G: Differences of Digital Maturity According to Professions

No	Null Hypothesis	Mean Rank					Sig.
		Architect	**Quantity Surveyor**	**C & S Engineer**	**M & E Engineer**	**Chartered Builder**	
B8	My organisation understand the value of digital and wants to learn more	111.86	111.83	103.20	106.83	81.49	0.045
B10	Digital is the principal way to achieve company's mission	106.47	119.05	100.69	111.17	78.08	0.006
B13	Projects are managed through a structured but often lengthy process	93.26	121.06	104.34	114.97	84.21	0.003
B14	Agile project management principles and practice are used. There is a launch, test and improve approach	107.17	126.87	99.68	105.03	75.14	0.001
B15	Agile principles of digital project management are consistently used in all projects	102.50	124.79	101.86	110.57	71.81	0.001

B19	My organisation use quality, integrated data across the company	97.82	116.84	105.89	104.08	94.08	0.031
B20	My organisation use live data to shape decisions and performance	103.50	122.14	100.57	102.06	88.94	0.011
B24	Tools and systems are delivering improvements in effectiveness	97.93	121.76	103.05	104.81	86.46	0.033
B25	Interconnected tools and systems provide a smooth internal and external user experience	95.16	128.51	100.04	102.89	86.24	0.005