LEVERAGE DIGITAL TOOLS IN CONSTRUCTION PROJECT DURING THE PANDEMIC AND TRANSITION TO ENDEMIC

KHOO YEE LENG

UNIVERSITI TUNKU ABDUL RAHMAN

LEVERAGE DIGITAL TOOLS IN CONSTRUCTION PROJECT DURING THE PANDEMIC AND TRANSITION TO ENDEMIC

KHOO YEE LENG

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

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

May 2023

DECLARATION

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

Signature :

Name : KHOO YEE LENG

ID No. : 18UEB03546

Date : 21 MAY 2023

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"LEVERAGE DIGITAL TOOLS IN CONSTRUCTION PROJECT DURING THE PANDEMIC AND TRANSITION TO ENDEMIC"** was prepared by **KHOO YEE LENG** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

Approved by,

Signature : ______________________

Supervisor : Sr LI ZI QIAN

Date : 21 MAY 2023

Signature : ______________________

Co-Supervisor : ______________________

Date : ______________________

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ABSTRACT

The Covid-19 pandemic has wreaked havoc across all sectors, with the construction industry being one of the hardest hits. The escalation of ramifications on construction projects has been noteworthy, highlighting the urgency for further research into the adoption of digital tools during the pandemic and the transition to an endemic phase. However, the majority of prior research have solely focused on the impacts of Covid-19 on the construction industry and the strategies to mitigate them. Thus, the aim of this research is to investigate the adoption of digital tools in the construction project during the Covid-19 pandemic and the transition to the current endemic. The objectives are to identify the types of digital tools leveraged in construction project during the pandemic and the transition to the current endemic, to explore the potentials of digital tools implementation in construction project during the pandemic and the transition to the current endemic and to uncover the barriers of the digital tools adoption in construction project during the pandemic and the transition to the current endemic. This research employed a quantitative research approach utilising questionnaire surveys that were participated by 135 construction practitioners hailing from the Klang Valley area in Malaysia. Through a thorough literature review, ten digital tools, eleven potentials and eleven barriers were identified and further examined in this research. Overall, the top 3 most widely adopted digital tools are Cloud Computing, BIM and Drone. Meanwhile, the top 3 most recognized potentials of these tools are "I adopt cloud computing to promote my project's communication and collaboration", "I adopt BIM to enhance my project's site planning and management" and "I adopt BIM, AR and VR to enhance my project design". However, the finding revealed that there is a moderate correlation between the respondents' recommendation and adoption level of digital tools The low level of adoption may be ascribed to 3 primary barriers, namely lack of top management support, organization culture and substantial initial investment. In short, this research has the potential to advance comprehension of the current level of digital tool adoption and the notable obstacles impeding their implementation, thereby facilitating improved readiness to combat pandemics or unanticipated occurrences in the future.

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LIST OF SYMBOLS / ABBREVIATIONS

3D	Three-Dimensional
4D	Four-Dimensional
AIHA	American Industrial Hygiene Association
ANOVA	Analysis of Variance
AR	Augmented Reality
BIM	Building Information Modelling
BQSM	Board of Quantity Surveyors Malaysia
CAD	Computer-Aided Design
CEO	Chief Executive Officer
CIDB	Construction Industry Development Board
CLT	Central Limit Theorem
CMCO	Conditional Movement Control Order
EMCO	Enhanced Movement Control Order
FMCO	Full Movement Control Order
GDP	Gross Domestic Product
GPS	Global Positioning System
ICT	Information and Communications Technology
ID	Identity / Identification
IoT	Internet of Things
IR 4.0	Fourth Industrial Revolution
MCO	Movement Control Order
NCP 2030	National Construction Policy 2030
PhD	Doctor of Philosophy
PKK	Pusat Khidmat Kontraktor
PPE	Personal Protective Equipment
PWD	Public Works Department
R-CNN	Region-based Convolutional Neural Network
RFID	Radio-Frequency Identification
RMCO	Recovery Movement Control Order
RTLS	Real Time Locating System
SMEs	Small and Medium-Sized Enterprises
SPSS	Statistical Program for the Social Sciences

SSM	Suruhanjaya Syarikat Malaysia
UAV	Unmanned Aerial Vehicle
VC	Video Conferencing
VR	Virtual Reality
WFH	Work From Home
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Chapter 1 is the overview of the research. It covers the background of study, problem statement, research aim and objectives, research methodology and chapter layout.

1.2 Background of Study

The construction industry is one of the most crucial cornerstones of a nation's economic development. This is because its vital contribution to country Gross Domestic Product (GDP), which accounts for 5% to 7 % in the majority of nations (Alaloul, et al., 2021). According to Yap, et al. (2019), the construction industry in Malaysia generates between 3% and 6% of the country's GDP annually. Department of Statistics Malaysia (2022) reported that in the first quarter of 2022, the construction sector had contributed up to 3.6% of Malaysia's GDP. Apparently, the construction industry acts as a critical driver of the nation's economy, thus the development of this sector ought to be regarded gravely.

The construction industry is often plagued with the fragmentation and low productivity. The intricacy nature of construction life cycle has aggravated the need of changing working method. Most construction professionals and academics convinced that digital technology may either directly or indirectly increase construction efficiency (Elrefaey, et al., 2022). With the sophisticated digital technology, the construction industry is gradually digitalising and transitioning toward the Fourth Industrial Revolution (4IR) (Maskuriy, et al., 2019). The essence of IR 4.0 is to provide customizable, smart and integrated building products that enhance the construction productivity, quality and efficiency. According to Hazim (2021), the National Construction Policy 2030 (NCP 2030) is introduced by the Work Ministry to digitalise the Malaysian construction industry. This policy aims to promote the technology application, establish exhaustive guidelines and enhance credibility, invigorate high-quality building environment and create a detailed and people-centred policy via integrating the entire project lifecycle. Apparently, Malaysia government has strong commitment in transforming Malaysian built environment. Besides, in the context of the Covid-19, it might spur a digital revolution in construction sector to cope with the pandemic's underlying issues.

An outbreak of the Covid-19 pandemic in early 2020 has propagated rapidly across the globe, wreaking havoc on almost every sector and locale in the world. It is widely believed that the construction industry was among the most devastated by the epidemic. Due to the high contagious rate and rapid dissemination of coronavirus among people, considerable measures were imposed at both the local and global levels, including limits on large-scale activities and partial or complete lockdown to mitigate the spread of the disease (Leontie, et al., 2022). As reported by Arnold and Romei (2020), the construction activities have plummeted by 60 to 70% due to an unprecedented shutdown induced by the surge of coronavirus spreading in Southern Europe.

Nevertheless, these actions had a substantial influence on construction progress, resulting in the increment of unemployment, project time and costs overrun, contractual disputes and others that significantly deteriorated economic activities (Ebekozien and Aigbavboa, 2021). In terms of initial Covid-19 pandemic's unemployment rate, the United States (US) peaked at roughly 14.7% unemployment rate in April 2020 (Bureau of Labour Statistics, 2020), United Kingdom (UK) jobless rate was 3.9% for the first three months of 2020 (Goodman and Aldrick, 2022), while China's unemployment rate peaked at 6.2% in the early of the Covid-19 pandemic (Hoskins, 2022). Aiming to curb the Covid-19 virus transmission jeopardizing the construction industry, World Health Organisation (2020) and World Bank (2020) have suggested the procedures such as remote working, social distancing for labours on-site, appropriate personal protective equipment (PPE), handwashing or sanitization. In this regard, the federal government has imposed Malaysia Government Movement Control Order (MCO) to against the Covid-19 pandemic onslaught in early 2020. Most businesses and sectors have been prohibited, excluding stores selling necessities such as supermarkets and grocery stores (Rahim, 2020). Thus, all construction works were forbidden, except for critical construction work and periodic inspection as well as maintenance of infrastructure works with the maximum of 60% worker capacity (The Star, 2021). Consequently, Minister of Work Department anticipated the construction industry lost RM 24 billion from MCO 1.0, from March to June 2020 (Jalil, 2021).

These above reports advocated the need of leveraging digital tools to alleviate the circumstances. These innovations enable construction sites to effortlessly comply with the Covid-19 regulations, assuring continuous construction progress and personnel's safety and health (Akmam, et al., 2021).

1.3 Problem Statement

In line with the outbreak of Covid-19, there is an exponential growth of issues influencing the built environment. It is not surprising that the studies explored the ramifications and strategies to mitigate the adverse effects of the pandemic on the building construction projects have been initiated (Biswas, et al., 2021; Pamidimukkala and Kermanshachi, 2021; Zamani, et al., 2021; Hatoum, et al., 2021; Oladimeji, 2022). Owing to vast spectrum of negative impacts of pandemic on the construction sector, some studies have focused particularly on the variables affecting delivery of safety and health as well as effective solutions to address these concerns (Krishnan, et al., 2021; Pamidimukkala and Kermanshachi, 2021; Chigara and Moyo, 2022). The other related studies by Yusuf, et al. (2021) and Elrefaey, et al. (2022) assess the critical factors influencing the project operational performance and productivity during the pandemic. In contrast, Esa, et al. (2020) and Ogunnusi, et al. (2021) have underlined the positive impacts of Covid-19 pandemic in initiating better construction practices and promoting construction business as well as health and safety.

On the other hand, numerous researchers have examined on the significance and application of the innovative technologies in various industries such as healthcare, education and manufacturing (Shibuya, et al., 2018; Anon, 2020; Liu et al., 2020). There are rooms of improvements for transforming digitalisation in construction albeit the needs of digitalisation are widely reported. The construction industry has started implemented digital tools. For instance, Onungwa, et al. (2017) advocated the utilization of BIM in streamlining the design process across the company. Besides, several studies have investigated the potentials of technologies in managing the project, thereby improving the productivity. In addition, the application of emerging technologies for construction health and safety management has been evaluated in numerous research (Lee, et al., 2019; Soto, et al., 2022).

Remarkably, the aforementioned studies have primarily focused on the impacts of Covid-19 towards the construction industry and strategies to mitigate them. Meanwhile, some research has solely explored the application of digital tools in specific domains, rather than their potential to address the challenges posed by the pandemic and the transition to endemic. In light of this, the prevalence of work from home (WFH) as the new norm has significantly increased the reliance on digital tools in construction project, making it crucial to explore their potential for maintaining project continuity and overcoming any obstacles to their adoption. Aiming to bridge the research gap, this research will investigate the adoption of digital tools in construction project during the pandemic and transition to current endemic. The research questions to be addressed are as follows: What and how the digital tools help the construction project during the pandemic and the transition to the current endemic? What are the potentials of implementing digital tools in construction project during the pandemic and the transition to the current endemic? What are the obstructions to adopt the digital tools in the construction project during the pandemic and the transition to the current endemic?

1.4 Aim and Objectives

The purpose of this research is to investigate the adoption of digital tools in the construction project during the Covid-19 pandemic and the transition to the current endemic. The research aim can be achieved through the following objectives:

1. To identify the types of digital tools leveraged in construction project during the pandemic and the transition to the current endemic.
2. To explore the potentials of digital tools implementation in construction project during the pandemic and the transition to the current endemic.
3. To uncover the barriers of the digital tools adoption in construction project during the pandemic and the transition to the current endemic.

1.5 Research Methodology

This research adopts the research philosophical of pragmatism. The quantitative approach is selected to be applied in this research via distributing survey questionnaires to the targeted respondents. The rationale is that the research aims to investigate the adoption of digital tools in the construction project during the pandemic and transition to endemic. The benefit of collecting questionnaires is that responses can be acquired in a short period. The questionnaires are created in Google form and disseminated through social platforms such as LinkedIn and WhatsApp. The scope of this research is confined to the construction players who are currently working in construction industry without any specific limitations or qualifications imposed on their inclusion. Due to the time constraints, this research covers the Klang Valley region only. In this research, the implemented influential tests comprise of Cronbach's Alpha Reliability test, Friedman test, Spearman's Rank Correlation Coefficient test, Kruskal-Wallis test and Pearson's Chi-Square test. The summary of approaches used to achieve each research aim is shown in Table 1.1.

Table 1.1: Summary of Approaches Used

	Literature Review	**Questionnaire Survey and Data Analysis**
Objective 1	To identify the types of digital tools leveraged in construction project during the pandemic and the transition to the current endemic	
Objective 2	To explore the potentials of digital tools implementation in construction project during the pandemic and the transition to the current endemic	
Objective 3	To uncover the barriers of the digital tools adoption in construction project during the pandemic and the transition to the current endemic	

1.6 Chapter Layout

This research is divided into five major sections: introduction, literature review, research methodology, results and discussion as well as conclusion and recommendation.

Chapter 1 is the introductory section which illustrates an overview of the entire research scope. It comprises the background of the construction sector, industrial revolution 4.0 and impact of Covid-19 on construction industry. This chapter also includes problem statement, research aim and objectives, research methodology as well as chapter outline.

Chapter 2 outlines a thorough review of relevant literature studies that carried out by previous researchers. A brief introduction of the chapter's content is provided at the commencement of this chapter. Next, it covers the introduction of Covid-19 in Malaysia and its impacts on the construction industry, the types of digital tools leveraged, the potentials of digital tools implementation as well as the barriers of adopting digital tools in the construction project during the pandemic and transition to endemic.

Following, Chapter 3 demonstrates the way of conducting the whole research. This chapter discusses the research methodologies and principles. It also encompasses the type of research philosophies and methods, justification of research philosophy and method, research design, research instrument, sampling and data analysis.

Chapter 4 discusses and evaluates the outcomes of the data collected via questionnaires from the targeted respondents. This chapter also concludes with a discussion of the key findings that drawn from the collected research data. It assesses the results obtained in relation to the research aim and objectives in order to attain the final research goal.

Ultimately, Chapter 5 is known as the last chapter of this research which summarizes the overall research findings. Furthermore, it reveals the research implications, limitations and recommendations to offer insights for future researchers exploring in a similar subject topic

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter investigates and discriminates current hypotheses and earlier studies done by other researchers. In this chapter, it commences with a succinct introduction of Covid-19 pandemic in Malaysia and its influences on the construction industry. By reviewing and interpreting the previous relevant studies, the type of digital tools leveraged in construction projects during the pandemic and transition to endemic is examined in this chapter. Moreover, this chapter also encompasses the potentials and barriers of adopting digital tools in construction project during the pandemic and transition to endemic. Ultimately, this chapter encloses the conceptual framework of this research as well.

2.2 Covid-19 Pandemic in Malaysia

According to World Health Organisation (2020), Covid-19 is a viral-borne disease caused by the SARS-CoV-2 virus. The symptoms comprise fever, coughing, sore throat, exhaustion and breathing difficulties. Most patients can recover from mild to moderate respiratory tract, however some need medical intervention due to critical state with respiratory or multiple organ failure (World Health Organisation, 2022). Based on AIHA (2021), SARS-CoV-2 virus is spread by direct contact, such as touch or droplets and aerosols, or through indirect contact with infected items or environments.

In Malaysia, the epidemic progression of Covid-19 has occurred in three distinct waves. According to Iderus, et al. (2022), the first case of COVID-19 infection was authentically detected on 25 January 2020, ushering in the first wave of 22 infections which persisted until 26 February 2020. Subsequently, commencing from 27 February 2020 to 19 September 2020, considerably broader wave of infections had resulted in a total of 3375 cases. Ultimately, the third wave which struck Malaysia on 20 September 2020, is still ongoing at this day. As such, federal government of Malaysia has enacted a series of countrywide quarantine and cordon sanitaire measures between 18 March 2020 to 27 June 2021 such as Movement Control Order (MCO), Conditional

Movement Control Order (CMCO), Recovery Movement Control Order (RMCO), Enhanced Movement Control Order (EMCO), semi-EMCO and Full Movement Control Order (FMCO) in response to handle Covid-19 onslaught (Zaki and Ng, 2022).

In an attempt to recover from the economy's prolonged prostration, Malaysia’s former Prime Minister, Datuk Seri Ismail Sabri Yaakob, announced that the nation would be entering a transition to an endemic phase on 1 April 2022 as an exit plan to return to normalcy (Kaos, 2022a). Kaos (2022b) reported that the changeover was deemed appropriate since the country has attained a 55% vaccination rate for adults. In this case, the government has reduced the Covid-19 standard operating procedure (SOP) to be practised by the public. In particular, the SOPs such as “reopening of international borders” and “interstate travel regardless of immunisation status” have aided the construction companies’ recovery over the past two years of enormous losses. According to Mardhiah (2022), the elimination of transportation and travel prohibitions have allowed the construction industry’s supply chain to resume and facilitate cross-border business activities as well as combat the issue of building material depletion. Moreover, the dilemma of foreign labour scarcity could be palliated with the gradual influx of foreign workers for the purpose of bolstering and ameliorating productivity.

2.3 Impact of Covid-19 Pandemic on the Construction Industry

The sudden outbreak of the infectious coronavirus disease has been proliferated drastically all over the world. Indeed, this has posed a major dilemma to the construction sector in various countries. The impact of Covid-19 has exacerbated the construction activities in different aspects such as mandatory stopped work at construction site, financial instability, unemployment and contractual implication issue.

Owing to the government’s implementation of lockdown for proximity restrictions and virus spreading control, the construction sites are mandatory to close temporarily (Jagun, et al., 2022). According to Zamani, et al. (2021), such imposition has contributed to suspension and postpone of projects which resulting in devasting loss of revenue and time-consuming. Additionally, this also severely interrupted the site operations, resulting in the failure to complete the project within the timeframe. Due to the uncertainties of future site operations, most construction companies, particularly small and medium enterprises (SMEs) are riddled with trepidation and struggling to survive in such a threatening and rigorous environment (Oladimeji, 2022). Under the influence of the project closedown, a chain effect ensued, resulting in a cascade of repercussions such as employee layoffs, financial crisis, contract disputes and others.

According to Zamani, et al. (2021), financial instability is one of the major impacts of the Covid-19 pandemic. This is due to the operational of a construction company is mainly depending on the financial flow from the client. On account of this, when clients paused their financial outflow due to the project's closedown or delay, the construction companies will encounter and experience financial hardships (Shibani, et al., 2020; Alsharef, et al., 2021; Ogunnusi, et al., 2021). As such, the financial matters such as project cost overrun and cash flow delay arouse, resulting in lack of funds to sustain the expenditures of company in terms of overhead costs, materials cost, machinery and equipment cost, labour cost and others (Hatoum, et al., 2021). For instance, despite the fact that the work is halted, the contractor is still required to pay machine tariffs and material delivery on-site as well as staff wages (Gamil and Alhagar, 2020; Pamidimukkala and Kermanshachi, 2021). In an effort to curb the deleterious impact of financial burdens on operating the business, Jagun, et al. (2022) revealed that most construction companies have opted to cut costs in various aspects such as employee wages, zero bonus, profit, marketing and other expenditures.

Conforming to Gamil and Alhagar (2020), labour scarcity has been intensified as construction activities were impelled to cease due to the proliferation of Covid-19 virus. In specific, as the construction workloads are expected to reduce tremendously, which prompting to initiate a massive number of layoffs (Shibani et al., 2020; Alsharef et al., 2021). Since most construction firms are incurring enormous financial losses, Biswas, et al. (2021) propounded that mass layoffs become an ideal strategy for navigating the current economic crisis. However, from the perspective of employees, they may suffer from psychological health issues including anxiety, depression, insomnia, stress or even worse due to the anxiousness over losing their jobs (Pamidimukkala and Kermanshachi, 2021).

Furthermore, the arising of contractual concerns due to suspension and postponement of project pursuant to the Covid-19 measures (Jagun, et al., 2022). In the midst of pandemic, it is inevitable that the contractors may face contractual disputes due to the unforeseen halt in project progress and material fluctuations, which are not in compliance with contracts (Gamil and Alhagar, 2020). Such circumstance has coerced the contractors to sustain the losses and expenses solely due to absence of pandemic provision in the contract (Ogunnusi, et al., 2021). However, Alsharef, et al. (2021) and Oladimeji (2022) argued that since the incident is unforeseen and beyond the control of the contractors, they are entitled to reimbursement for their losses and expenditures under the force majeure contractual provision.

2.4 Type of Digital Tools Leveraged in Construction Project during the Pandemic and Transition to Endemic

The available digital tools to be utilized in construction project during the pandemic and transition to endemic, comprising Building Information Modelling (BIM), cloud computing, Internet of Things (IoT), Unmanned Aerial Vehicle (UAV), autonomous robotics, Radio Frequency Identification Device (RFID), Augmented Reality (AR) and Virtual Reality (VR), blockchain, smart wearables and 3D printing.

2.4.1 Building Information Modelling (BIM)

BIM is a digital construction model that incorporates data from all stages of project’s lifespan (Liu, et al., 2021; Rodrigues, et al., 2022). Muhammad, et al. (2021) perceived that BIM is a contemporary construction management approach that enables the creation of object-based multidimensional parametric models to optimise project collaboration. With the Covid-19 pandemic, BIM adoption has unleashed prodigious influence on construction project management.

BIM has been deployed to facilitate seamless building design coordination and collaboration among multiple stakeholders during the pandemic (Ekanayake, et al., 2021; Rajenthiran, et al., 2021). Ibrahim, et al.

(2021) declared that BIM's digitalisation system enables the transition of project data to visualize the real picture of project in a 3D environment from various aspects. In this vein, the virtual BIM platform works in centralized way to promote the interoperability in data exchange, effective communication and sponsible decision-making among stakeholders (Li, et al., 2022). In addition, Tuval and Isaac (2022) noticed that 4D BIM technology can be leveraged to support consultant in monitoring and tracking the up-to-date status of the design progress remotely in order to diminish the face-to-face interactions due to social distancing requirements. Seemingly, BIM has the potential to integrate project members in full-scale 3D platform for the design coordination and collaboration, thus limiting physical movements and contacts (Akmam, et al., 2021).

Besides, Ramachandra and Gupta (2020) and Lu, et al. (2022) have emphasized the significance of BIM in establishing a framework that allow the planning and management of the site activities to deal with the threat of Covid-19 pandemic. According to Kaklauskas, et al. (2021), the virtual counterpart of BIM stimulates the tracking and securitizing of environment metrics and human physical activities on project site in pursuance of allowing for the daily health reporting and remote diagnostics. In such manner, Akmam, et al. (2021) stressed that BIM can be deliberated as efficacious supporting device in assuring the delivery of construction project while catering the criterion of project site's safety protocols and labours' health. In an attempt to intensify performance of BIM in the domain of reducing infection risk on site, BIM can be amalgamated with other digital technology tools such as radio frequency identification device (RFID), virtual reality (VR) and augmented reality (AR) (Ali, et al., 2020; Ibrahim, et al., 2021)

2.4.2 Cloud Computing

Cloud computing refers to a service that can supply a vast quantity of virtual data storage and strong computational capabilities to customers or users across a network based on their demand and use (Tea, et al., 2022). In other words, it is an internet-based computing technology that shares resources via software and hardware to offer application services needed by terminal devices. In fact, the construction sector is data-intensive because diverse data is continually created as the project advances. With an intention of optimizing the performance of cloud computing in project management, it can be merged with other technologies such as BIM, IoT, AR and RFID (Ibrahim, et al., 2021). Thus, the significance of cloud computing to the project management should not be overlooked.

Considering the imposed measures of Covid-19 on the limiting travel, physical distancing and WFH, the cloud computing application is utmost important medium to support remote work by allowing information sharing and collaborative communication among the stakeholders (Tuval and Isaac, 2022). As stated by Oke, et al. (2021), when project members save and interpret the data and workload such as drawings, specifications and tender documents on the cloud computing dedicated platform, an organisation acquires complete control over cloud-stored data throughout project lifecycle. For instance, the most commonly used cloud storage for the documents are Dropbox, OneDrive, Google Drive, Google Cloud Storage and iCloud Drive. The real-time information can be accessed and displayed on internet-enabled electronic devices such as laptops, tablets, and smartphones, resulting in efficient information exchange. In addition, Sivanesan, et al. (2021) proposed that the embedded firewall of cloud computing is designed to protect and secure the database in order to hinder the jeopardization of privacy and confidential of project documents. Conjunction with all aforementioned characteristics, Rajenthiran, et al. (2021) concluded that the involvement of stakeholders via cloud-based application is more effective than the conventional method of paper-based or verbal coordination. Eventually, the study implies that cloud computing technology is superior in dealing with pandemic situation and avoiding contact contaminated facilities and documents.

Moreover, the emerging of virtual space with cloud-based video conferencing (VC) platform is introduced to tackle devasting influence of viral disease since the collocated meetings are substantially restricted. Rout, et al. (2022) uttered that cloud-based VC platform is the key-enabler of telework to allow the project participants in communicating virtually through video and audio features over the internet and share information among them. The meeting process can be recorded for the absentees to refer or as valuable legal evidence if any decision is made. For instance, the cloud-based VC digital platform that widely used are Google Meet, Zoom, Microsoft Teams and Skype (Heer, et al., 2021).

2.4.3 Internet of Things (IoT)

Internet of Things (IoT) is identified as a network that bridges machineries and gadgets to enable them in generating and transmitting data through internet and administration system (Abdullah and Abdullah, 2021). Pursuant to Starr, et al. (2021), the concept of IoT embraces three core components, which are the devices such as sensors and actuators for data gathering, internet and other communication systems for connectivity, processor for data processing. In an effort to refine the capability of IoT in manipulating the construction development progress, IoT can integrate with other innovative smart technologies such as BIM, cloud computing, drone, radio frequency identification device (RFID), augmented reality (AR) and drone (Ibrahim, et al., 2021). With the IoT mechanisms as mentioned, it has contributed intrinsic value to project development during the Covid-19 outbreak and transition to endemic.

As illustrated by Heer, et al. (2021), Ranasinghe and Pathirana (2021) and Li, et al. (2022), the association of IoT sensor devices with other construction technologies can achieve real-time data and surveillance on site to conquer the travel restrictions and social distancing reinforcement during the pandemic. The feature of real-time data collection and analytics can lead to the reasonable management of project status such as work schedules, usage of funds and workforce distribution (Li, et al., 2021). In this regard, all operational activities can be proceeded in accordance with the plan in an attempt to accomplish the construction works within the timeframe. Apparently, IoT has the capability to enhance the project productivity while protect health and safety of labour force.

Since the outset of pandemic, the boundless propagation of Covid-19 virus owing to close contact has resulted in the high proportion of construction personnel has been screened positive. In light of the rapid transmission of pathogens, Fernandes (2021) opined that IoT-enabled sensors and technologies can be utilized for the contact tracing and body temperature examining. Essentially, IoT sensor devices such as thermal camera and infrared distance sensor can capture the workers' heat profile and assess their vicinity, respectively. The data is harvested and developed to react to functions such as real-time notifications on devices such as mobile phone and tablet to exhibit the records of personal temperature, proximity measurement and high infection area alerts (Lin, et al., 2021). In such wise, Khanfor, et al. (2020) articulated that IoT acts as a pivotal role in alleviating the risk of cluster infections and refraining the institution's entire closure in construction sector.

2.4.4 Unmanned Aerial Vehicle (UAV) / Drone

Unmanned Aerial Vehicle (UAV) is also ordinarily known as drone. It is an autonomous flying robot that can be commanded remotely using software in its established system to manage flight plans, functioning directly with GPS and built-in sensors (Alsamarraie, et al., 2022). There are various types of drones which can be classified as Fixed-Wing, Rotary-Wing and Multi-Router. As annotated by Chaibi, et al. (2021), Fixed-Wing drone is typically employed for long-distance operations but not precise missions. The research also explained that Rotary-Wing drone is well-suited to confined space practice and precise application. Additionally, this study also described that the Multi-Rotor drone with several rotor blades which rotate around a fixed mast offers greater stability but with constricted flight duration. Generally, drones can be equipped with different types of sensors such as video cameras, infrared cameras, 3D laser scanners, radar detectors and others to conduct multiple tasks on the construction site.

In a study undertaken by Wahab (2020), drones are adopted for remote monitoring and surveillance operation activities in construction project to resolve the concerns associated with catastrophe threats such as Covid-19 pandemic and mitigation operations. Owing to the operational flexibility and portability attributes, drones are able to explore various geographical locations and enclose expansive scale of the construction projects, while retaining non-hazardous social distance (Akmam, et al., 2021). Contemporaneously, this statement implies that the efficiency of the workflows on site can be secured without physical engagement of the site supervisors. Moreover, Razavi, et al. (2022) developed that drone associated with object identification algorithms such as Region-Based Convolutional Neural Networks (R-CNN) is robust in recognising face masks on human faces and accurately detecting the vicinity of workers. Subsequently, the data acquired on site can be further monitored by the contractors and stored in system as a record. Due to high labour-intensive on construction site, there is an enormous risk of infection spreading, therefore drones are imperative in infrastructure project to promote workers' safety and health. (Razavi, et al., 2022)

In the realm of construction surveying, the prominence of drones emerges explicitly in topographic mapping and photogrammetry during this Covid-19 pandemic's limited mobility (Gara, et al., 2022). In the past study conducted by Alsamarraie, et al. (2022), 3D models of immense landscapes can be generated in a software program by using drones with laser scanners coupled with a classical topographic survey. In addition, the research also highlighted that the utilization of drones' photogrammetry technique can measure and compute the volume of earthwork in expeditious and accurate manner, which is commonly surveyors spend days or weeks to estimate. As such, drones with the aforementioned properties are beneficial in aiding construction project during the critical period of virus invasion.

2.4.5 Autonomous Robotics

In earlier research, Abioye, et al. (2021) defined that robotics is known as a multidisciplinary engineering field concerned with the creation, maintenance, and control of robots and other computer-based systems that imitate real-world human behaviours. To put it another way, robotics has an edge over human manual operations by possessing innovative features such as manoeuvring heavy workloads and high-risk task effectively within short period of time to improve the construction productivity. However, Hazem, et al. (2021) argued that fewer operators and assistants are indispensable in maintaining the autonomous system and overhauling the malfunctions in place of utterly substituting manual workforce. In relation to coincide with specific duties of different scale construction projects, Muhammad, et al. (2021) asserted that various types of robotics and mechatronics systems such as painting robots, finishing-laying robots, project progress inspecting mobile robot can be exploited. Thus, the contribution of autonomous robotics in tackling the dilemma of coronavirus in construction projects should not be underrated.

On account of promulgating the Covid-19 containment measures, which interrupted the construction works, the construction industry's unemployment rate has drastically exacerbated. With the purpose of combating the labour shortage issue, the adoption of autonomous robotics is a viable option to assure the ongoing operations of construction projects (Le, 2021). Akmam, et al. (2021) revealed that the robots with full capacity operation features can intensify the productivity via executing repetitive and monotonous tasks without being constrained by the pandemic-imposed measures. Concurrently, it also can significantly stimulate little or zero human interventions in construction tasks, hence impeding the dependence solely on the on-site crew (Onososen and Musonda, 2022). By such means, the communication and interaction between labours may be tremendously curtailed to curb the contagious disease from spreading, consequently diminishing the severe delays of construction projects. Inevitably, autonomous robotics are crucial in assisting the continuous operations of construction projects during the Covid-19 plague.

2.4.6 Radio Frequency Identification Device (RFID)

According to Ibrahim, et al. (2021), RFID is a wireless communication technology that applies radio waves of varying frequencies to identify objects or humans by reading the microchip embedded in RFID tags. There are three core elements of RFID system, which consist of readers, tags and servers. Besides, RFID tags can be distinguished into two categories: passive RFID tags and active RFID tags. Laurini, et al. (2021) expounded that passive RFID tags can be charged via electromagnetic pulses emitted by RFID readers, whereas active RFID tags are charged by their own batteries and therefore can be scanned by RFID readers over longer distances. Apart from monitoring the data collected from RFID scanners using computers, a dedicated web application can be designed for each worker to install on their mobile phones and tablets. Due to the function in detecting numerous RFID tags simultaneously, RFID systems are vital for construction site management and should be extensively adopted to cope with the contagious environment.

With the aim of promoting the remote project management during the pandemic, Ekanayake, et al. (2021) signified that the application of RFID systems is conducive in fostering the supply chain coordination as well as material and equipment flows visibility. Once RFID tags affixed to the materials and equipment access the construction site detection region, the location and routeways of each item can be spotted effortlessly. The RFID systems are able to capture reliable information on site in order to avoid losing, misplacing or late deliveries. As attested by Loh, et al. (2021), this approach can overcome the human error in materials and equipment identification, delay in supply, a shortage of storage space. Additionally, this study also alluded that the traditional paper-based materials tracking method can be replaced to lessen the necessity for human recording of entire materials and equipment circulation. In view of this, the construction project can be prosecuted as planned, while preventing direct contact of personnel with the contaminated materials.

Furthermore, various researchers demonstrated that RFID has been seen as an ID identifier in reading employee identification and attendance counting. (Duan and Cao, 2020; Abdullah and Abdullah, 2021; Lin, et al., 2021) In addition, the RFID-based Real Time Location System (RTLS) is developed to track the real-time location of a person wearing an RFID tag (Kir, 2022). This study also explained that the RFID tags in the form of personnel ID cards with a vibration feature can alert for the social distance violations and any dangerous scenarios that jeopardize occupational health and safety. Indeed, RFID can substantially mollify the diffusion of coronavirus in the construction project.

2.4.7 Augmented Reality (AR) and Virtual Reality (VR)

Augmented Reality (AR) and Virtual Reality (VR) are the two major types of virtual technologies that are broadly used in the construction field. AR is identified as a virtual object that replicate the real-world environment into a digital simulation in order to visualize actual images of objects or items utilizing electronic gadgets such as smartphones, tablets, AR glasses and others (Ibrahim, et al., 2021; Sivanesan, et al., 2021). VR is defined as a technology that uses a VR headset to immerse individuals in digital content or a virtual area created by a computer (Tea, et al., 2022). In accordance with the previously mentioned abilities of AR and VR, they are ideally suited to bridge the gap between the construction office and site, providing for a better grasp of overall project information.

In line with challenges of physical coordination and collaboration, AR and VR can be applied to the pre-construction phase for the simulation and visualization of building design. As a visualization and communication technology, Nikoli and Whyte (2021) denoted that VR serves an immersive real-time communication platform to present the design and democratize the process of intervening, discussion modification among the stakeholders. Besides, Akmam, et al. (2021) raised that AR-based platform enables the construction practitioners to view the full-scale 3D world as planned on construction site and identify components concealed from different views. Thus, the visualization technologies are outstanding in boosting the understanding of spatial perception and sharing the details of the facility design among the construction players (Ali, et al., 2020; Tea, et al., 2022). Further, Nassereddine, et al. (2022) pointed out that the client also has the opportunity to remotely envisage the design alternatives and appreciate the project's rationale, results or outputs in an attempt to make any appropriate augmentations or amendments prior to the construction commences. Consequently, the deployment of AR and VR enables the architectural and engineering design to be performed from the office or at home, while decreasing the hazard of Covid-19.

In the midst of Covid-19 epidemic, the difficulty to conduct hands-on training on site has massively elevated. With the target of sorting the vexatious problem, several researchers propounded that AR and VR are imperative in offering a virtual training platform that can vastly ameliorate employee engagement (Hirani and Patel, 2020; Starr, et al., 2021; Onososen and Musonda, 2022). As enunciated by Akmam, et al. (2021), AR and VR are the important platforms for conveying responsibility and knowledge in terms of safety and health aspects in the construction. Conjointly, the previous study also proclaimed that visualization technologies can apply real-time simulation technique to duplicate the actual site scenarios in guaranteeing the workers achieve particular degree of proficiency before delivering their duties on-site. For instance, virtual vocational welding training simulators with high realism and detectors for hand-eye coordination, welding posture versatility, and multiple welding positions and joints can drive trainees to repeat exercises for trial and error to determine optimal welding method (Chan, et al., 2022). Eventually, virtual technologies enable employees to improve their expertise and familiarity with their jobs, while also supporting remote learning, particularly during the pandemic.

2.4.8 Blockchain

As defined by Lu, et al. (2021), blockchain is a distributed ledger of pertinent transaction data that are explicitly consented upon and shared among all peer-to-peer network participants. There are a few fundamental components that support blockchain to function which are networked database, consensus mechanism, cryptography and smart contract (Li, et al., 2022). This study also illustrated the distinctive attributes of the blockchain information, which include transparency, privacy, decentralization, traceability, immutability and smartness. Referring to the aforesaid core components and features, blockchain has the potential to subjugate the restriction of project management operations during the Covid-19 prevalence.

In the context of worldwide epidemic, e-procurement is a preferable method. The blockchain-based electronic bidding enables the tenderers submit their bids remotely and anonymously to secure their privacy and identity (Liu, et al., 2021). Besides, using a blockchain system with smart contracts can facilitate or impose the contractual commitments by incorporating contractual terms and conditions in computer software as well as automating agreement fulfilment (Li, et al., 2021). Additionally, the previous research also explicated that the contractual fraud can be detected and prevented due to blockchain's distributed character. The term "distributed" refers that those ledgers are dispersed across many nodes in a shared manner in order to record transaction data and resist tampering (Lu, et al., 2022). In such a manner, the blockchain is vital in propelling the project contract administration while retaining physical distancing measures.

Apart from that, payment delays are a serious concern in the construction industry, which has been exacerbated by the Covid-19 outbreak. In the light of alleviate the uncertainties and hurdles associated with acquiring payment, Alhanaee and Alhanaee (2021) affirmed that smart contract-based blockchain technology can be leveraged to profoundly impact on the project progress. The application of blockchain-enabled smart contracts for payment processing can establish a seamless and automatic payment mechanism that ensures the funds are accessible or collected within the acceptable stipulated period (Hamledari and Fischer, 2021). In other words, Li, et al. (2021) clarified that the pre-coded smart contracts of blockchain is feasible in recognizing the accountability and prompting automatic mile-stone based payment for supply chain and interim payments. Undoubtedly, blockchain serves as a catalyst for addressing the issues in terms of project management and financial throughout the coronavirus crisis.

2.4.9 Smart Wearables

As the term entails, smart wearables are referred to the small electronic devices that attached to the workers' body with the capability to receive and transfer data. Typically, smart wearables can be designed and developed in various forms such as wristbands, keychains, badges, boots, safety goggles, safety vest, safety helmet and safety glove. Conforming to Mejia, et al. (2021), this digital tool can help to attenuate the coronavirus dissemination via aiding with biometrics and gauging physiological metrics on construction site. In this respect, the physical proximity and the health conditions of the workers can be traced consistently and continuously. For instance, Ranasinghe and Pathirana (2021) advocated that employing smart wearable such as wristband will be able to alert the on-site staffs if they congregate in crowds or disregard the social distancing measures. Additionally, wearable technology with illness recognition features will recognize individuals with high body temperatures, triggering self-isolation mechanism to reduce the possibility of contaminating others (Mejia, et al., 2021).

2.4.10 3D Printing

As specified by Pasco, et al. (2022), 3D printing is known as a sophisticated digital technique that generates three-dimensional structures by depositing layer-by-layer of material from computer-aided-design (CAD) model. In other words, based upon the formation of 3D digital model using 3D modelling software, 3D printer can read the design and apply sequential layers of printing substance that are spliced to manufacture the product. This technology can act as a predominant practice to be applied in construction industry in reducing the requirement of manpower in order to offer contact-free working environment in line with the Covid-19 pandemic's measures (Ramachandra and Gupta, 2020). For instance, Hazem, et al. (2021) elucidated that automation trait of 3D concrete printing performs off-site prefabrication of desired building component such as fibre reinforced concrete to shrink the time-consuming for on-site assembly. Eventually, on-site congestion can be prevented to mitigate the risk of infection and impede coronavirus proliferation.

2.4.11 Summary of Types of Digital Tools Leveraged in Construction Project during the Pandemic and Transition to Endemic

Table 2.1 below summarises the applications of numerous different digital tools identified during the pandemic and transition to endemic from literature review study.

Table 2.1: Summary of Types of Digital Tools Leveraged in Construction Project during the Pandemic and Transition to Endemic

No.	Digital Tools	Abdullah and Abdullah (2021)	Abioye, et al. (2021)	Akmam, et al. (2021)	Alhanaee and Alhanaee (2021)	Ali, et al. (2020)	Alsamarraie, et al. (2022)	Chaibi, et al. (2021)	Chan, et al. (2022)	Duan and Cao (2020)	Ekanayake, et al. (2021)	Fernandes (2021)	Gara, et al. (2022)	Hamledari and Fischer (2021)	Hazem, et al. (2021)	Heer, et al. (2021)	Hirani and Patel (2020)	Ibrahim, et al. (2021)	Kaklauskas, et al. (2021)	Khanfor, et al. (2020)	Kir (2022)	Laurini, et al. (2021)	Le (2021)	Li, et al. (2021)	Li, et al. (2022)
1	BIM			✓		✓					✓							✓	✓						✓
2	Cloud Computing															✓									
3	IoT	✓										✓				✓		✓		✓				✓	✓
4	Drone			✓			✓	✓					✓												
5	Autonomous Robotics		✓	✓											✓								✓		
6	RFID	✓								✓	✓							✓			✓	✓			
7	AR & VR			✓		✓			✓								✓	✓							
8	Blockchain				✓									✓										✓	✓
9	Smart Wearables																								
10	3D Printing														✓										

Table 2.1 (Continued)

No.	Digital Tools	Lin, et al. (2021)	Liu, et al. (2021)	Loh, et al. (2021)	Lu, et al. (2021)	Lu, et al. (2022)	Mejia, et al. (2021)	Muhammad, et al. (2021)	Nassereddine, et al., (2022)	Nikoli and Whyte (2021)	Oke, et al. (2021)	Onososen and Musonda (2022)	Pasco, et al. (2022)	Rajenthiran, et al. (2021)	Ramachandra and Gupta (2020)	Ranasinghe and Pathirana (2021)	Razavi, et al. (2022)	Rodrigues, et al. (2022)	Rout, et al. (2022)	Sivanesan, et al. (2021)	Starr, et al. (2021)	Tea, et al. (2022)	Tuval and Isaac (2022)	Wahab (2020)
1	BIM		✓			✓		✓						✓	✓			✓					✓	
2	Cloud Computing										✓			✓					✓	✓		✓	✓	
3	IoT	✓														✓					✓			
4	Drone																✓							✓
5	Autonomous Robotics							✓				✓												
6	RFID	✓		✓																				
7	AR & VR								✓	✓		✓								✓	✓	✓		
8	Blockchain		✓		✓	✓																		
9	Smart Wearables						✓									✓								
10	3D Printing												✓		✓									

2.5 Potentials of Digital Tools Implementation in Construction Project during the Pandemic and Transition to Endemic

There are numerous potentials of employing digital technologies in construction project during the Covid-19 epidemic and transition to endemic, which will be further discussed in following sections.

2.5.1 Enhance Project Design

It is obvious that the advent of revolutionary advanced technology has radically altered the traditional practice of construction designing. The utilization of integrated visualization technologies such as BIM, AR and VR in offering multi-disciplinary collaborative environment immensely improve the design quality, design workflow efficiency and productivity (Chen, et al., 2021; Ogunnusi, et al., 2021). Vasista and Abone (2018) specified that such novel approach of collaboration enables the construction stakeholders to pool their modelling effort and express ideas in tandem to satisfy the proposed project's functional criteria and standards. As such, these technologies have evinced their potentials to facilitate remote work practices without compromising desired design quality, notably in mitigating the impact of unforeseen occurrences such as Covid-19, which necessitated working in isolation (Akhmetzhanova, et al., 2022). Besides, this technology is mighty in mass customization of alternative designs and parameters for functional and aesthetic uses (Swallow and Zulu, 2019; Ikuabe, et al., 2020; Ebekozien and Aigbavboa, 2021). Accordingly, this trait has granted an opportunity for construction design team to assess and compare the design alternatives in order to discover the optimal outcome. At the same time, design-related flaws or project collisions can be spotted and scrutinized early in the design phase, resulting in a high degree of accuracy final output that also considerably minimizes the probability of litigations and claims (Ibrahim, et al., 2021; Elrefaey, et al., 2022).

2.5.2 Enhance Site Planning and Management

To furnish a safe and healthy construction environment especially during the pandemic and transition to endemic, an effective site planning throughout the project cycle is mandatory. According to Swallow and Zulu (2019), early precise planning and management of site activities during the preliminary stage is key indicator for project success. Numerous studies have revealed that the deployment of technology has fostered the effectiveness of project management via altering the way in allocating project resources and adjusting schedules for each project phase (Alim and Said, 2021; Ibrahim, et al., 2021; Elrefaey, et al., 2022). According to Jana and Martin (2021), the application of BIM-supporting software, such as Microsoft Project, which is typically used for the project activity sequences planning, may aid in developing a logical allocation of adequate resources for each construction stage. Simultaneously, the study claimed that it might also illustrate the critical path layout to assist in time estimation and determination to ensure the successful completion of the whole project. In view of these, a realistic and precise schedule planning can be generated to ensure the continuity of project delivery within reasonable time. Besides, this technology also proven feasible in workforce allocation to strike a balance between pandemic prevention and work resumption (Wang, et al., 2021). In particular, it allows for the prioritization of works to further delegate and alter an adequate number of existing competent labour to the specific work in compliance with the completion deadline and conquering the impact of pandemic. Apparently, such planning tool should be associated with more flexible construction teams who are adaptable to changes and adversities in order to be relevant in administering and cushioning the detrimental effect of epidemic (Ogunnusi, et al., 2021). As a result, effective project delivery and satisfactory hygiene on construction sites in line with the Covid-19 measures are attainable via proper site operational planning (Renukappa, et al., 2021).

2.5.3 Enhance Material Supply Chain and Inventory Management

In general, project delivery is inconceivable without an organized and reliable supply chain. According to Ogunnusi, et al. (2021), with the onset of the Covid-19 pandemic, the customs delays and safety regulations for cross-border distribution of building materials had hindered supply chains. By incorporating technological advancements, it can be a vital holistic approach for ramping the construction logistics and inventory management (Swallow and Zulu, 2019; Jana and Martin, 2021). For instance, RFID is utilised to trace the material flow process, monitor supply chain condition and transmit warning signals to on-site crews in order to plan and manage for material arrival (Chen, et al., 2021). Such feature provides the project manager with precise information on travel routes, vehicle speed and traffic condition, thus allowing to keep the project schedule with the most recent updates (Ibrahim, et al., 2021). In particular, most construction manufacturers ceased operations during the pandemic since only essential services were permitted, thus this approach allows for anticipating material supply and resolving with alternative solutions. Subsequently, this innovation also assists project manager to perform on-site material inventory checking by providing real-time information (Ikuabe, et al., 2020). For instance, the sensors located at the warehouse entrance can capture attached RFID tags on bulk materials to identify the types of construction material as well as compute and record the quantity of materials into the control system (Patil and Shelake, 2021). The database that captured by the system comprises the RFID tag serial number which represents different type of material, manufacturer name, date of manufacture, location of manufacture, material specifications, date and time of receipt and others as per management requirements to ensure the utmost accurateness of inventory checking (Parker and Stopforth, 2021).

2.5.4 Enhance Site Inspection

Irrespective of the construction project scale, site inspection is an inherent part of the construction process to keep the project on schedule and regulate the site conditions. The study of Ibrahim, et al. (2021) showed that the facilitation of monitoring system with sensors such as IoT and drone assists the site manager to continuously monitor of entire project progress in real time in order to verify the project constructability and conformance with the project design and specifications within a reasonable time. These innovations also allow for the analysing of labour productivity and overall project performance via the practical usage of personnel, equipment and expenses (Alim and Said, 2021). Besides, the occurrence of Covid-19 measures restriction has further hindered the monitoring of the workers migration from one activity to another within a same project. As such, drone with high mobility is deemed to be a powerful instrument in scrutinizing across vast acres of land and detecting whether the workers are wearing masks in an appropriate manner as well as complying with social distancing rules (Elrefaey, et al., 2022). Seemingly, the site inspection is feasible remotely and virtually in order to bridge the information gap between the office and site conditions. With the proper deployment of smart technology on the construction project, the construction team can effectively dominant the workflow while deal with the immediate consequences of Covid-19 (Lota, et al., 2022).

2.5.5 Improve Covid-19 Virus Infection Identification

Covid-19 virus infection identification refers to the detection of worker's health status. Given the current state of affairs with the Covid-19 outbreak, it is imperative that the health of all employees on workplace be constantly monitored using the available health sensor at all times (Ibrahim, et al., 2021). By leveraging real-time identification technologies such as drone and sensors, abnormal body temperature assessments and breaches of safe distance as well as overcrowding regulations will trigger the system and send warning alerts or notifications to relevant site personnel for immediate action (Goh, et al., 2022). Thereafter, in the event of workers showing any symptoms of the coronavirus, the workers can be enforced to conduct isolation practice rapidly to avoid further spreading (Elrefaey, et al., 2022). Thence, deploying innovative technology for prompt detection of Covid-19 infection is crucial in order to ensure site hygiene as well as preserve the safety and health of on-site labours (Chigara and Moyo, 2022).

2.5.6 Promote Communication and Collaboration

The archaic forms of communication approaches such as in-person meetings and printed form documents are customarily performed in the bulk of construction projects. In the recent years of coexistence with Covid-19, it has been acted as a stimulant in offering an unanticipated impetus to the employment of innovative communication method. It is apparently that the application of cloud-based communication applications such as Zoom Meetings, Google Docs, Dropbox, email has promoted the productivity and performance of the works (Ibrahim, et al., 2021; Elrefaey, et al., 2022). These technologies have the potential in facilitating the seamless merging of project data acquired at various stages to foster real-time information visibility and communication among the construction participants (Vasista and Abone, 2018). From this perspective, both construction site and office personnel manage to update their job completion percentages on the shared platform, such as Google Spreadsheets, allowing for routine checks on work in progress and ensuring plan can be evaluated remotely (Oke, et al., 2021). Simultaneously, Edirisinghe (2019) and McNamara and Sepasgozar (2021) ascertained that diverse real-time data on the cloud-based communication platform are accessible by the construction stakeholders from scattered locations via any internet-capable communication device. The advanced technological innovations enable teams work closely and flexibly with various disciplines in an effective way to enhance the productivity and timesaving (Ogunnusi, et al., 2021; Elrefaey, et al., 2022). Additionally, Ebekozien and Aigbavboa (2021) declared the satisfactory precautions to against the infestation of pandemic also can be achieved by meeting the physical distancing guidelines and allowing for the self-isolation at home via virtual platform of the communication technologies. Eventually, several studies have validated that the adoption of innovative technology has contributed to a greater flexibility in communication, collaboration and information sharing (Swallow and Zulu, 2019; Ikuabe, et al., 2020; Syamimi, et al., 2020; Hasan, et al., 2021; Renukappa, et al., 2021; Lota, et al., 2022).

2.5.7 Enhance Efficiency of Repetitive Task and Monotonous Workflows

It is common for linear construction projects to have a vast bulk of highly recursive tasks. On that account, the productivity is the major concern to the project delivery within the timeframe. However, Delgado, et al. (2019) stressed that the conventional construction method has reached the limit in terms of productivity, quality control and performance, therefore the application of technology is recommended to overcome the impediment. Other than that, Ebekozien and Aigbavboa (2021) claimed that the unforeseen event such as Covid-19 pandemic which caused the absence or shortage of workforce also can be compensated by utilizing the technologies such as autonomous robotic and 3D printing to restore and expedite the construction activities. In specific, the increasingly automated nature of built environment has the potential to stupendously reduce the necessity of labor-intensive repetitive tasks, thereby lowering workforce requirements (Bogodukhova, et al., 2021; Pasco, et al., 2022). With the aid of robot’s microscopic precision feature in erecting repetitive building elements at a brisk and consistent pace, the adverse impact of labour scarcity on project quality and productivity can be subjugated (Ikuabe, et al., 2020). Conjointly, robot can perform continuous operation for 24 hours constantly and efficiently without any shift to overcome human shortcomings such as negligence and fatigue when working for extended periods of time. Eventually, efficiency of executing monotonous tasks can be improved through implementation of digital technology to enhance the project productivity.

2.5.8 Enrich Education and Training

The primary purpose of education and training during the pandemic and transition to endemic is to enable the construction employees to comprehend the Covid-19 safety and health protocols, site safety measures as well as enhance the vocational skills. With the exponential growth of digital technology, digital education and training are expected to become the norm for boosting employees' recognition and learning in the near future. As a matter of fact, traditional hands-on training is proven to be notoriously inconvenient since it requires actual equipment and physical on-site space, perhaps exposing worker safety and health at risk. On account of this, the pioneering of intelligent technologies in construction education and training establishes a new framework to promote the efficiency and conveniency of the learning environments (Syamimi, et al., 2020). For example, the integration of AR, VR and BIM provides a virtual platform for the simulation and rehearsal of potential safety issues in a variety of construction site contexts and vocational training in a range of technical work skills (Chiang, et al., 2022). Simultaneously, Nnaji, et al. (2022) suggested that these technologies can be used to educate workers on the impact of Covid-19, the potential risks and virus spreads and the method of maintaining personal hygiene. Considering the possible literacy and understanding hurdles, such virtual video-based training has been highlighted more efficient form of convey policies, procedures, and standards to construction workers (Edirisinghe, 2019). Thus, it is deemed to be user-friendly methodology for the immigrant labours to absolutely comprehend the digital-based education and training.

2.5.9 Enhance Procurement Contracting Management

In construction industry, the procurement contracting procedure is significant for the contractor to be legally bound to a construction agreement prior to the project commencement. Owing to the fast pace of industrial revolution and impact of Covid-19 pandemic, the paper-based procurement approach in handling the intricate and multi-dimensional construction projects is gradually being replaced by technology. According to Perera, et al. (2021) and Nitharsan and Francis (2022), the application of blockchain technology boosts the security, confidentiality, transparency and work efficiency of construction procurement. In view of the decentralisation and immutability attributes, blockchain-based e-contract can strengthen confidence between the parties involved without a mediator since the centralized information is prohibited to alter, discard or tamper, unless authorised by relevant parties (Khalfan, et al., 2022). According to Hassija, et al. (2021), such mechanism will ensure the entire workflow fraught with transparency and visibility which capable to demotivate the occurrence of malpractices such as information leaks, corruption, fraudulent, bribery and others. Thereupon, it is apparent that the potential of blockchain-based e-procurement contracting has the ability to secure the benefits of multiple parties engaged and lubricate the contract administration cycle (Matyskevic and Matyskevic, 2021).

2.5.10 Enhance Payment Claim

Over the years, most construction participants have found that the conventional lengthy milestone payment periods are extraordinarily burdensome. Owing to improve the productivity and efficiency, the digital solution is to be introduced for the evolution of contractual process. Numerous researchers have established that the potential of the blockchain-enabled smart contract as a centre for automation payment is a tremendous benefit to the construction industry (Perera, et al., 2021; Khalfan, et al., 2022; Nitharsan and Francis, 2022). Conforming to McNamara and Sepasgozar (2021), as the contractual parameters such as performance criteria, work completion and on-site material delivery are fulfilled and verified, the payment becomes an immediate procedure that is instantly transfer among the contracted parties. The view is that such an operation can offer an opportunity in securing the payment and protecting all parties from the insolvencies, late payments or no payment that have always plagued in this industry. Thus, such digital contract enforcement system has the capability in addressing the payment disputes and averting the initiation of juridical proceedings (Wu, et al., 2022). As a result, the usage of blockchain to digitalise the payment process potentially led to optimal efficiency in business-to-business commerce.

2.5.11 Enhance Safety and Risk Management

Inevitably, most construction projects are riffed with risks and controversies that must be dealt with, especially the more challenges during the pandemic and transition to endemic. Thereby, the technology implementation is vital in offering an effective safety and risk management. According to Pasco, et al. (2022), the motivation for the smart technology application is to pursue safety in hostile construction environments, which might result in massive enhancements to onsite assembly operations. The utilization of on-site automation and robotic systems has the ability to revolutionise the traditional on-site practices by offering a factory-like construction environment to secure the safety and health requirements (Delgado, et al., 2019). Meanwhile, drones and smart wearables can offer instantaneous tracking of workers' vital signs and location, along with immediate alerts in the event of emergencies, rendering them especially advantageous for medium and large construction projects (Yap, et al., 2021). In light of these, the risks of severe strains, lifelong impairments and fatal risks suffered by human workers can be significantly mitigated, thereby minimizing the catastrophic damages to the construction project. Thus, it can be affirmed that the avant-garde digital technology has profoundly alleviate the risks and mishaps on-site that might endanger people, property and project (Ikuabe, et al., 2020).

2.5.12 Summary of Potentials of Leveraging Digital Tools in Construction Project during the Pandemic and Transition to Endemic

Table 2.2 below summarises the potentials of digital tools implementation in construction project during the pandemic and transition to endemic from the literature review study.

Table 2.2: Summary of Potentials of Digital Tools Implementation in Construction Project during the Pandemic and Transition to Endemic

No.	Potentials	Akhmetzhanova, et al. (2022)	Alim and Said (2021)	Bogodukhova, et al. (2021)	Chen, et al. (2021)	Chiang et al. (2022)	Chigara and Moyo (2022)	Delgado, et al. (2019)	Ebekozien and Aigbavboa (2021)	Edirisinghe (2019)	Elrefaey, et al. (2022)	Goh, et al. (2022)	Hasan, et al. (2021)	Hassija, et al. (2021)	Ibrahim, et al. (2021)	Ikuabe, et al. (2020)	Jana and Martin (2021)	Khalfan, et al. (2022)	Lota, et al. (2022)
1	Enhance Project Design	✓			✓				✓		✓				✓	✓			
2	Enhance Site Planning and Management		✓								✓				✓		✓		
3	Enhance Material Supply Chain and Inventory Management				✓										✓	✓	✓		
4	Enhance Site Inspection		✓								✓				✓				✓
5	Improve Covid-19 Virus Infection Identification						✓				✓	✓			✓				
6	Promote Communication and Collaboration								✓	✓	✓		✓		✓	✓			✓
7	Enhance Efficiency of Repetitive Task and Monotonous Workflows			✓				✓	✓							✓			
8	Enrich Education and Training					✓				✓									
9	Enhance Procurement Contracting Management													✓				✓	
10	Enhance Payment Claim																	✓	
11	Enhance Safety and Risk Management							✓								✓			

Table 2.2 (Continued)

No.	Potentials	Matyskevic and Matyskevic, (2021)	McNamara and Sepasgozar (2021)	Nitharsan and Francis (2022)	Nnaji, et al. (2022)	Ogunnusi, et al. (2021)	Oke, et al. (2021)	Parker and Stopforth (2021)	Pasco, et al. (2022)	Patil and Shelake (2021)	Perera, et al. (2021)	Renukappa, et al. (2021)	Swallow and Zulu (2019)	Syamimi, et al. (2020)	Vasista and Abone (2018)	Wang et al. (2021)	Wu, et al. (2022)	Yap, et al. (2021)
1	Enhance Project Design					✓							✓		✓			
2	Enhance Site Planning and Management					✓						✓	✓			✓		
3	Enhance Material Supply Chain and Inventory Management					✓		✓		✓			✓					
4	Enhance Site Inspection																	
5	Improve Covid-19 Virus Infection Identification																	
6	Promote Communication and Collaboration		✓			✓	✓					✓	✓	✓	✓			
7	Enhance Efficiency of Repetitive Task and Monotonous Workflows								✓									
8	Enrich Education and Training				✓									✓				
9	Enhance Procurement Contracting Management	✓		✓							✓							
10	Enhance Payment Claim		✓	✓							✓						✓	
11	Enhance Safety and Risk Management								✓									✓

2.6 Barriers of Digital Tools Adoption in Construction Project during the Pandemic and Transition to Endemic

Owing to limited studies conducted on the barriers of leveraging digital tools in construction project during the pandemic and transition to endemic, this section also covers the general barriers of leveraging digital tools in construction project. Only main barriers are reviewed in this section such as substantial initial investment, shortage of professionals, lack of training level of workers, lack of top management support, poor internet connectivity, lack of government regulations and financial assistance, lack of individual privacy, unproven reliability of digital tools, organization culture, legal and contractual uncertainties and cybersecurity risk.

2.6.1 Substantial Initial Investment

Several studies have found that ginormous financial investment is one of the most prominent obstacles that stakeholders encountered when adopting innovation technologies (Hai, et al., 2021; Murguia, et al., 2021; Kissi, et al., 2022). In the light of the project delayed and project site closure during the pandemic, most of construction firms encountered financial burdens such as high levels of debt and low cash revenues which can lead liquidity crises (Assaad and El-Adaway, 2021; Gara, et al., 2022; Tan and Zainon, 2022) Additionally, Ayat, et al. (2021) and Stride, et al. (2022) noticed that the employers are obliged to provide personnel protective equipment (PPE) such as face mask for the workers in adhering the novel safety guidelines which resulting in the increment of financial burden. Thus, the resolution of the financial crisis and the expense of compliance with health and safety regulations take precedence over the investment in technology.

Besides, Hong, et al. (2019) stated that the license purchasing prices, expense of updating hardware and software and recurring maintenance payments are the principal financial struggles encountered by the stakeholders in implementing technologies. Additionally, the expenses on equipment and implementation cost also recognized as additional financial burden for organizations that lack affordability (Edirisinghe, 2019). With the vast amount of capital required and an undetermined rate of return, technology adoption is viewed as a high-risk investment, resulting in opposition to its implementation (Wee, et al., 2022).

2.6.2 Shortage of Professionals

In Nigeria, the official statistics revealed that about 39.4 million Nigerians were likely lose their employment due to Covid-19 pandemic, with construction workers losing the most jobs (Ebekozien and Aigbavboa, 2021). Correspondingly, Stride, et al., (2022) unveiled that in the UK, the epidemic exacerbates the skills deficit since up to 75% of the construction personnel loses their employments, along with a potential recession has ushering in several of construction firms ceasing operations. The aforementioned circumstances have evinced that the construction industry is prodigiously experiencing the catastrophe of professional layoffs in adopting smart technologies during the pandemic outbreak. In this respect, several construction organizations perceived that a dearth of qualified professionals in adopting innovative technologies can lead to the low productivity and disappointing performance (Demirkesen and Tezel, 2022). This is because high competency professionals are required to manipulate and supervise in order to ensure the technology operation throughout the construction project progress (Wee, et al., 2022). Thence, the shortage of specialists can severely hamper the technology adoption (Yang, et al., 2021).

2.6.3 Lack of Training Level of Workers

Training is defined as the development of one's knowledge or abilities in relation to specified relevant competencies. According to Kissi, et al. (2022), training highly competent employees for high-tech sectors such as construction is indispensable and arduous task, however it is also one of the most effective strategies to guarantee quality and escalate production's technical level. Nonetheless, Covid-19 epidemic has prompted a reassessment of human resource training practises due to cash flow issues arising from the project closure and project delayed (Mazurchenko and Zelenka, 2022). In this context, most construction companies, especially small-to-medium enterprises (SME), have less resilience and flexibility in dealing with the enormous training expenditures on numerous employees.

Besides, Evans and Farrell (2021) and Hasan, et al. (2021) presented that training requirements are commonly disregarded owing to the familiarity and user-friendliness of the smart technologies, even as they are gradually equipped with novel features and functionalities. In addition, as alluded by Camngca, et al. (2022), most of the contractors believed that training workers in technology application would be detrimental to a firm since the workers might job-hop to other construction firms. Thus, the contractors considered workers training as a waste of resource and productivity, which arising to the unwillingness and reluctance of contractors to invest in training (Tan, et al., 2019).

2.6.4 Lack of Top Management Support

Top management support refers to the extent at which top executives' comprehension and acknowledgement of the technology use toward the construction projects. In fact, most organizations underprepared for disaster management and relying on learning from bad experiences rather than taking a proactive approach, top executives have been less responsive in assessing the viability of organizations adopting technology to combat Covid-19 (Stride, et al., 2022). On the grounds that the unpredictable successful rate of newly introduced systems and technologies in an organization has prompted the fearness of risk-taking and project failure among senior management (Camngca, et al., 2022). Thus, top management hesitates to devote resources and inspire the subordinates to implement technology due to the limited recognition of technology usage. Eventually, Kissi, et al. (2022) further emphasized that the top management serves as a significance role in overhauling the working dynamics of firms in order to boost technology adoption.

2.6.5 Poor Internet Connectivity

The internet connectivity is the ability of individual or organizations to connect to internet for the data access using electronic devices. As specified by Oke, et al., (2021), the findings showed that internet connectivity is one of the potential issues that must be addressed to appropriately deploy smart technologies in developing countries. Owing to the global pandemic, the number of individuals working from home has grown exponentially, leading to the insufficient network capacity (Mazurchenko and Zelenka, 2022). This is because the internet access demand has raised abruptly, triggering an inevitable surge in internet traffic and causing the internet congestion. Consequently, the technology is incapable to attain the desired quality and performance of works due to the inadequate internet connection (Rachmawati, et al., 2021).

Furthermore, by the reason that most project sites are situated in underdeveloped rural areas, low or no internet access is commonplace (Bello, et al., 2021). This research also declared that the projects such as subterranean cabling, overhead lines, and substations covering a wider geographic region would suffer from insufficient connectivity along the project development. Thereby, fragile networks and unforeseen network disruptions can substantially hamper the potential of technologies such as cloud computing and IoT, which rely on ubiquitous high-speed internet for data access, processing, and storage (Kissi, et al., 2022). Ultimately, internet connectivity is found as a key factor in hindering the technology adoption (Ozumba and Shakantu, 2018).

2.6.6 Lack of Government Regulations and Financial Assistance

Government is playing vital role in driving and facilitating broader technology implementation using regulations and pecuniary aid. Numerous earlier studies emphasized that the lack of regulation and standardization in enforcing the technology application could be a critical obstruction to drive the wide-scale adoption (Edirisinghe, 2019; Tan, et al. 2019; Zhou, et al., 2019; Evans and Farrell, 2021). This is because the paucity of exhaustive detail policies, standards and procedures on digital technologies implementation can resulted in contradictory application outcomes amongst construction projects and organisations (Hasan, et al., 2021; Murguia, et al., 2021; Demirkesen and Tezel, 2022) Thus, this indicates that the absence of explicit guidelines may influence the motivation and decision making on technology adoption.

Besides, Ayat, et al. (2021) related that the lack of government subsidies or interest-less loans for construction industry is one of the potential issues in hindering the smart technology adoption. This is due to fact that the governments of underdeveloped nations have a limited understanding and awareness of technology use, which leads to negligence of financial aid. In this respect, construction corporations, particularly SMEs, would have a difficulty in accommodating the enormous implementation expenditure of digitalised tools. For instance, the Hong Kong Construction Innovation and Technology Fund granted subsidies for the costs associated with innovation adoption in order to mitigate financial burden and stimulate the immense usage of technologies (Yang, et al., 2021). As a consequence, the government incentive to intensify the technology diffusion is substantial.

2.6.7 Lack of Individual Privacy

Individual privacy becomes an importance aspect as the digital usage increases. During the pandemic, the use of technologies with tracing and monitoring attributes such as smart wearable, RFID and tracing application, transmitting of substantial amount of personal information such as identify, location and health status over the wireless network, may jeopardize the safety of workers (Siddiqui, et al., 2021). In this aspect, these sophisticated digital technologies have compelled the users to bear the risk of being tracked due to the location leakage. In addition, the workers might feel insecure due to the lack of authority to control over their own data. Thus, several researchers proclaimed that the construction personnel are predicted to resist technology adoption in order to against the invasion of privacy (Ozumba and Shakantu, 2018).

2.6.8 Unproven Reliability of Digital Tools

As delineated by Edirisinghe (2019), reliability of technology is the ability of the technology to perform effectively in a consistent manner and available to satisfy the user's requirements. Generally, the major concern of construction practitioners about the adoption of digital tools is the capability to achieve overall project performance in respects of client's satisfaction, quality, cost and time. This demonstrates that reliable technologies have the ability to address challenges in various manifestations, depending on their functionalities, to fulfil project development and operational requirements (Ozumba and Shakantu, 2018). Thus, the proven reliability of digital tools might be a crucial consideration for the decision makers in adopting digitalised technology.

2.6.9 Organization Culture

Pursuant to Evans and Farrell (2021) and Hai, et al. (2021), one of the most significant impediments to digital technology deployment is construction professionals' resistance to alter their current workflow. In other words, since the employees are too accustomed to perform their duties in conventional manner, organizations tend to preserve the traditional paper-based approach in order to retain the productivity, resulting in a reluctance to accept technology (Tan, et al., 2019). As enunciated by Edirisinghe (2019), the technology adoption will be futile if users refuse to accept and embrace it, regardless of how efficiency, generalizable and flexible the technology is. Thus, the reluctance to embrace technologies has placing them far behind in the development of reliable data and information processing capabilities (Kissi, et al., 2022). As a result, the omnipresent of pervasive conservatism in the building sector may jeopardise technology deployment (Ozumba and Shakantu, 2018; Yang, et al., 2021).

2.6.10 Legal and Contractual Uncertainties

Legal and contractual uncertainties refer to the absence of terms and clauses or ambiguity in legal declarations for certain project contracts. As adduced by Demirkesen and Tezel (2022), without explicit contract terms and unproven legal issues with the use of construction technologies, the probability of unanticipated liabilities and the hazard of litigation increases. Thus, Yang, et al. (2021) implicated that the conflicts in terms legal and contractual issues should be resolved to address the evasion of contractual responsibilities on the construction projects. Otherwise, engaging stakeholders required to endure uncertainty and possibly commit more time and money on coping with potential threats (Tan, et al., 2019). Thence, the absence of proper provision inclusion and adjustment to serve as a legal framework is a critical barrier to implement smart technology in construction projects (Jo, et al., 2018; Zhou, et al., 2019).

2.6.11 Cybersecurity Risk

The cybersecurity can be known as the safeguarding of computer systems and networks from detrimental intrusions. Conforming to Demirkesen and Tezel (2022), the pervasiveness of cyberattacks such as theft of confidential information, unsanctioned access to data and destruction of records has become a key issue for construction practitioners to utilize innovative digital tools. Oke, et al. (2021) claimed that the construction practitioners are sceptical of the technology ability in providing adequate security to data access control, data transmission across a distributed system, data confidentiality, service availability and safe communication. For instance, technologies such as IoT and cloud computing, which may create massive volumes of data and have unceasingly accessible to the internet, should be extraordinarily concerned since the tools are susceptible to daily assault (Kissi, et al., 2022). Thus, cybersecurity is also a significant hurdle for construction companies using internet-based technology in their projects.

2.6.12 Summary of Barriers of Digital Tools Adoption in Construction Project during the Pandemic and Transition to Endemic

Table 2.3 below summarises the barriers of digital tools adoption in construction project during the pandemic and transition to endemic from the literature review study.

Table 2.3: Summary of Barriers of Digital Tools Adoption in Construction Project during the Pandemic and Transition to Endemic

No.	Barriers	Assaad and El-Adaway	Ayat, et al. (2021)	Bello, et al. (2021)	Camngca, et al. (2022)	Demirkesen and Tezel (2022)	Ebekozien and Aigbavboa (2021)	Edirisinghe (2019)	Evans and Farrell (2021)	Gara, et al. (2022)	Hai, et al. (2021)	Hasan, et al. (2021)	Hong, et al. (2019)	Jo, et al. (2018)	Kissi, et al. (2022)	Mazurchenko and Zelenka (2022)	Murguia, et al. (2021)	Oke, et al. (2021)	Ozumba and Shakantu (2018)	Rachmawati, et al. (2021)	Siddiqui, et al. (2021)	Stride, et al. (2022)	Tan and Zainon (2022)	Tan, et al. (2019)	Wee, et al. (2022)	Yang, et al. (2021)	Zhou, et al. (2019)
1	Substantial Initial Investment	✓	✓					✓		✓	✓		✓		✓		✓					✓	✓		✓		
2	Shortage of Professionals					✓	✓															✓			✓	✓	
3	Lack of Training Level of Workers				✓				✓			✓			✓	✓								✓			
4	Lack of Top Management Support				✓										✓							✓					
5	Poor Internet Connectivity			✓											✓	✓		✓	✓	✓							
6	Lack of Government Regulations and Financial Assistance		✓			✓		✓	✓			✓	✓				✓							✓		✓	✓
7	Lack of Individual Privacy																		✓		✓						
8	Unproven Reliability of Digital Tools							✓											✓								
9	Organization Culture							✓	✓		✓				✓				✓					✓		✓	
10	Legal and Contractual Uncertainties					✓								✓										✓		✓	✓
11	Cybersecurity Risk					✓												✓									

2.7 Proposed Conceptual Framework

According to Dickson, et al. (2018), conceptual framework is a model that the researcher has developed to describe the development of the phenomena under study. Kivunja (2018) defined that conceptual framework is an overall, logical direction and associations of all elements that constitutes the fundamental ideas, structures, schemes, procedures and operations of the whole research. In other words, it is a structure to describe the relationships between the key variables or concepts of the entire research study (Tsiulin, et al., 2020). As shown in figure 2.1, the conceptual framework for this research outlines an overview of the interrelationships among the multiple variables. The variables for this research are the types of digital tools leveraged, potentials and barriers of digital tools implementing in construction project during the pandemic and transition to endemic.

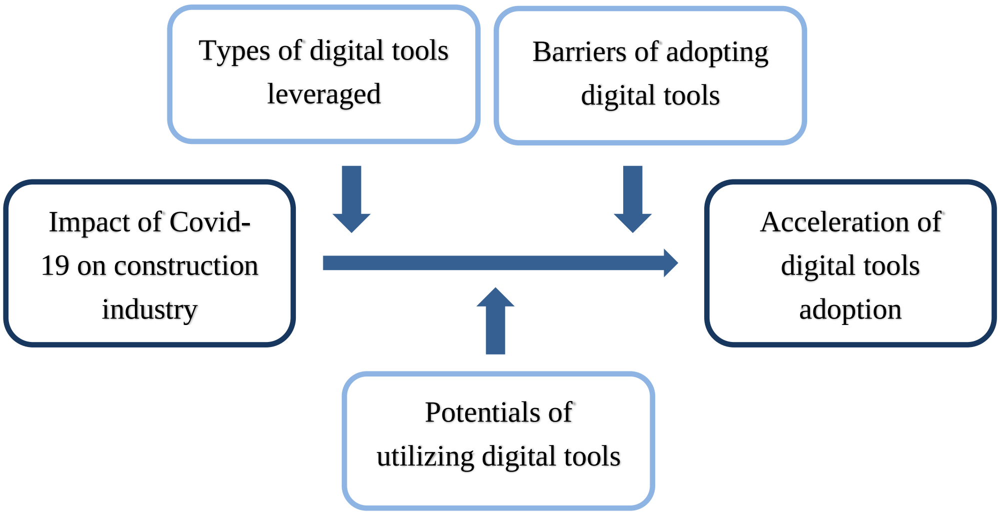

Figure 2.1: Conceptual Framework for the Adoption of Digital Tools in Construction Project during the Pandemic and Transition to Endemic

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapters primarily discusses the research methodology applied in this research. This chapter encompasses the definition of research, research philosophy, research methods, justification of selected philosophy and research method, research design, research instrument, sampling and data analysis.

3.2 Definition of Research

Research is a careful study of topic, particularly in an effort to uncover new facts or information about it (Oxford English Dictionary, 2022). According to Saunders, et al. (2016), research is defined as a systematic process that individuals engage in to discover new information and broaden one's horizons. The two phases are important in the definition: ‘systematic process’ and ‘discover new information’. As highlighted by Ghauri and Gronhaugh (2010), the term ‘systematic’ indicates that the research’s findings are grounded in logic rather than speculation, while the phrase ‘discover new information’ denotes refers to a broad range of research objectives that comprising defining, justifying, comprehending, commenting and interpreting.

3.3 Research Philosophy

According to Saunders, et al. (2016), research philosophy refers to a set of beliefs and hypotheses on the knowledge development. To put it simply, it is a development of knowledge in a certain topic is exactly what research entails. As defined by Creswell and Creswell (2018), individuals’ philosophy is shaped by their previous research experiences, discipline orientations as well as research communities. Through reflecting their own beliefs and assumptions in connection to the chosen philosophy, the individuals are able to defend and explain methodological choice, research approach, data collecting processes, and analytic methodologies. Positivism, critical realism, interpretivism, postmodernism, and pragmatism are the five key philosophies that will be discussed.

3.3.1 Positivism

Positivism is associated with the natural scientist and includes using empirical data from the social world to develop rule-like generalisations (Saunders, et al., 2016). In other words, examined problems highlight the need of discovering and analysing variables that impact outcomes, such as those discovered in experiments (Creswell and Creswell, 2018). According to Ghauri and Gronhaugh (2010), it includes scientific, objective, and quantifiable facts that can be used to forecast the future.

3.3.2 Critical Realism

Critical realism is also named as direct realism, aims to explain the environment around in terms of the fundamental reality structures that determine the observable occurrences (Saunders, et al., 2016). It holds that reality is objectively existing but is opaque to human perception and understanding. Conforming to Ghauri and Gronhaugh (2010), it states that diverse data and methodologies are permissible so long as the researcher is as impartial and practical as feasible.

3.3.3 Interpretivism

Interpretivism is a subjectivist criticism of positivism, emphasising that people are distinct from physical facts since they generate meanings (Saunders, et al., 2016). In specific, the purpose of research is to develop new, more nuanced understandings and interpretations of social environments and circumstances. As explained by Ghauri and Gronhaugh (2010), it aims to promote comprehension by presenting a variety of interpretational narratives with contextual considerations.

3.3.4 Post Modernism

Post modernism places an emphasis on language and power relations in challenging conventional ways of thinking and amplify underrepresented perspectives (Saunders, et al., 2016). As defined by (Ghauri and Gronhaugh (2010), post modernism comprises scrutinising prevalent discourses and uncovering hidden meanings. To put it simply, this philosophy is to drastically question the dominant methods of thinking and knowing by giving a platform to previously unheard perspectives.

3.3.5 Pragmatism

According to Saunders, et al. (2016), pragmatism holds that conceptions are only meaningful to the extent that they facilitate action. It attempts to seek a balance between objectivism and subjectivism, realism and idealism, rigour and variation in knowledge as well as diversity of contextualised experiences. As claimed by Creswell and Creswell (2018), there are various variations on this philosophy, but for many, this mode of thinking emerges from acts, circumstances, and results rather than prior conditions.

3.4 Research Methods

Research methods are the systematic, targeted, and organised data collection for the goal of extracting information in order to solve or answer a particular research question or issue (Ghauri and Gronhaugh, 2010). There are two forms of research method, which are qualitative research and quantitative research. Alternatively, researchers may merge these two methodologies into a single study, which is known as mixed methods research.

3.4.1 Qualitative research

According to Cooper and Schindler (2014), qualitative research involves a range of interpretative approaches aimed to express, interpret, translate or otherwise agreeing with the meaning rather than the frequency of certain more or less naturally occurring events in the social environment. In specific, it is prevalent in social and behavioural sciences for the purpose of gaining insight into human behaviour and functions (Ghauri and Gronhaugh, 2010). This approach is ideal in giving granular information and in-depth knowledge when studying an event or social process that is difficult to investigate using quantitative methods. The approaches in collecting data of qualitative research might consist of visiting a study location and observing people's behaviour without asking any leading questions, or it could consist of an interview in which the interviewee is given the freedom to speak freely about a subject without being prompted by the interviewer (Creswell and Creswell, 2018).

3.4.2 Quantitative research

Quantitative research is focusing on the relationships between variables, which use numerical measurements and other statistical and graphical methods for analysis (Saunders, et al., 2016). Conforming to Creswell and Creswell (2018), the variables should be measurable or observable features or properties of an individual or organization that varies among the individuals or organisations being investigated. Typical study variables comprising age, gender, education, job position, views or behaviours. Generally, questionnaires and semi-structured interviews are the techniques used for data collection in this methodology (Ghauri and Gronhaugh, 2010).

3.4.3 Mixed methods research

The mixed methods research is defined as the approach that merging qualitative and quantitative data collection methods and analytical procedures (Cooper and Schindler, 2014). Pertaining to Saunders, et al. (2016), the combination of both types of techniques can be in variety forms, ranging from basic, contemporaneous forms to more complicated and sequential configurations. In contrast to employing a mono method design, such technique integration provides for a deeper and more thorough solution to the research issue. This implies that the qualitative research can countervail the quantitative research's shortcomings and vice versa. Creswell and Clark (2018) declared that the qualitative and quantitative research can be either equal or unequal in the mixed methods research. The weight attributed to quantitative or qualitative research may be differ since it is primarily depending on the research objectives. Thus, one approach dominates while the another serves as an auxiliary.

3.5 Justification of Selected Philosophy and Research Method

The pragmatism philosophy is the ideal approach for this research as it emphasises the practical application of knowledge and the significance of empirical evidence. Thus, it fits well with the research objectives which attempt to identify the types of digital tool leveraged, as well as the potentials and barriers of adopting digital tools in the construction project throughout the pandemic and transition to endemic. As a result, the researcher can delve deeper into the perceptions and experiences of construction practitioners in implementing digital tools to achieve the aim of this research which is to investigate the adoption of digital tools in construction project during the pandemic and transition to endemic. The Covid-19 pandemic has acted as a catalyst for boosting digitalisation in the construction industry, which makes it an important empirical event to study.

Owing to the massive number of respondents are required as the research sample data to generate plentiful of statistical data, the quantitative method is chosen for data collection in this research. As such, the stances of respondents on the leveraging of digital tools in construction project during the pandemic and transition to endemic will be identified. A survey research technique will be employed via distributing questionnaires to a sizable population of targeted respondents in an utterly cost-effective manner. Such approach allows the researcher to acquire a prodigious quantity of data efficiently and effectively in a relatively limited time frame. Besides, the collected quantitative data permits the formulation of plausible explanations for specific correlations between variables and the development of models of these interactions. In this respect, the data obtained may be interpreted to determine the frequency of adopting each digital tool, the potentials of various digital tools applications and the barriers inhibiting the digital tools implementation in construction project during the pandemic and transition to endemic. As a consequence of exploiting such scientific and relatable quantitative methods, the findings generated will be more consistent, dependable, and organised.

3.6 Research Design

According to Ghauri and Gronhaugh (2010), research design is defined as the entire strategy plan for connecting the theoretical study's issue with relevant and feasible empirical study. In specific, it outlines the steps to be taken in gathering and analysing the research data. The research design provides an investigation framework to aid the researchers in obtaining solutions to research questions.

Initially, the research scope “information and communications technology (ICT)” is selected prior proceed to the selection of research topic. Since the scope of ICT is too vast to investigate thoroughly in a single report, ancillary subjects should be included to restrict and narrow the area of research study. In light of the current trend of IR 4.0 in the construction sector and the outbreak of Covid-19, "Leverage digital tools in construction project during the pandemic and transition to endemic" was selected as the topic of this research.

After settling on a research topic, reams of research resources in the form of academic journals, conference papers, review articles and e-books pertaining to the keywords such as ‘adoption of construction digital tools’ and ‘Covid-19 pandemic in construction industry’ are retrieved and studied. During the retrieving process, the issue of this research topic is identified. Following that, the reviewed resources are sifted further to suit the research topic and contribute useful content. Throughout the process of literature review, the areas of research covered by the previous researchers are explored and analysed in order to discover the research gap. The research gap found was the adoption of digital tools in construction project during the pandemic and transition to endemic. Afterwards, the identified issue has prompted the establishment of objectives and aim in order to address the problem or answer the research gap.

Next, the types of research philosophy and method are recognized and studied in order to determine and apply them to this research. For this research, the primary data of quantitative method is selected to explore the types of digital tools leveraged, potentials and barriers of adopting digital tools in the construction project during the pandemic and transition to endemic via questionnaire distribution. Whereas, the secondary data of this research is acquiring from the journal, review articles, conference papers, e-books, news and government statistics. Once the data is collected from the respondents via questionnaire, the outcomes are evaluated to properly aggregate data. Subsequently, the collected data is subject to data analysis. The descriptive and influential tests are employed to analyse the data for this research. Accordingly, the data analysis outcomes are discussed and conclusions are drawn in order to attain the research objectives and aim.

Ultimately, a comprehensive conclusion is developed, encompassing the accomplished objectives, research implications, limitations, and recommendations for future research. Figure 3.1 illustrates the research design workflow of this research from scope identification to the research conclusion.

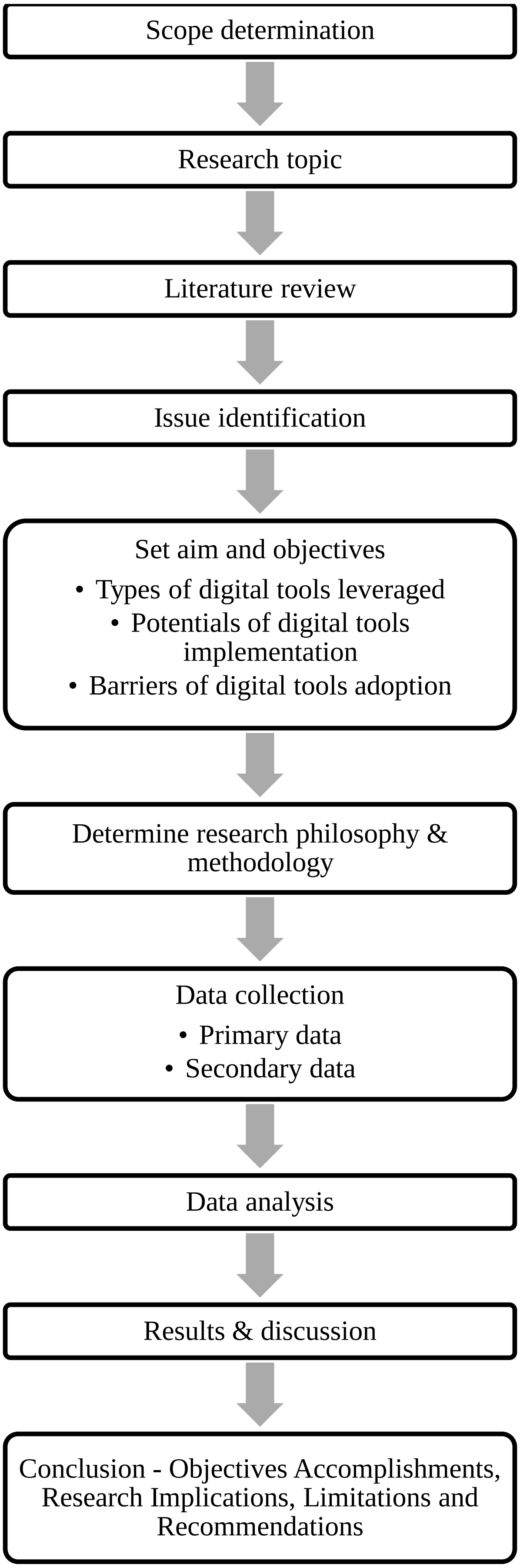

Figure 3.1: Research Design Workflow

3.7 Research Instrument

The term "research instrument" exists to describe the approach, procedure, or tool used to collect, measure, and analyse data relevant to the research's theme. The procedures of collecting data for this final year project is explained in the followings.

3.7.1 Questionnaire Design

In this research, the questionnaire survey was deployed to elicit responses from the targeted respondents. This questionnaire is divided into four distinct sections, as indicated in Table 3.1. The first section, Section A probed the demographic data of the respondents which encompasses nature of company's business, position in organization, working experience in the construction industry, highest academic qualification and size of company. All of these data will serve as independent variables to scrutinize the relationship with the dependent variables in the Section B3, C and D of the questionnaire.

Further, Section B is further divided into three subsections. Question B1 and B2 were chiefly concerned with the recommendation to adopt and the exact adoption level of digital tools in construction project in the midst of the pandemic and including the transition to endemic. In both questions, respondents were asked to rate their opinions with a set of 10 various digital tools on a five-point Likert scale. On the other hand, question B3 was created to explore the respondents' preference in utilizing traditional or digitalised method in their construction projects.

Subsequently, Section C covered the potentials of digital tools implementation, whereas Section D exposed the barriers of adopting digital tools in construction projects in the context of pandemic and including the transition to endemic. There are 11 assertions mentioned in both sections and a five-point Likert scale rating was used in an attempt to unravel the respondents' viewpoints.

Table 3.1: Summary of Questionnaire Design

Section	Description
A	Demographic Information
B	Adoption Level of Digital Tools in Construction Project during the Pandemic (Including the Transition to Endemic)
C	Potentials of Leveraging Digital Tools in Construction Project during the Pandemic (Including the Transition to Endemic)
D	Barriers of Leveraging Digital Tools in Construction Project during the Pandemic (Including the Transition to Endemic)

3.8 Sampling

The term "sampling" refers to an alternate technique of selecting a representative subset of a population which is known as sample (Saunders, et al., 2016). In order to bolster the reliability of the study's findings, it is indeed crucial to discover and select a sufficient sample of suitable respondents from the study's target population in a methodical manner. The stages in the sampling process are expounded in the following subsections: defining the population, determining the sample frame, determining the sample design, determining the sample size as well as executing the sampling process.

3.8.1 Defining the Population

Population refers to the complete collection or group of cases or elements from which a sample is derived (Saunders, et al., 2016). This step is imperative in diminishing the possibility of recruiting respondents who are not appropriate for the aims of the research. In a view to achieve the research's objectives and goals, the population is bounded to construction practitioner who are presently active in the construction sector since they are most qualified to answer the questions and provide insight into the research issues.

3.8.2 Determining the Sampling Frame

Sampling frame is essentially a list of elements that serves as the basis for selecting a sample during a research study (Cooper and Schindler, 2014). In other words, it is a limit imposed on the sample size from a huge population group. In general, it is conceivable and desirable to have more than one sample frame in a research study since each sampling frame will present various sorts or levels of information and perspectives on the research topic.

In this research, the four groups of the sampling frame which comprise of the consultant, contractor, developer and supplier or subcontractor or specialist who are legitimate party in carrying out construction-related activity. The information on the legal registration and certification of a construction company is easily accessible and obtained via the government bodies and relevant authorities such as Construction Industry Development Board (CIDB), Board of Quantity Surveyors Malaysia (BQSM), Pusat Khidmat Kontraktor (PKK) and Suruhanjaya Syarikat Malaysia (SSM).

3.8.3 Determining the Sampling Design

There are two types of sampling designs: probability sampling and non-probability sampling. According to Ghauri and Gronhaugh (2010), the term "probability sampling" denotes a sample drawn at random from a population where every unit in the population having an equal and predictable probability of being chosen. On the contrary, non-probability sampling is a sample that was not picked using a random selection method. Non-probability sampling is divided into several sorts, including convenience sampling, quota sampling, purposive sampling, voluntary response sampling, and snowball sampling.

In this study, the convenience sampling and snowball sampling were employed to collect the sample. Conforming to Nikolopoulou (2022), the convenience sampling enables the researcher to recruit any readily available individuals as the respondents based on their availability at a specific time, geographical vicinity, or desire to participate in the study. On the other hand, the snowball sampling refers to new units being brought into the sample by other units (Nikolopoulou, 2022). To put it simply, it offers respondents the opportunity to aid the researcher in disseminating the questionnaire to others who are eligible to participate in this study. Eventually, both approaches have significantly magnified the efficiency, speed, accessibility and reduced the cost in collecting the data.

3.8.4 Determining the Sampling Size

Sampling size can be simply known the total number of individuals or events that are involved in the research. Pertaining to Cooper and Schindler (2014), the Central Limit Theorem (CLT) specifies that the means of multiple random samples taken from a population will tend to cluster around the population mean. This property holds true for sample sizes of at least 30, where the distribution of the sample means will closely approximate a normal distribution. To put it concisely, a sample size of 30 or more is adequate to resemble a normal distribution, meaning that it is valid and dependable for reflecting the vast majority of the population. As such, a minimum of 30 responses for each demographic information would be gathered in order to ensure the reliability of the study's outcomes. As a result, it is estimated that a minimum of 120 samples is required with consideration of four categories of respondents' attributes.

3.8.5 Executing the Sampling Process

Once the population, sampling frame, sampling design and sample size were determined, the data collection would be executed. The data was collected by disseminating via social media platforms including LinkedIn and WhatsApp. The survey questionnaire was created in Google form. The questionnaire was circulated to target respondents who are the construction practitioners in the Klang Valley region to tease out their perceptions and attitudes on leveraging digital tools in construction project in the course of the pandemic and during the transition to endemic. Subsequently, the acquired data would be assessed via applying the influential tests as enunciated in the following section.

3.9 Data Analysis

This section clarifies the data analysis methodologies used in this study. The analysis of the data was performed by using SPSS (Statistical Program for the Social Sciences). There are multiple of influential tests would be implemented in this research, encompassing the Cronbach's Alpha Reliability test, Friedman test, Spearman's Rank Correlation Coefficient test, Kruskal-Wallis test and Pearson's Chi-Square test.

3.9.1 Cronbach's Alpha Reliability Test

Cronbach's Alpha Reliability test is an approach to assesses the reliability of an instrument by comparing the degree of shared variance or covariance among its items to the overall variance in the scores. (Collins, 2007). In other words, it is utilized evaluate the consistency of a scale that measures a particular construct. (Saunders, et al., 2016). The outcome of this test will be an alpha coefficient, which falls between 0 and 1. As stated by Ghauri and Gronhaugh (2010), the coefficient value higher than 0.7 is regarded as indicative of good reliability, while a value below 0.5 is seen as inadequate and unreliable. The rule of thumb for the result of this test are depicted in Table 3.3. In this research, this test is exploited to measure the internal consistency of the Likert scale questions in Sections B, C, and D of the questionnaire.

Table 3.2: Cronbach's Alpha Reliability Coefficient Range (Glen, 2023)

Cronbach's alpha	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.9.2 Friedman Test

The Friedman test serves as a non-parametric substitute for the one-way Analysis of Variance (ANOVA) with repeated measures, and it is employed to gauge the differences between groups when the dependent variable is presented in ordinal scale (Laerd Statistics, 2018). In essence, this test examines the relative rankings of different groups and determines if the observed differences between them are statistically significant. In this study, this test is employed to evaluate the importance level of the dependent variables in questionnaire Section B1, B2, B3, C and D.

3.9.3 Spearman's Rank-Order Correlation Coefficient Test

The Spearman rank-order correlation coefficient is a statistical method that can assess the direction and strength of the relationship betwixt two variables, which are measured at least on an ordinal scale (Laerd Statistics, 2018). In other words, it is fruitful in diagnosing whether there is a monotonic relation between the two variables and determining the strength of correlations. In further detail, the range of Spearman's correlation coefficients is between -1 and +1, with the coefficient's sign revealing whether there is a positive or negative monotonic relationship between the variables being studied (Frost, 2021). As asserted by Glen (2023), a positive correlation means that when one variable increases, the other variable tends to increase as well. Conversely, a negative correlation indicates that as one variable increases, the other tends to decrease. The grading standards table of Spearman correlation coefficient (ρ) are delineated in Table 3.4. As such, this test is deployed to appraise the correlation betwixt questionnaire Section B1 and B2 which are the recommendation to adopt digital tools and the actual adoption level of such tools in construction projects during the pandemic and the transition to an endemic respectively.

Table 3.3: Grading Standards Table of Spearman Correlation Coefficient (ρ) (Yan, et al., 2019)

Grading standards	**Correlation Degree**
$\rho = 0$	No correlation
$0 < \lvert\rho\rvert \leq 0.19$	Very weak
$0.20 \leq \lvert\rho\rvert \leq 0.39$	Weak
$0.40 \leq \lvert\rho\rvert \leq 0.59$	Moderate
$0.60 \leq \lvert\rho\rvert \leq 0.79$	Strong
$0.80 \leq \lvert\rho\rvert < 1.00$	Very strong
1.00	Monotonic correlation

3.9.4 Kruskal-Wallis Test

Kruskal-Wallis test is a nonparametric statistical method that compares two or more independent groups based on their rank data to assess if there are significant differences between the dependent variables which are in continuous or ordinal scale (Laerd Statistics, 2018). It is an augmentation of the Mann-Whitney U test in order to allow for comparisons between more than two groups. If the p-value is less than or equal to the predetermined level of significance of 0.05, it indicates that there is a statistically significant relationship between the independent and dependent variables, which means that the null hypothesis can be rejected in favour of the alternative hypothesis. Thereupon, this test is engaged to determine the rejected null hypotheses for all the variables in Section C and D which are the potentials and barriers of leveraging digital tools in construction projects during the pandemic and including the transition to endemic, respectively.

3.9.5 Pearson's Chi-Square Test

Pearson's Chi-Square test also referred to as the Chi-Square test of association or independence, is a statistical hypothesis test that is non-parametric in nature. The main objective of this test is to determine if there is any relationship between two categorical variables (Turney, 2022). As asserted by Frost (2021), if the p-value of a Chi-square test is less than or equal to the significance level selected, it denotes that there is adequate evidence to infer that the observed distribution is different from the anticipated distribution. As such, this finding authenticated that there is a relationship between the categorical variables. Thence, this test is implemented with the objective of discerning the associations between the categorical variables present in Sections A and B3, with the purpose of uncovering the specific categories that exhibit the greatest predilection towards either traditional or digitalised methodologies.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapters reveals the outcomes of deciphering data from the questionnaire surveys. The acquired data was sorted, processed and tabulated using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. The purpose of this chapter's analysis and discussion is to attain the goals and objectives set forth in Chapter 1.

4.2 Demographic Information of Respondents

In this research, there is a total of 135 respondents who are employed in the construction sector and have cordially acquiesced to partake in an all-encompassing questionnaire. The explained questionnaire in Chapter 3 was disseminated from 1st February 2023 to 31st March 2023 via Google Form. A total of 250 invitations were sent through LinkedIn, e-mail and personal contacts. As of 3rd April 2023, 135 valid responses were received which is tantamount to 54%. The demographic information of the respondents has been succinctly encapsulated in Table 4.1.

According to Table 4.1, there are 35 consultants, 36 contractors, 33 developers, and 31 specialists, subcontractors, or suppliers. Besides, respondents are divided into four categories: 35 are junior executives, 36 are senior executives, 34 are supervisors, team leaders or managers, and 30 are Directors, Managing Directors, CEOs or Assistant Directors. Out of the total respondents, approximately 59 individuals had work experience ranging from 0 to 5 years, 30 individuals had 6 to 10 years of work experience and 46 individuals more than 10 years of work experience. Furthermore, the data indicates that over half of the participants which is 73 of them possessed a Bachelor's Degree, while 32 of them held a High School Diploma or Certificate, and the remaining 30 respondents had a Postgraduate Degree, including PhD or Master's Degree. Ultimately, the participants are mainly from three different categories of company sizes, with 44 individuals from micro or small-sized companies, 41 individuals from medium-sized companies, and 50 individuals from large-sized companies.

Table 4.1: Demographic Information of Respondents

Demographic Information	**Categories**	**Frequency (n)**	**Percentage (%)**
Company business nature	Consultant	35	25.90
	Contractor	36	26.70
	Developer	33	24.40
	Specialist/ Subcontractor/ Supplier	31	23.00
Position	Junior executive	35	25.90
	Senior executive	36	26.70
	Supervisor/ Team Leader/ Manager	34	25.20
	Director/ Managing Director/ CEO/ Assistant Director	30	22.20
Working Experience	0 - 5 years	59	43.70
	6 - 10 years	30	22.20
	> 10 years	46	34.10
Academic Qualification	High School/ Diploma/ Certificate	32	23.70
	Bachelor's Degree	73	54.10
	Postgraduate Degree (PhD, Master's Degree)	30	22.20
Company Size	Micro-sized (< 5 employees) & Small-sized (5 - 29 employees)	44	32.60
	Medium-sized (30 - 75 employees)	41	30.40
	Large-sized (> 75 employees)	50	37.00

4.3 Cronbach's Alpha Reliability Test

Table 4.2 depicts the outcomes of the Cronbach's Alpha Reliability Test conducted on section B, C, and D of the questionnaire. According to the table 4.2, the Cronbach Alpha value of each section has surpassed the value of 0.7, signifying that these three sections have met the criteria of good internal consistency.

Table 4.2: Cronbach's Alpha Test Result for Each Section of Questionnaire

Section	Cronbach's Alpha	Number of Items
B	0.899	38
C	0.907	11
D	0.845	11

4.4 Adoption of digital tools in Construction Project during the Pandemic and Including the Transition to Endemic

Table 4.3 illustrates the mean ranking of the adoption level of digital tools in construction project during the pandemic and the transition to an endemic phase by the targeted respondents. Conforming to the findings, the most widely adopted digital tool is cloud computing, followed by Building Information Modelling (BIM), Unmanned Aerial Vehicles (UAVs) or drones, smart wearables, Internet of Things (IoT), Radio-Frequency Identification (RFID), Augmented Reality (AR) and Virtual Reality (VR), blockchain, 3D printing, and finally autonomous robotics.

Table 4.3: Mean Ranking of Digital Tools Adoption Level

Code	Statements	Mean Rank	Chi-square	Asymp. Sig.
B2A2	Cloud Computing	8.80	498.227	<.001
B2A1	Building Information Modelling (BIM)	7.19		
B2A4	Unmanned Aerial Vehicle (UAV) / Drone	6.04		
B2A9	Smart Wearables	5.81		
B2A3	Internet of Things (IoT)	5.57		
B2A6	Radio Frequency Identification Device (RFID)	5.36		
B2A7	Augmented Reality (AR) and Virtual Reality (VR)	4.79		
B2A8	Blockchain	3.87		

Table 4.3 (Continued)

Code	Statements	Mean Rank	Chi-square	Asymp. Sig.
B2A10	3D printing	3.85		
B2A5	Autonomous Robotics	3.72		

4.5 Recommendation Towards Digital Tools Adoption in Construction Project during the Pandemic and Including the Transition to Endemic

The mean ranking of the recommended digital tools in construction projects during the pandemic and the shift towards an endemic state by the target respondents is elucidated in Table 4.4. The results show that the most highly ranked tool is cloud computing, followed by BIM, smart wearables, IoT, drone, AR and VR, RFID, 3D printing, autonomous robotics, and lastly blockchain.

Table 4.4: Mean Ranking of Digital Tools Recommendation

Code	Statements	Mean Rank	Chi-square	Asymp. Sig.
B1R2	Cloud Computing	7.78	276.450	<.001
B1R1	Building Information Modelling (BIM)	6.70		
B1R9	Smart Wearables	5.81		
B1R3	Internet of Things (IoT)	5.73		
B1R4	Unmanned Aerial Vehicle (UAV) / Drone	5.73		
B1R7	Augmented Reality (AR) and Virtual Reality (VR)	5.45		
B1R6	Radio Frequency Identification Device (RFID)	5.39		
B1R10	3D printing	4.36		
B1R5	Autonomous Robotics	4.15		
B1R8	Blockchain	3.91		

With the purpose of scrutinizing the relationship between the recommendation and adoption level of digital tools in construction project during the pandemic and the transition to an endemic phase, the Spearman rank-order correlation coefficient was conducted. Each digital tool was tested to determine whether it correlated with its corresponding tool, for instance, the correlation between the recommendation of BIM and the adoption level of BIM.

Table 4.5 presented the strength and ranking of correlation coefficient between the recommendation and adoption level of digital tools.

Table 4.5: Correlation Coefficient between the Recommendation and Adoption Level of Digital Tools

Statements	Correlation coefficient	Sig.
Cloud Computing	0.542	0.000
Radio Frequency Identification Device (RFID)	0.498	0.000
Smart Wearables	0.497	0.000
Building Information Modelling (BIM)	0.495	0.000
3D printing	0.482	0.000
Blockchain	0.472	0.000
Augmented Reality (AR) and Virtual Reality (VR)	0.418	0.000
Internet of Things (IoT)	0.394	0.000
Autonomous Robotics	0.356	0.000
Unmanned Aerial Vehicle (UAV) / Drones	0.312	0.000

4.6 Preference Between Traditional and Digitalised Method

Table 4.6 delineates the frequency and percentage of respondents who preferred traditional or digitalised methods for conducting construction project activities during the pandemic and the transition to an endemic phase. In order to disclose and compare the relationship between the respondents' demographic profile and their preferred method, the Pearson's Chi-Square test was adopted. Table 4.7 summarizes the rejected null hypothesis for the relationship between the respondents' background and preference between traditional and digitalised method which are statistically significant with $p < 0.05$.

Table 4.6: Preference of Traditional and Digitalised Method among the Respondents

Code	Statements	Traditional Frequency (N)	Traditional Percentage (%)	Digitalised Frequency (N)	Digitalised Percentage (%)
B3TD1	Design or Modelling / Measurement (Printed or CAD drawings / Microsoft Excel vs BIM)	6	4.40	129	95.60
B3TD2	Planning and Management of Construction Activities (Physical site visit vs BIM)	49	36.30	86	63.70
B3TD3	Data Transfer/Sharing (Pendrive/Email vs Cloud Computing)	6	4.40	129	95.60
B3TD4	Data Storage (Pendrive/Email/Hard disk vs Cloud Computing)	8	5.90	127	94.10
B3TD5	Meeting (Physical meeting vs Cloud Computing [eg: Cloud-based Google meet, Zoom, Microsoft Team, Skype])	43	31.90	92	68.10
B3TD6	On-site Real Time Data Collection/Site Surveillance (Physical site visit/ On-site video and photos capturing vs Internet of Things (IoT))	64	47.40	71	52.60
B3TD7	Body Temperature Checking (Temperature screener with manual recording vs Internet of Things (IoT))	37	27.40	98	72.60
B3TD8	Monitoring and Supervising Site Activities (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	66	48.90	69	51.10
B3TD9	Topographic Survey (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	43	31.90	92	68.10
B3TD10	Construction Tasks such as Concreting, Bricklaying, Finishing Laying (Manual workforce vs Autonomous Robotics)	67	49.60	68	50.40
B3TD11	Material and Equipment Tracking and Checking (Manual recording/ barcodes vs Radio Frequency Identification Device (RFID))	42	31.10	93	68.90
B3TD12	Worker Identification / Attendance Checking (Manual recording/ ID card scanning vs Radio Frequency Identification Device (RFID))	44	32.60	91	67.40

Table 4.6 (Continued)

Code	Statements	Traditional		Digitalised	
		Frequency (N)	**Percentage (%)**	**Frequency (N)**	**Percentage (%)**
B3TD13	Pre-construction Building Design Concept (Printed or CAD drawings vs Augmented Reality (AR) and Virtual Reality (VR))	24	17.80	111	82.20
B3TD14	Employee Training Programs (Physical site visit vs Augmented Reality (AR) and Virtual Reality (VR))	58	43.00	77	57.00
B3TD15	Procurement (Printed drawings and documents vs Blockchain)	35	25.90	100	74.10
B3TD16	Interim Payment/Supply Chain Payment (Manual payment/ banking/cheque vs Blockchain)	53	39.30	82	60.70
B3TD17	Health or Safety Condition Checking (Self-reporting vs Smart Wearables)	37	27.40	98	72.60
B3TD18	Manufacturing and Installation of Construction Elements (Off-site manufacturing, transportation and on-site manual construction vs 3D printing)	51	37.80	84	62.20

Table 4.7: Pearson's Chi-Square Test for the Preference of Traditional and Digitalised Method among the Respondents

Code	Statements	Categories	Traditional		Digitalised		Asymp. Sig.
	Business nature		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
B3TD7	Body Temperature Checking (Temperature screener with manual recording vs Internet of Things (IoT))	Consultant	12	34.30	23	65.70	0.031
		Contractor	5	13.90	31	86.10	
		Developer	14	42.40	19	57.60	
		Specialist/ Subcontractor/ Supplier	6	19.40	25	80.60	

Table 4.7 (Continued)

Code	Statements	Categories	Traditional		Digitalised		Asymp. Sig.
	Business nature		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
B3TD7	Body Temperature Checking (Temperature screener with manual recording vs Internet of Things (IoT))	Consultant	12	34.30	23	65.70	0.031
		Contractor	5	13.90	31	86.10	
		Developer	14	42.40	19	57.60	
		Specialist/ Subcontractor/ Supplier	6	19.40	25	80.60	
B3TD8	Monitoring and Supervising Site Activities (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	Consultant	15	42.90	20	57.10	0.018
		Contractor	14	38.90	22	61.10	
		Developer	24	72.70	9	27.30	
		Specialist/ Subcontractor/ Supplier	13	41.90	18	58.10	
B3TD12	Worker Identification / Attendance Checking (Manual recording/ ID card scanning vs Radio Frequency Identification Device (RFID))	Consultant	16	45.70	19	54.30	0.038
		Contractor	7	19.40	29	80.60	
		Developer	14	42.40	19	57.60	
		Specialist/ Subcontractor/ Supplier	7	22.60	24	77.40	
B3TD17	Health or Safety Condition Checking (Self-reporting vs Smart Wearables)	Consultant	8	22.90	27	77.10	0.048
		Contractor	6	16.70	30	83.30	
		Developer	15	45.50	18	54.50	
		Specialist/ Subcontractor/ Supplier	8	25.80	23	74.20	

Table 4.7 (Continued)

Code	Statements	Categories	Traditional		Digitalised		Asymp. Sig.
	Position		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
B3TD4	Data Storage (Pendrive/Email/Hard disk vs Cloud Computing)	Junior Executive	1	2.90	34	97.10	0.009
		Senior Executive	0	0.00	36	100.00	
		Supervisor / Team Leader / Manager	6	17.60	28	82.40	
		Director/ Managing Director/ CEO/ Assistant Director	1	3.30	29	96.70	
B3TD9	Topographic Survey (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	Junior Executive	9	25.70	26	74.30	0.032
		Senior Executive	6	16.70	30	83.30	
		Supervisor / Team Leader / Manager	14	41.20	20	58.80	
		Director/ Managing Director/ CEO/ Assistant Director	14	46.70	16	53.30	
B3TD14	Employee Training Programs (Physical site visit vs Augmented Reality (AR) and Virtual Reality (VR))	Junior Executive	18	51.40	17	48.60	0.035
		Senior Executive	15	41.70	21	58.30	
		Supervisor / Team Leader / Manager	8	23.50	26	76.50	
		Director/ Managing Director/ CEO/ Assistant Director	17	56.70	13	43.30	

Table 4.7 (Continued)

Code	Statements	Categories	Traditional		Digitalised		Asymp. Sig.
	Position		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
B3TD16	Interim Payment/Supply Chain Payment (Manual payment/ banking/cheque vs Blockchain)	Junior Executive	16	45.70	19	54.30	0.009
		Senior Executive	18	50.00	18	50.00	
		Supervisor / Team Leader / Manager	5	14.70	29	85.30	
		Director/ Managing Director/ CEO/ Assistant Director	14	46.70	16	53.30	
	Working Experience						
B3TD3	Data Transfer/Sharing (Pendrive/Email vs Cloud Computing)	0 - 5 years	0	0.00	59	100.00	0.016
		6 - 10 years	4	13.30	26	86.70	
		> 10 years	2	4.30	44	95.70	
B3TD14	Employee Training Programs (Physical site visit vs Augmented Reality (AR) and Virtual Reality (VR))	0 - 5 years	18	30.50	41	69.50	0.031
		6 - 10 years	17	56.70	13	43.30	
		> 10 years	23	50.00	23	50.00	
B3TD16	Interim Payment/Supply Chain Payment (Manual payment/ banking/cheque vs Blockchain)	0 - 5 years	16	27.10	43	72.90	0.031
		6 - 10 years	16	53.30	14	46.70	
		> 10 years	21	45.70	25	54.30	
	Academic Qualification						
B3TD16	Interim Payment/Supply Chain Payment (Manual payment/ banking/cheque vs Blockchain)	High School/ Diploma/ Certificate	20	62.50	12	37.50	0.000
		Bachelor's Degree	29	39.70	44	60.30	
		Postgraduate Degree	4	13.30	26	86.70	

4.7 Agreement on the Potentials of Digital Tools Implementation in Construction Project during the Pandemic and Including the Transition to Endemic

Table 4.8 displays the mean ranking of the potentials of digital tools implementation in construction project during the pandemic and the transition to an endemic phase by the target respondents. The top three potentials ranked by the respondents were CP6 - I adopt cloud computing to promote my project's communication and collaboration, CP 2 - I adopt BIM to enhance my project's site planning and management and CP1 - I adopt BIM, AR and VR to enhance my project design. On the other hand, the last two rankings were CP7 - I adopt autonomous robotics and 3D printing to efficiency of repetitive task and monotonous workflows of my project and CP5 - I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification.

Table 4.8: Mean Ranking of the Respondents' Agreement on the Potentials of Digital Tools Implementation

Code	Statements	Mean Rank	Chi-square	Asymp. Sig.
CP6	I adopt cloud computing to promote my project's communication and collaboration	7.99	274.582	<.001
CP2	I adopt BIM to enhance my project's site planning and management	7.63		
CP1	I adopt BIM, AR and VR to enhance my project design	7.04		
CP8	I adopt BIM, AR and VR to enrich my project members' education and training	6.51		
CP4	I adopt UAV/drone and IoT (sensors) to enhance my project's site inspection	6.23		
CP11	I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management	5.43		
CP3	I adopt RFID to enhance my project's material supply chain and inventory management	5.33		
CP10	I adopt blockchain to enhance my project's payment claim	5.27		
CP9	I adopt blockchain to enhance my project's procurement contracting management	5.21		
CP7	I adopt autonomous robotics and 3D printing to efficiency of repetitive task and monotonous workflows of my project	4.86		
CP5	I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification	4.50		

The Kruskal Wallis test was performed in this research to compare the differences in agreement among respondents regarding the potentials of digital tools implementation in accordance with their demographic information. Table 4.9 presents the rejected null hypothesis for the potentials of digital tools implementation against the demographic information of respondents which are the statistically significant with $p < 0.05$.

Table 4.9: Rejected Null Hypothesis for the Respondents' Agreement on the Potentials of Digital Tools Implementation

Code	Null Hypothesis	Asymp. Sig.
	Business Nature	
CP3	I adopt RFID to enhance my project's material supply chain and inventory management is same among respondents with the group of Consultant, Contractor, Developer and Specialist/ Subcontractor/ Supplier.	0.038
CP5	I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification is same among respondents with the group of Consultant, Contractor, Developer and Specialist/ Subcontractor/ Supplier.	0.015
CP8	I adopt BIM, AR and VR to enrich my project members' education and training is same among respondents with the group of Consultant, Contractor, Developer and Specialist/ Subcontractor/ Supplier.	0.017
CP9	I adopt blockchain to enhance my project's procurement contracting management is same among respondents with the group of Consultant, Contractor, Developer and Specialist/ Subcontractor/ Supplier.	0.020
CP11	I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management is same among respondents with the group of Consultant, Contractor, Developer and Specialist/ Subcontractor/ Supplier.	0.048
	Academic Qualification	
CP1	I adopt BIM, AR and VR to enhance my project design is same among respondents with academic qualification of High School/ Diploma/ Certificate, Bachelor's Degree and Postgraduate Degree.	0.005
CP5	I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification is same among respondents with academic qualification of High School/ Diploma/ Certificate, Bachelor's Degree and Postgraduate Degree.	0.048

Table 4.9 (Continued)

Code	Null Hypothesis	Asymp. Sig.
	Company Size	
CP1	I adopt BIM, AR and VR to enhance my project design is same among respondents with company size of Micro-sized (< 5 employees) and Small-sized (5 - 29 employees), Medium-sized (30 - 75 employees) and Large-sized (> 75 employees).	0.023
CP9	I adopt blockchain to enhance my project's procurement contracting management is same among respondents with company size of Micro-sized (< 5 employees) and Small-sized (5 - 29 employees), Medium-sized (30 - 75 employees) and Large-sized (> 75 employees).	0.007

The result of the Kruskal Wallis test for the potentials as illustrated in Table 4.9 are summarized below:

(A) The group of Developer agreed

(i) more towards CP3 - I adopt RFID to enhance my project's material supply chain and inventory management (mean rank = 83.32) than group of Consultant (mean rank = 68.79), Contractor (mean rank = 60.33) and Specialist/ Subcontractor/ Supplier (mean rank = 59.71)

(ii) more towards CP5 - I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification (mean rank = 77.33) than group of Consultant (mean rank = 76.01), Contractor (mean rank = 67.01) and Specialist/ Subcontractor/ Supplier (mean rank = 50.16)

(iii) more towards CP8 - I adopt BIM, AR and VR to enrich my project members' education and training (mean rank = 85.76) than group of Contractor (mean rank = 63.35), Consultant (mean rank = 63.30) and Specialist/ Subcontractor/ Supplier (mean rank = 59.81)

(iv) more towards CP9 - I adopt blockchain to enhance my project's procurement contracting management (mean rank = 84.64) than group of Consultant (mean rank = 68.80), Specialist/ Subcontractor/ Supplier (mean rank = 59.90) and Contractor (mean rank = 58.94)

(v) more towards CP11 - I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management (mean rank = 79.64) than group of Consultant (mean rank = 71.40), Specialist/ Subcontractor/ Supplier (mean rank = 67.27) and Contractor (mean rank = 54.65)

(B) The group of Postgraduate Degree agreed

(i) more towards CP1 - I adopt BIM, AR and VR to enhance my project design (mean rank = 74.53) than group of Bachelor's Degree (mean rank = 73.53) and High School/ Diploma/ Certificate (mean rank = 49.25)

(ii) more towards CP5 - I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification (mean rank = 79.65) than group of Bachelor's Degree (mean rank = 68.47) and High School/ Diploma/ Certificate (mean rank = 56.00)

(C) The group of Large-sized (>75 employees) company agreed

(i) more towards CP1 - I adopt BIM, AR and VR to enhance my project design (mean rank = 75.42) than group of Medium-sized (30 - 75 employees) (mean rank = 72.38) and Micro-sized (< 5 employees) & Small-sized (5 - 29 employees) (mean rank = 55.49)

(ii) more towards CP9 - I adopt blockchain to enhance my project's procurement contracting management (mean rank = 75.38) than group of Medium-sized (30 - 75 employees) (mean rank = 74.83) and Micro-sized (< 5 employees) & Small-sized (5 - 29 employees) (mean rank = 53.25)

4.8 Perception towards the Barriers that Obstruct Digital Technologies Deployment in Construction Project during the Pandemic and Including the Transition to Endemic

The mean ranking of the barrier that obstruct digital tools deployment in construction project during the pandemic and the transition to endemic phase by the target respondents is shown in Table 4.10. The top three ranking of barriers were DB4 - Lack of Top Management Support, followed by DB9 - Organization Culture and DB1 - Substantial Initial Investment. On the contrary, the last two barriers were DB8 - Proven Reliability of Digital Tools and DB7 - Individual Privacy.

Table 4.10: Mean Ranking of the Barriers that Obstruct Digital Technologies Deployment

Code	Statements	Mean Rank	Chi-square	Asymp. Sig.
DB4	Lack of Top Management Support	6.86	108.443	<.001
DB9	Organization Culture (eg: resistance to change and prefer to adopt traditional method)	6.69		
DB1	Substantial Initial Investment	6.49		
DB6	Lack of Government Regulations and Financial Assistance	6.49		
DB3	Lack of Training Level of Workers	6.31		
DB2	Shortage of Professionals	6.27		
DB11	Cybersecurity Risk	6.10		
DB10	Legal and Contractual Uncertainties	5.55		
DB5	Poor Internet Connectivity	5.30		
DB8	Unproven Reliability of Digital Tools	5.29		
DB7	Lack of Individual Privacy	4.65		

The Kruskal Wallis test was performed to examine whether there were significant differences in respondents' perceptions of the barriers to digital tool deployment in construction projects based on their demographic characteristics. Table 4.11 displays the rejected null hypothesis for the barriers that obstruct digital tools deployment against the demographic information of respondents which are statistically significant with $p < 0.05$.

Table 4.11: Rejected Null Hypothesis for the Perception towards the Barriers that Obstruct Digital Tools Deployment

Code	Null Hypothesis	Asymp. Sig.
	Business Nature	
DB3	Lack of Training Level of Workers is same among respondents with the group of Consultant, Contractor, Developer and Specialist/ Subcontractor/ Supplier.	0.001

Table 4.11 (Continued)

Code	Null Hypothesis	Asymp. Sig.
	Position	
DB10	Legal and Contractual Uncertainties is same among respondents with the position of Junior Executive, Senior Executive, Supervisor / Team Leader / Manager and Director/ Managing Director/ CEO/ Assistant Director.	0.003
	Working Experience	
DB6	Lack of Government Regulations and Financial Assistance is same among respondents with the working experience of 0 - 5 years, 6 - 10 years and > 10 years.	<.001
DB10	Legal and Contractual Uncertainties is same among respondents with the working experience of 0 - 5 years, 6 - 10 years and > 10 years.	0.005
	Academic Qualification	
DB6	Lack of Government Regulations and Financial Assistance is same among respondents with academic qualification of High School/ Diploma/ Certificate, Bachelor's Degree and Postgraduate Degree.	0.007
DB10	Legal and Contractual Uncertainties is same among respondents with academic qualification of High School/ Diploma/ Certificate, Bachelor's Degree and Postgraduate Degree.	0.008

(A) The group of Contractor perceived

(i) more towards DB3 - Lack of Training Level of Workers (mean rank = 77.63) as the barrier of digital tools deployment than group of Consultant (mean rank = 75.80), Developer (mean rank = 69.33) and Specialist/ Subcontractor/ Supplier (mean rank = 46.60)

(B) The group of Junior Executive perceived

(i) more towards DB10 - Legal and Contractual Uncertainties (mean rank = 80.83) as the barrier of digital tools deployment than group of Senior Executive (mean rank = 75.07), Supervisor/ Team Leader/ Manager (mean rank = 63.78) and Director/ Managing Director/ CEO/ Assistant Director (mean rank = 49.33)

(C) The group of > 10 years working experience perceived

(i) more towards DB6 - Lack of Government Regulations and Financial Assistance (mean rank = 83.95) as the barrier of digital tools deployment than group of 0 – 5 years working experience (mean rank = 62.92) and 6 – 10 years working experience (mean rank = 53.55)

(D) The group of 0 - 5 years working experience perceived

(i) more towards DB10 - Legal and Contractual Uncertainties (mean rank = 75.46) as the barrier of digital tools deployment than group of 6 – 10 years working experience (mean rank = 75.22) and > 10 years working experience (mean rank = 53.73)

(E) The group of Postgraduate Degree perceived

(i) more towards DB6 - Lack of Government Regulations and Financial Assistance (mean rank = 80.93) as the barrier of digital tools deployment than group of High School/ Diploma/ Certificate (mean rank = 76.88) and Bachelor's Degree (mean rank = 58.96)

(ii) more towards DB10 - Legal and Contractual Uncertainties (mean rank = 79.98) as the barrier of digital tools deployment than group of Bachelor's Degree (mean rank = 70.16) and High School/ Diploma/ Certificate (mean rank = 51.84)

4.9 Discussion

This section serves to expound upon the outcomes that were previously explicated in the antecedent sections in a comprehensive manner. The discussion is bifurcated into a few distinct subdivisions, which are types of digital tools leveraged, potentials and barriers of digital tools adoption in construction project during the pandemic and the transition to endemic phase.

4.9.1 Cloud Computing Appears as the Most Leveraged Digital Tool in Construction Project during the Pandemic and the Transition to Endemic

a) Digital Tools Adopted in Construction Projects during the Pandemic and the Transition to Endemic

As revealed in Table 4.3, the digital tool with highest adoption level in construction project during the pandemic and its aftermath is B2A2 - Cloud

Computing. This finding is concurrent with the finding of research by Narayanamurthy and Tortorella (2021), Demirkesen and Tezel (2022), Leontie, et al. (2022), who all conclude that cloud computing is the most widely adopted technology in the course of Covid-19 interventions. Firstly, the cloud computing offers an economical, boundless capacity and entirely virtual data storage that effectively eliminate the concern of organization’s financial burden to invest in the extravagant hardware (Taghipour and Mahboobi, 2020; Bello, et al., 2021). As such, enormous amount of project files and other data can be stored in cloud without the need for costly filing cabinets. Secondly, cloud computing serves as a seamless integration platform by enabling centralized data sharing (Elrefaey et al., 2022; Saratchandra, et al., 2022). This allows diverse teams and stakeholders to access the same data, assuring consistency and accuracy throughout the project regardless of location or appliance. For instance, the construction practitioners can share and modify the documents in real-time and interact through video conferencing while adhering to Covid-19 measures such as social distancing and remote work. In addition, Hemanth, et al. (2017) highlights that cloud computing proffers a sense of security for the organizations and users, safeguarding the confidential information from unauthorised access by outsiders or the public.

The second highest digital tools adopted in construction project is B2A1 - BIM. This discovery aligns with the conclusions drawn by the studies, including Demirkesen and Tezel (2022) and Leontie, et al. (2022), which both conclude that BIM is one of the most commonly deployed technologies in reaction to the Covid-19 outbreak. As posited by CIDB (2020), the implementation of BIM has been made obligatory for public projects costing RM100 million or more beginning in 2019, which has played a significant role in initiating its adoption. In extra, the Public Works Department (PWD) Strategic Plan for 2021 to 2025 has inaugurated a target of 50% mechanism adoption in 2021 and 80% by 2025 (Aziz, 2020). With the BIM initiatives mentioned earlier, these was deemed as a logical rationale for the considerable number of private sector respondents interested to learn about and adopt this innovative technology in their own building projects (Othman, et al., 2021). With the effort of demonstrating the practicality and successes of BIM adoption by public sector as a concrete example, private sector companies can learn from and utilize as a valuable reference point to implement BIM in their own private projects. Additionally, CIDB has funded RM 2.5 million in a one-stop referral centre which is known as myBIM centre, that offers BIM software training to developers, contractors, consultants, and suppliers. These companies can apply for BIM training courses under the CIDB Transformation Fund program, which has allocated RM 1 million as a financial incentive for BIM adoption (Sinoh, et al., 2020). Consequently, these initiatives play a key role in propelling BIM adoption in construction industry, leading to its position as the second most adopted digital tool.

Besides, B2A4 - Drone is becoming increasingly prevalent in the construction industry, ranking third among digital tools used in construction projects. According to Nwaogu, et al. (2023), drones have proven highly useful in a range of purposes within the construction industry, including aerial photography, site surveys, site inspection, drop and delivery, mapping, and terrestrial surveying. In addition, their adoptions have been accelerated by a surge in drone readiness in several countries, including Malaysia, the United Kingdom, Brazil, Switzerland, Taiwan, Japan, South Korea, and China, highlighting the recognition of the value of this technology across various fields (Lo, 2023). In the similar vein, Abualigah, et al. (2021) attested that the drones have been successfully adopted across the commercial, manufacturing, agricultural, military, search and rescue, and transportation realms. In light of these, it is probable that the degree of confidence among construction professionals with regard to the deployment of drones will outweigh the considerable costs associated with purchasing and operating such technology.

b) Construction Practitioners' Preferences towards Either Traditional or Digitized Approaches in Executing Construction Tasks

As illustrated in Table 4.6, there were eighteen propositions with respect to the construction activities for the respondents to select their preference between traditional and digitalised methods. Based on the tabulated data, the majority of the respondents have preferred to perform the construction activities using digitalised approach. This implies that the respondents acknowledge the potentials that digital tools in multiple aspects of construction work to improve efficiency, precision, and communication, while simultaneously reducing expenses and increasing profitability. The potentials of the digital tools implementation will be further discussed in Section 4.9.2.

As reflected in Table 4.7, it was found that most of respondents employed in contractor companies exhibited a greater inclination towards utilizing digitalised means for monitoring construction site activities such as B3TD7 - Body Temperature Checking, B3TD8 - Monitoring and Supervising Site Activities, B3TD12 - Worker Identification / Attendance Checking and B3TD17 - Health or Safety Condition Checking. As asserted by CIDB (2019), the contractor is mandated to cover all activities related to the construction production process and prepare progress reports for clients to review. In this regard, they typically bear the responsibility in the event of mishaps, making it crucial for them to be vigilant and proactive in monitoring and supervising the building work progress. Owing to their greater level of accountability and volume of on-site tasks, digital tools are deemed to be an efficient resolution for overseeing construction operations and detecting issues in real-time, thereby reducing the likelihood of errors or accidents. Thereupon, it is beneficial for contractors to embrace digital tools for the building works instead of relying solely on traditional methods.

Furthermore, the employment of digitalised approaches in data utilization, such as B3TD4 - Data Storage, B3TD9 - Topographic Survey, B3TD14 - Employee Training Programs and B3TD16 - Interim Payment/Supply Chain Payment, is more preferred by respondents in senior level and above than those in junior executive positions. The rationale for this preference can be attributed to their role and authority in making critical decisions for the success of the project. As they hold higher positions, they are responsible for managing resources, assessing risks, and making strategic decisions that can significantly impact the project's outcome. As such, digital technologies play a critical role in facilitating prompt access to the physical layer and a profusion of data, which is indispensable in supporting informed decision-making and enhancing managerial efficiency (Vasista and Abone, 2018; Maskuriy, et al., 2019; Osunsanmi, et al., 2020). Henceforth, it is imperative to utilize digital tools that grant access to precise and updated data to enable informed decision-making at the managerial level.

Moreover, it was revealed by the study that the utilization of digital methods for collecting data, including B3TD3 - Data Transfer/Sharing, B3TD14 - Employee Training Programs, and B3TD16 - Interim Payment/Supply Chain Payment, are highly favoured by respondents who have worked between 0 to 5 years. This underscores the point that the younger novice workers who are more familiar with technology prone to embrace digital techniques more readily, especially for entry-level duties like data gathering. In order to uphold their competitiveness in the industry, Auta and Onwusuru (2022) advocated that entry-level construction practitioner should be well-equipped with a thorough understanding of advanced machineries and gadgets. Conversely, individuals who lack proficiency in operating digital tools are perceived as antiquated and may be less likely to be engaged. In the construction sector, data collection is an entry level task that requires precision, productivity, and meticulousness. As such, it is worth noting that the utilization of digital tools in data collection can mitigate errors, amplifying output, and conserving time, which is particularly advantageous for novice practitioners with limited experience. Therefore, it is vital to integrate digital tools into data collection process, as it can prove to be a precious resource for entry-level practitioners in construction industry.

Besides, it was discovered that the majority of participants possessing a Postgraduate Degree displayed a proclivity for exploiting digitalised methods in the realm of financial management, specifically in relation to B3TD16 - Interim Payment/Supply Chain Payment, as compared to those holding Bachelor's Degrees or High School, Diploma or Certificate credentials. This may be attributed to their exposure to the concept of digitalisation through their studies and research. In addition, owing to the overwhelming of late payment and cash flow related issues associated with the traditional contract, it is essential to seek for more efficient and secure way in managing payments in the course of IR 4.0 blooming. In view of these, blockchain provides secure and transparent management of transactions, with the use of smart contracts ensuring payments are made only upon meeting specific conditions (Perera, et al., 2020). By using smart contracts, real-time tracking and monitoring of transactions can prevent disputes, delays, and improve financial planning and management for all parties involved (Li and Kassem, 2021). In contrary, the process of traditional paper-based payment is time-consuming and information-intensive, as it still relies on manual and intermediated workflows (Ye, et al., 2018; Hamledari and Fischer, 2021). For instance, the traditional cheque payment system can be inconvenient and costly because it requires physical transportation and processing through intermediaries like banks, which can add to the complexity and increase the expenses associated with the transaction. Thus, respondents with Postgraduate Degree tend to favour blockchain over traditional payment methods due to its ability to provide secure and transparent transactions that can prevent delays, disputes and improve financial management.

c) Summary of Construction Practitioners' Preferences towards Either Traditional or Digitized Approaches in Executing Construction Tasks

Table 4.12 illustrates a summary of the Pearson’s Chi-Square test results of the respondents' preference towards digitalised methods. According to the table, it can be inferred that most respondents with demographic background of contractor and 0 to 5 years working experience showed a stronger preference for digitalised method over traditional methods.

As per Table 4.12, the contractors prefer digitalised methods in building works for several reasons. Initially, digital tools can improve the efficiency and accuracy of construction processes in order to ensure the project completion. In particular, digital tools have proven to be useful in managing on-site works during the Covid-19 pandemic, allowing for compliance with social distancing requirements and enabling stakeholders to share data on virtual platforms. Second, the adoption of digital technologies is the core concept of Industry 4.0, which is transforming the construction industry and making it more competitive. Contractors who fail to embrace Industry 4.0 may struggle to remain competitive in the market. Thus, the use of digital technologies can assist contractors in distinguishing themselves from their rivals and gaining a competitive edge in the market.

On the other hand, younger practitioners who have had 0 to 5 years of experience are more likely to gravitate toward digital approaches since they grew up in a digital era and are more familiar with technology. These young professionals consider digital tools to be an essential part of their daily life and demand the same degree of accessibility in their work. Furthermore, younger professionals are more receptive to new technologies and willing to engage them to improve their efficiency and effectiveness at work. The construction sector is progressively embracing digital technology and numerous companies recognize the benefits of these tools. As a result, young practitioners who are well-versed in digital technologies may have a competitive advantage in the job market and be more appealing to employers seeking tech-savvy candidates.

Table 4.12: Summary of Pearson's Chi-Square Test Results of the Respondents' Preference Towards Digitalised Methods

Code	Preference between Traditional and Digitalised	Demographic Information		Digitalised method	
				Frequency (N)	Percentage (%)
B3TD1	Design or Modelling / Measurement (Printed or CAD drawings / Microsoft Excel vs BIM)	-			
B3TD2	Planning and Management of Construction Activities (Physical site visit vs BIM)	-			
B3TD3	Data Transfer/Sharing (Pendrive/Email vs Cloud Computing)	Working Experience	0 - 5 years	59	100.00
B3TD4	Data Storage (Pendrive/Email/Hard disk vs Cloud Computing)	Position	Senior Executive	36	100.00
B3TD5	Meeting (Physical meeting vs Cloud Computing [eg: Cloud-based Google meet, Zoom, Microsoft Team, Skype])	-			
B3TD6	On-site Real Time Data Collection/Site Surveillance (Physical site visit/ On-site video and photos capturing vs Internet of Things (IoT))	-			
B3TD7	Body Temperature Checking (Temperature screener with manual recording vs Internet of Things (IoT))	Business nature	Contractor	31	86.10
B3TD8	Monitoring and Supervising Site Activities (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	Business nature	Contractor	22	61.10
B3TD9	Topographic Survey (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	Position	Senior Executive	30	83.30
B3TD10	Construction Tasks such as Concreting, Bricklaying, Finishing Laying (Manual workforce vs Autonomous Robotics)	-			

Table 4.12 (Continued)

Code	Preference between Traditional and Digitalised	Demographic Information		Digitalised method	
				Frequency (N)	**Percentage (%)**
B3TD11	Material and Equipment Tracking and Checking (Manual recording/ barcodes vs Radio Frequency Identification Device (RFID))	-			
B3TD12	Worker Identification / Attendance Checking (Manual recording/ ID card scanning vs Radio Frequency Identification Device (RFID))	Business nature	Contractor	29	80.60
			Specialist/ Subcontractor/ Supplier	24	77.40
B3TD13	Pre-construction Building Design Concept (Printed or CAD drawings vs Augmented Reality (AR) and Virtual Reality (VR))	-			
B3TD14	Employee Training Programs (Physical site visit vs Augmented Reality (AR) and Virtual Reality (VR))	Position	Supervisor / Team Leader / Manager	26	76.50
		Working Experience	0 - 5 years	41	69.50
B3TD15	Procurement (Printed drawings and documents vs Blockchain)	-			
B3TD16	Interim Payment/Supply Chain Payment (Manual payment/ banking/cheque vs Blockchain)	Position	Supervisor / Team Leader / Manager	29	85.30
		Working Experience	0 - 5 years	43	72.90
		Academic Qualification	Postgraduate Degree	26	86.70

Table 4.12 (Continued)

Code	**Preference between Traditional and Digitalised**	**Demographic Information**		**Digitalised method**	
				Frequency (N)	**Percentage (%)**
B3TD17	Health or Safety Condition Checking (Self-reporting vs Smart Wearables)	Business nature	Contractor	30	83.30
B3TD18	Manufacturing and Installation of Construction Elements (Off-site manufacturing, transportation and on-site manual construction vs 3D printing)	-			

4.9.2 Promote Communication and Collaboration Emerges as Key Potential of Digital Tools in Construction Project during the Pandemic and the Transition to Endemic

a) Potentials of the Digital Tools Implementation in Construction Project during the Pandemic and the Transition to Endemic Agreed by the Respondents

Referring to Table 4.8, CP6 - I adopt cloud computing to promote my project’s communication and collaboration has been determined as the digital tool implementation potential that received the highest agreement from respondents. The Covid-19 pandemic has led to new norms such as WFH and virtual meetings, making cloud computing an essential tool for organizations to maintain communication and collaboration among team members. This digital tool has proven to be particularly beneficial in facilitating remote work and providing the necessary scalability and flexibility in the face of Covid-19 pandemic (Liew, 2020). Besides, cloud computing plays a crucial role in enabling more intensive and effective video meetings virtual communication through video and audio-conferencing platforms like Microsoft Teams, Zoom, and Skype (Kohont and Ignjatović, 2022). This integration has aided organizations to overcome the limitation of social contact boundary, thereby maintaining a sense of teamwork, collaboration and interactions without being physically present in the same location. Simultaneously, the deployment of cloud-based systems for document storage, accessibility, and sharing has been effortless and efficient for multiple tasks, enabling individuals to maintain productivity while working from homes comfortably (Oyesode, et al., 2022). In addition, Bello, et al. (2021) appended that cloud-based services are highly scalable, which makes them ideal for organizations with fluctuating project requirements. In other words, this digital tool has the capability to be scaled to accommodate additional project team members, subcontractors, or stakeholders if required, without necessitating additional hardware or software and additional costs.

Subsequently, it can be inferred that the second most agreed potential of digital tools implementation is CP2 - I adopt BIM to enhance my project’s site planning and management. According to Tan and Samad (2022), pandemic prevention measures have hindered construction projects' progress, resulting in project timeline rescheduling and workforce reorganization to comply with safety protocols such as limiting the number of workers on-site. In view of this, Assafi, et al. (2022) denoted that BIM design review tool, namely Autodesk Navisworks Manage with 4D TimeLiner function has the capability in coordinating and simulating different construction project phases to resolve the pandemic-related scheduling conflicts and optimize resource allocation, ultimately leading to timely and budget-compliant project completion. Apparently, the utilization of BIM can mitigate the dilemma of ceaseless delay that led to cost overruns, minimizing the potential negative impact of the pandemic on construction projects.

Furthermore, it is worth noting that CP1 - I adopt BIM, AR and VR to enhance my project design is positioned as the third most potential of digital tools implementation by the respondents. Conforming to the research of Luo, et al. (2020), it is proven that BIM is a valuable digital tool in enhancing design accuracy while effectively avoiding or reducing bottlenecks and omissions. BIM enables designers to create a virtual model of their designs, which helps identify potential issues in an early stage of the project, avoiding costly errors and delays. At the same time, AR and VR technologies can revolutionize the design process by creating an immersive experience that enhances the accuracy and quality of the design process. By allowing multiple designers to join the same virtual environment and interact with each other in real-time, AR and VR enable collaborative design platform that overcomes physical boundaries due to the Covid-19 pandemic (Tea, et al., 2022). Consequently, adopting these digital tools can significantly enhance the design process and quality of design outcomes.

b) Relationships Between the Potentials of the Digital Tools Implementation in Construction Project and the Attributes of Respondents

As indicated in Table 4.9, there are significant differences in six potentials, namely CP1 - I adopt BIM, AR and VR to enhance my project design, CP3 - I adopt RFID to enhance my project’s material supply chain and inventory management, CP5 - I adopt UAV/drone and IoT (sensors) to improve my project’s Covid-19 virus infection identification, CP8 - I adopt BIM, AR and

VR to enrich my project members' education and training, CP9 - I adopt blockchain to enhance my project's procurement contracting management and CP11 - I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management across business nature, education qualification and company size.

The respondents working for developer firm are more agreed on the potentials of digital tools in data acquisition and analytic compared to consultant, contractor and subcontractor/ specialist/ supplier, including CP3 - I adopt RFID to enhance my project's material supply chain and inventory management, CP5 - I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification, CP8 - I adopt BIM, AR and VR to enrich my project members' education and training, CP9 - I adopt blockchain to enhance my project's procurement contracting management and CP11 - I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management. The rationale for this may be the developers typically take a client-centric approach when working on projects, where project feasibility and budget allocation are given utmost priority to ensure the successful completion of projects (Bajjou and Chafi, 2020; Mishra and Priyadarshini, 2021). Given that developer's profits fluctuate violently with changes in economic conditions, which can make generalizing their profits dangerous. Thereupon, they tend to be more cautious about budget allocation and avoid excessive spending to achieve a considerable return on investment. In this context, developers are more likely to adopt digital tools that facilitate project control and supervision. By utilizing digital tools in project management, developers can ensure timely and precise control over project execution, which helps keep the project on track. This approach enables them to make any necessary adjustments promptly and ultimately contribute to the project's success while maintaining budget constraints.

Besides, the majority of the respondents who working in large-sized company (> 75 employees) are more agreed on the potentials of digital tools in project management compared to micro-sized or small-sized company and medium-sized company, comprising CP1 - I adopt BIM, AR and VR to enhance my project design and CP9 - I adopt blockchain to enhance my project's procurement contracting management. This could be attributed to the fact that large-sized company possesses more extensive resources to allocate towards digital tools and availability of in-house tools for employment. Prior research found that large-sized company has the mean to invest in costly in-house groupware systems to facilitate the sharing of internal information (Pan and Pan, 2019; Bajjou and Chafi, 2020; Greco, et al., 2021). In addition, large-sized companies can tailor in-house tools to suit specific project requirements, providing greater control over the project management process. These advantages are particularly relevant for large-sized companies which have a greater probability of securing larger and intricate projects that necessitate advanced design, management proficiencies and data interoperability. By leveraging their greater resources and in-house tools, large-sized companies can establish data standards and protocols that promote interoperability between different systems, resulting in more efficient project design and contract procurement management.

c) Summary of Relationships Between the Potentials of the Digital Tools Implementation in Construction Project and the Attributes of Respondents

Table 4.13 summarizes the relationships between the potentials of the digital tools implementation in construction project and the attributes of respondents. Based on the table, it can be concluded that respondents who work for developer companies and large-sized firms are more likely to acknowledge the potentials of digital tools implementation in construction projects during the pandemic and transition to endemic.

The developers tend to agree with the potential of digital tools in construction project, as they hold responsibility for overseeing the entire project and aim to ensure its success through a client-centric approach. In light of this, developers recognize the importance of staying up-to-date on the project's status from the client's viewpoint. This has prompted them to realise the potentials of digital tools that provide real-time information, better communication channels, and cost management capabilities. Particularly during the pandemic and transition to endemic, these tools are imperative for developers to make informed decisions that ensure proper budget allocation, on-time completion and continuity of the project. Ultimately, the use of digital tools enables developers to deliver high-quality projects to their clients or the public.

Large-sized companies tend to exhibit a greater inclination towards recognising the potential of digital tools in construction projects due to their access to a wide range of resources and in-house tools. These companies have the financial capacity allocate resources towards acquiring advanced technology and software, thereby streamline project management operations and enhance collaboration between team members. Additionally, larger companies may encounter more complex projects with greater susceptibility to cost overruns and delays, thus accentuating the significance of digital tools in guaranteeing the successful completion of the project. As a result, digital tools are a valuable asset for large companies seeking to improve the overall quality and efficiency of their construction projects.

Table 4.13: Summary of Relationships Between the Potentials of the Digital Tools Implementation and the Attributes of Respondents

Code	Potentials	Demographic Information		Mean Ranking
CP1	I adopt BIM, AR and VR to enhance my project design	Education Qualification	Postgraduate Degree	74.53
			Bachelor's Degree	73.53
		Company Size	Large-sized (>75 employees)	75.42
CP2	I adopt BIM to enhance my project's site planning and management	-		
CP3	I adopt RFID to enhance my project's material supply chain and inventory management	Business nature	Developer	83.32
CP4	I adopt UAV/drone and IoT (sensors) to enhance my project's site inspection	-		
CP5	I adopt UAV/drone and IoT (sensors) to improve my project's Covid-19 virus infection identification	Business nature	Developer	77.33
		Education Qualification	Post	79.65
CP6	I adopt cloud computing to promote my project's communication and collaboration	-		
CP7	I adopt autonomous robotics and 3D printing to efficiency of repetitive task and monotonous workflows of my project	-		
CP8	I adopt BIM, AR and VR to enrich my project members' education and training	Business nature	Developer	85.76
CP9	I adopt blockchain to enhance my project's procurement contracting management	Business nature	Developer	84.64
		Company Size	Large-sized (>75 employees)	75.38
CP10	I adopt blockchain to enhance my project's payment claim	-		
CP11	I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management	Business nature	Developer	79.64

4.9.3 Lack of Top Management Support Remains the Main Barrier in Construction Project during the Pandemic and the Transition to Endemic

a) Barriers of Digital Tools Adoption in Construction Project during the Pandemic and the Transition to Endemic Perceived by the Respondents

As disclosed by Table 4.5, the outcomes reveal that there is a moderate correlation between the respondents' recommendation and adoption level of digital tools. This insinuates that despite the construction practitioners' recommendation to leverage digital tools in performing construction tasks, there is still low adoption level of digital tools during the pandemic and the shift to an endemic phase in the construction sector. The grounds for the low adoption level may be attributed to the obstacles outlined in Table 4.10.

The first ranked barrier that obstruct the digital tool adoption is DB4 - Lack of Top Management Support. The discovery is correspondent with the findings of the research by Ahmed, et al. (2022) and Chigara and Moyo (2022). As contended by Lashitew (2023), top management holds considerable influence over strategic decisions made by a corporation, which encompasses choices related to the implementation and utilisation of technology. The adoption decisions pertaining to technology can be influenced by the risk appetite of top management, their crisis navigation strategies, and their willingness to embrace novel digital technologies. According to Piyathanavong, et al. (2022), pandemic is widely regarded as a significant risk factor that has heightened the urgency for companies to embrace Industry 4.0 technologies as a means of enhancing their operational capabilities. Nonetheless, the comprehensive integration of Industry 4.0 technologies remains restricted and has yet to be fully implemented across the entirety of the organisation, as it is a gradual process that occurs over an extended period. In addition, the pandemic has prompted the company to shift its focus and strategies towards minimising and abstaining from superfluous expenditures on the inventory, materials, workforce and production in order to sustain the longevity of company's operations while adhering to Covid-19 safety protocols, rather than investing in technological advancements. Thus, significance of top management support cannot be understated in terms of facilitating cultural transformation and promoting the uptake of innovative technologies throughout an organisation.

Besides, DB9 - Organization Culture is the second significant barrier that confronted by the respondents. This disclosure is concurrent with the research by Ebekozien and Aigbavboa (2021), Low, et al. (2021) and Waqar, et al. (2023), who found that construction practitioners exhibit a reluctance to change the pre-existing surroundings, thereby leading to a rise in the resistance in adopting technologies. Owing to the construction industry's deeply entrenched conservative and risk-averse processes and systems, making it difficult to overcome resistance to change and shift towards more innovative practices. As a result, tried and tested methods are often prioritized over new and untested technology. Further, the fear towards unknown or acknowledgment of the benefits that digital tools, may pose challenges in obtaining consensus and support from all members of the organization. In view of these, the dilemma of adopting digital tools for responding to the pandemic effectively while sustaining the operations of construction projects is anticipated to be exacerbated.

Furthermore, the result discloses that the third critical barrier is DB1 - Substantial Initial Investment. This finding is concurrent with the research by Balasubramanian, et al. (2021) and Ebekozien and Aigbavboa (2021). The rationale behind is the lack of confidence of return on investment in digital tools implementation since there is often a significant lag time between the implementation of digital technologies and the realisation of a return on investment (Kumar, et al., 2022). The return on investment can be a complex undertaking, as it is contingent upon the actions of construction practitioners who are accountable for task implementation. Similarly, Awada, et al. (2021) supplemented that there is still paucity of real-world cases and proof of positive return of investment to convince the adoption of digital tools. In addition, the construction practitioners faced financial constraint due to the additional costs incurred as a result of work delays caused by Covid-19 pandemic, which aggravate their affordability and capacity in the substantial expenditures associated with advance technology. In a similar vein, most clients see the heavy upfront outlay as a deterrent, without taking into account the immense cost savings brought by digital tools in the later phases of the project (Olanrewaju, et al., 2020).

b) Relationships Between the Barriers of Digital Tools Adoption in Construction Project and the Attributes of Respondents

Based on the information presented in Table 4.11, there are three barriers that show significant differences across the respondents' demographic profile, including DB3 - Lack of Training Level of Workers, DB6 - Lack of Government Regulations and Financial Assistance and DB10 - Legal and Contractual Uncertainties.

The respondents who working for contractor firm are more agreed on DB3 - Lack of Training Level of Workers as the barrier of digital tools adoption than those working in consultant, developer and specialist, subcontractor or supplier company. Owing to the fact that contractor is the one who responsible for managing and coordinating the work of the various labours and subcontractors on the project site, it is crucial for them to prioritize the training and upskilling of their workers to improve their competency in using digital tools. This is especially crucial in the Malaysian construction industry, which is overdependent on untrained foreign workers due to the nature of the work is being dirty, demeaning, and dangerous (3D), making it unappealing to local labour (Wong, 2022). Concurrently, Ne'Matullah, et al. (2021) and Waqar, et al. (2023) also stressed that the diverse workforce, primarily composed from countries such as Indonesia, Bangladesh, India, Nepal and Myanmar, further intensify the dilemma of miscommunication or using digital tools effectively. In the context of these, the contractors are compelled to bridge the language and cultural barriers via investing language programs prior to the digital technology related training. Likewise, Fateh, et al. (2022) revealed that most contractors exhibit a predilection for hiring trained labour over allocating substantial funds towards labour training programmes, as the retention rate of trainees is merely around 50%.

On top of that, a significant proportion of respondents with the demographic profile of junior executive, 0 to 5 years working experience and Postgraduate Degree, expressed a higher level of agreement on DB10 - Legal and Contractual Uncertainties as the barrier of digital tools adoption. The rationale behind this trend could be attributed to their relative novelty in the industry, which may result in limited experience or understanding in dealing with legal and contractual matters. As a result, they may lack confidence in their ability to navigate these complexities when implementing new digital tools, potentially resulting in negative consequences for the project and their careers. On the other hand, individuals who have attained advanced levels of education, such as Postgraduate Degree, may possess a greater comprehension of availability of contract clauses and provisions in affecting the adoption of technology, which can lead them to perceive legal and contractual uncertainties as a hindrance to adopting new digital tools. Almarri, et al. (2019) discovered that the absence of incorporating technology protocols in contract documents from the outset increases the likelihood of legal and contractual risks arising due to unclear responsibilities of parties towards each other. This can lead to issues related to liability for contribution waivers, indemnities, and other legal matters. Thereupon, the tracking of responsibility and liability becomes challenging since the anticipated risk cannot be transformed into contractual obligations. Without reasonable allocation in the basis of mutual agreement among project team members, technology adoption may face significant hurdles and hinder its smooth implementation.

Meanwhile, most of the respondents who possess more than 10 years working experience and Postgraduate Degree are more perceived towards DB6 - Lack of Government Regulations and Financial Assistance as the barrier of digital tools adoption. This finding may be attributed to the fact that respondents with extensive experience and expertise in the industry have likely witnessed the evolution of the sector and the introduction of new technologies over time. Most of them are in management positions and responsible for devising company strategy planning, including digital transformation. Thus, they recognize the pivotal role of clear government policies in facilitating the adoption of digital tools. Without such policies in response to current affairs, construction companies may struggle to make necessary adaptive management changes to their organizational structure, marketing, product design, and employment practices to the implementation of technologies effectively (Li, et al., 2022). This ultimately affects their ability to compete in the market and maintain their competitiveness. Concurrently, management levels hold authority of making decisions that can significantly influence the financial allocation within an organization. Henceforth, they are more likely to aware of government financial assistance programs that can ease the burden of adopting digital tools and reduce the potential risk of exacerbating the company's cash flow issues.

c) Summary of Relationships Between the Barriers of The Digital Tools Adoption in Construction Project and the Attributes of Respondents

Table 4.14 presents a summary of the relationships between the barriers of the digital tools adoption in construction project and the attributes of respondents. In general, the table displays eleven obstacles that companies commonly encounter in the context of digital tool adoption. According to this table, it appears that the demographic information provided does not yield a clear and consistent pattern in terms of which group has the highest frequency for the rejected null hypothesis of barriers. However, it was found that there is a slight difference between some categories of particular demographic profile. For instance, the contractor was found to have the highest perception of the barrier of DB3 - Lack of Training Level of Workers, followed by the consultant. However, the difference in mean rankings between the two groups was relatively minor, with values of 77.63 and 75.80, respectively. Besides, different companies may have varying cultures, policies, and management systems that can cause slight differences in perceptions of particular barriers such as DB3 - Lack of Training Level of Workers, DB6 - Lack of Government Regulations and Financial Assistance and DB10 - Legal and Contractual Uncertainties that impede the adoption of digital tools in construction project during the pandemic and transition to endemic.

Table 4.14: Summary of the Relationships Between the Barriers of the Digital Tools Adoption and the Attributes of Respondents

Code	Barriers	Demographic Information		Mean Ranking
DB1	Substantial Initial Investment	-		
DB2	Shortage of Professionals	-		
DB3	Lack of Training Level of Workers	Business nature	Contractor	77.63
			Consultant	75.80
DB4	Lack of Top Management Support	-		
DB5	Poor Internet Connectivity	-		
DB6	Lack of Government Regulations and Financial Assistance	Working Experience	> 10 years	83.95
		Education Qualification	Postgraduate Degree	80.93
DB7	Lack of Individual Privacy	-		
DB8	Unproven Reliability of Digital Tools	-		
DB9	Organization Culture (eg: resistance to change and prefer to adopt traditional method)	-		
DB10	Legal and Contractual Uncertainties	Position	Junior Executive	80.83
		Working Experience	0 - 5 years	75.46
			6 – 10 years	75.22
		Education Qualification	Postgraduate Degree	79.98
DB11	Cybersecurity Risk	-		

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter comprises a conclusive overview of the research findings in line with the research aim and objectives. It also entails the implications and limitations of this research as well as the recommendations for future studies on similar topic.

5.2 Accomplishments of Research Objectives

The onset of the Covid-19 pandemic in early 2020 has resulted in considerable detrimental effects on various sectors and regions, with the construction industry being one of the most impacted. In light of this, the issues that influence the construction industry have been increasing at an alarming rate, which in turn has had numerous repercussions on construction projects. Thus, this research is crucial in offering a better understanding of the digital tools that aid the construction practitioners in managing the construction project during the pandemic and transition to endemic while adhering to the Covid-19 safety protocols. This research also identified the most adopted digital tools in construction project and underscored the most acknowledged potentials of implementing digital tools among the construction practitioners. Additionally, the findings provide valuable insights for construction professionals to identify the primary barriers that obstruct the adoption of digital tools in construction projects amidst the pandemic and the shift towards an endemic state. The objectives of the study were fulfilled and summarized as follows:

5.2.1 Objective 1: To Identify the Types of Digital Tools Leveraged in Construction Project during the Pandemic and the Transition to the Current Endemic

A total of 10 digital tools leveraged in construction project during the pandemic and the transition to the current endemic have been identified via literature review and further tested in this research. The digital tools comprise of BIM, cloud computing, IoT, drone, autonomous robotics, RFID, AR and VR, blockchain, smart wearables and 3D printing. Overall, the findings revealed that Cloud Computing, BIM, and Drone are the digital tools with the highest mean ranking in terms of adoption. However, the research discovered a moderate correlation between the respondents' recommendation and adoption level of digital tools. Besides, it was found that the respondents with the demographic background of contractor and 0 to 5 years of working experience showed a stronger preference for digitalised method over traditional methods. The rationale behind contractors' preferring digitalised methods is that digital tools can boost productivity in managing on-site works while complying with Covid-19 safety protocols, and enable contractors to remain competitive in the market, giving them a distinct advantage over their rivals. Concurrently, younger practitioners with 0 to 5 years of experience prefer digital approaches due to their familiarity with technology, making them receptive to new tools that enhance work efficiency and giving them a competitive advantage in the job market.

5.2.2 Objective 2: To Explore the Potentials of Digital Tools Implementation in Construction Project during the Pandemic and the Transition to the Current Endemic

This research delved into 11 potentials of digital tools implementation in construction project during the pandemic and the transition to the current endemic. These potentials were extracted from a literature review and further tested in this research. The potentials encompass a wide range of areas, including "Enhance Project Design", "Enhance Site Planning and Management", "Enhance Material Supply Chain and Inventory Management", "Enhance Site Inspection", "Improve Covid-19 Virus Infection Identification", "Promote Communication and Collaboration", "Enhance Efficiency of Repetitive Task and Monotonous Workflows", "Enrich Education and Training", "Enhance Procurement Contracting Management", "Enhance Payment Claim" and "Enhance Safety and Risk Management".

According to the result, the three statements with highest mean ranking are "I adopt cloud computing to promote my project's communication and collaboration”, followed by “I adopt BIM to enhance my project’s site planning and management” and “I adopt BIM, AR and VR to enhance my project design”. These aforementioned statements reflect the most widely acknowledged potentials by the respondents to the digital tools implementation in construction project during the pandemic and the transition to the endemic. Additionally, the findings concluded that respondents who work for developer companies and large-sized firms are more inclined to acknowledge the potentials of digital tools implementation. The reason behind is that developer take a client-centric approach, thereby need to stay up-to-date on a project's status, making them more likely to acknowledge the potential of digital tools for timely decision-making to ensure proper budget allocation, on-time completion, and project continuity. Simultaneously, large companies are more likely to recognise the potential of digital tools to streamline project management operations and improve construction project quality and efficiency due to their financial resources and in-house tools.

5.2.3 Objective 3: To Uncover the Barriers of the Digital Tools Adoption in Construction Project during the Pandemic and the Transition to the Current Endemic

This research also uncovered 11 barriers of digital tools adoption in construction project during the pandemic and the transition to the current endemic. These barriers were derived from a literature review and further tested in this research. The barriers include “Substantial Initial Investment”, “Shortage of Professionals”, “Lack of Training Level of Workers”, “Lack of Top Management Support”, “Poor Internet Connectivity”, “Lack of Government Regulations and Financial Assistance”, “Lack of Individual Privacy”, “Unproven Reliability of Digital Tools”, “Organization Culture”, “Legal and Contractual Uncertainties” and “Cybersecurity Risk”.

The results indicated that the three most significant barriers are lack of top management support, organization culture and substantial initial investment. In extra, there is absence of consistent pattern in terms of which demographic group experiences the highest frequency for rejected null hypothesis of barriers. However, certain barriers such as “Lack of Training Level of Workers”, “Lack of Government Regulations and Financial Assistance" and "Legal and Contractual Uncertainties" has elicited slight differences in perceptions among the respondents due to the distinct cultures, policies, and management systems of various companies.

Ultimately, this research has established a conceptual framework that delineates the relationships between Covid-19 pandemic and the adoption of digital tools, as depicted in Figure 2.1. It also magnifies the understanding of the current level of digital tools adoption and the prominent barriers that hamper their successful implementation. As such, it can increase the readiness of the construction practitioners in coping with forthcoming pandemics or unanticipated occurrences.

5.3 Research Implications

This research contributes to an overview of the extent of adoption of digital tools in construction projects during the pandemic and the transition to the endemic phase. The overarching results of this research facilitate a deeper comprehension of the present adoption level of digital tools among construction practitioners, thereby allowing them to progressively acclimate themselves to the burgeoning domain of innovative technology. Moreover, this study pinpoints the key digital tools that are efficacious in a variety of aspects, while simultaneously highlighting the latent barriers that have impeded the progress of digitalisation within the construction industry.

Primarily, this research may glean valuable insights that are immensely beneficial for construction firms in revolutionizing their current operations and identifying areas for refinement. This research facilitates the seamless integration of digital tools by construction companies in addressing the impediments that have arisen as a result of Covid-19 pandemic, while taking into account their unique business needs. Additionally, this research aids construction professionals in gaining a better understanding of the barriers that hinder the adoption of digital tools. This can assist them in identifying the most crucial barriers that necessitate careful consideration in order to improve the acceptance and integration of digital tools. Consequently, this study plays a pivotal role in augmenting their preparedness to combat pandemics or unforeseen events.

Furthermore, this research can render contributions to the policymakers, governmental bodies, and proficient organizations, including Ministry of Works and CIDB, in devising and implementing proactive and efficacious strategies and protocols for augmenting the digital transformation in the construction sector. In a similar vein, this scrutinization also enables policymakers to take a proactive approach in considering and analysing the impact of digitalisation on the workforce within the construction sector. As digitalisation is expected to create new employment opportunities, the policymakers should prioritise the development of a highly skilled and knowledgeable workforce in advanced technologies. This will not only create more job opportunities but also stimulate economic growth and improve global competitiveness.

Moreover, this research can assist universities in anticipating the surging demand for digital tool specialization in the job market, thereby enabling them to equip students with the requisite digital skills that are increasingly critical in a post-pandemic world. In an era where remote work is becoming increasingly prevalent, students possessing knowledge of digital tools and remote collaboration will be primed for success in the highly competitive job market. Simultaneously, this will facilitate the preparedness of recent graduates for the advent of the IR 4.0 and the assimilation of digital technologies in the construction industry.

5.4 Research Limitations

Firstly, time constraints during the data acquisition process can be a paramount impediment. This has led to the incomprehensive and inconsistency data for each demographic background of respondents. For example, the data collected for the group with 0 - 2 years of experience amounted to only 26 samples, which fell below the recommended minimum of 30 samples for reliable statistical analysis. Due to this limitation, a decision was made to combine the 0-2 years experience group with the 3-5 years experience group. This was done to increase the sample size and meet the requirements of the CLT, which assumes that larger sample sizes tend to yield approximately normal distributions for sample means.

Apart from that, research discoveries which originating from theoretical concepts may have limitations in their applicability to particular contexts or populations under investigation. The theoretical concepts may solely derived from the assumptions that do not accurately reflect the realities of the subject being studied. The absence of empirical evidence may hinder the formulation of comprehensive conclusions, resulting in the curtailment of the practical utility of research findings in actual-world scenarios. This underscores the importance of empirical evidence in validating theoretical assumptions.

Eventually, the Likert scale is a prevalent tool utilized in social science research to gauge attitudes, opinions, and behaviours. Nonetheless, it suffers from a significant drawback, whereby divergent interpretations and perspectives among the respondents may result in inconsistency of responses. To elaborate, discrepant responses may arise due to difference in cultural backgrounds, educational levels, and life experiences, which inevitably shape individuals' comprehension and discernment of the meaning behind expressing "strongly agree" or "strongly disagree" towards a particular assertion.

5.5 Research Recommendations

Numerous recommendations have been proffered to highlight the gaps and surmount the constrictions in current research, with the ultimate aim of eliciting more exhaustive and all-encompassing research in the future. Firstly, the mixed method which including qualitative and quantitative methods should be taken into consideration to conduct the research. The quantitative research provides numerical data, it may neglect pertinent contextual information, whereas qualitative research offers comprehensive contextual details but lacks statistical power and generalizability. By amalgamating both approaches, researchers can formulate more substantial conclusions and overcome the constraints of utilizing a single data collection method. In addition, it also overcome the limitations of Likert scales, which may not capture the full range of participant opinions or attitudes. Consequently, mixed-methods research can furnish a more comprehensive understanding of the research subject matter.

On top of that, it is imperative to allocate ample time for data collection due to two key factors: access to participants and sample size. The arduous task of recruiting participants can be a time-intensive affair, especially when the target population is diverse, specialized, or has unique characteristics. This may necessitate the establishment of relationships, networking, or the deployment of alternative recruitment strategies to identify suitable participants. As such, researchers may have adequate duration to secure an adequate number of participants, ensuring the sample is representative of the population. This, in turn, enhances the comprehensiveness of the data analysis, enabling more robust and accurate conclusions to be drawn from the findings.

Furthermore, it is advisable for forthcoming research to conduct an in-depth analysis of a specific element within a broader topic. This approach allows the researchers to scrutinize the intricacies and complexities of the particular area, thereby leading to a thorough understanding of the particular topic being explored. By executing a more targeted and meticulous study, researchers can produce more precise and insightful findings that can make substantial contributions to the existing knowledge on the topic. For example, the research topic can be narrowed down to examine the adoption and effectiveness of a specific digital tool, such as BIM, during the pandemic and the transition to endemic.

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APPENDICES

Appendix A: Questionnaire

Section A: Demographic Information

A1) Which of the following best reflects the nature of your company's business?

- ☐ Consultant
- ☐ Contractor
- ☐ Developer
- ☐ Specialist/ Subcontractor/ Supplier

A2) What is your position in your organization?

- ☐ Junior Executive
- ☐ Senior Executive
- ☐ Supervisor / Team Leader / Manager
- ☐ Assistant Director
- ☐ Director/ Managing Director/ CEO

A3) How many years of working experience do you have in the construction industry?

- ☐ 0 - 2 years
- ☐ 3 – 5 years
- ☐ 6 – 10 years
- ☐ 11 – 20 years
- ☐ > 20 years

A4) What is your highest academic qualification?

- ☐ High School
- ☐ Diploma/ Certificate
- ☐ Bachelor’s Degree
- ☐ Postgraduate Degree (PhD, Master's Degree)

A5) What is your company’s size?

- ☐ Micro-sized (< 5 employees)
- ☐ Small-sized (5 - 29 employees)
- ☐ Medium-sized (30 - 75 employees)
- ☐ Large-sized (> 75 employees)

Section B: Adoption level of digital tools in construction project during the pandemic (Including the Transition to Endemic)

B1) How likely are you going to **recommend the following digital tools to be adopted** in your project during the pandemic, including the transition to endemic?

Type of digital tools leveraged in construction project during the pandemic	**Extremely unlikely (1)**	**Unlikely (2)**	**Neutral (3)**	**Likely (4)**	**Extremely likely (5)**
a) Building Information Modelling (BIM)	☐	☐	☐	☐	☐
b) Cloud Computing (eg: Dropbox, Google Drive, One Drive, Google Cloud Storage, iCloud Drive)	☐	☐	☐	☐	☐
c) Internet of Things (IoT) (eg: Thermal camera, infrared distance sensor)	☐	☐	☐	☐	☐
d) Unmanned Aerial Vehicles (UAV) / Drones	☐	☐	☐	☐	☐
e) Autonomous Robotics (eg: painting	☐	☐	☐	☐	☐

	robot, finishing-laying robot, project progress inspecting mobile robot)					
f)	Radio Frequency Identification Device (RFID) (eg: tags, ID card)	☐	☐	☐	☐	☐
g)	Augmented Reality (AR) and Virtual Reality (VR)	☐	☐	☐	☐	☐
h)	Blockchain (eg: smart contract)	☐	☐	☐	☐	☐
i)	Smart Wearables (eg: wristbands, keychains, badges, boots, safety goggles, safety vest, safety helmet and safety glove)	☐	☐	☐	☐	☐
j)	3D printing	☐	☐	☐	☐	☐

B2) To what extent you **adopt the following digital tools** in your project during the pandemic, including the transition to endemic?

Type of digital tools leveraged in construction project during the pandemic	**Never Adopt (1)**	**Seldom Adopt (2)**	**Sometimes Adopt (3)**	**Frequently Adopt (4)**	**Always Adopt (5)**
a) Building Information Modelling (BIM)	☐	☐	☐	☐	☐
b) Cloud Computing (eg: Dropbox, Google Drive, One Drive, Google Cloud Storage, iCloud Drive)	☐	☐	☐	☐	☐
c) Internet of Things (IoT) (eg: Thermal camera, infrared distance sensor)	☐	☐	☐	☐	☐
d) Unmanned Aerial Vehicles (UAV) / Drones	☐	☐	☐	☐	☐
e) Autonomous Robotics (eg: painting robot, finishing-laying robot, project progress	☐	☐	☐	☐	☐

	inspecting mobile robot)					
f)	Radio Frequency Identification Device (RFID) (eg: tags, ID card)	☐	☐	☐	☐	☐
g)	Augmented Reality (AR) and Virtual Reality (VR)	☐	☐	☐	☐	☐
h)	Blockchain (eg: smart contract)	☐	☐	☐	☐	☐
i)	Smart Wearables (eg: wristbands, keychains, badges, boots, safety goggles, safety vest, safety helmet and safety glove)	☐	☐	☐	☐	☐
j)	3D printing	☐	☐	☐	☐	☐

B3) Which method would you prefer in your project?

Activity	Traditional Method	Digitalised Method
a) Design or Modelling/ Measurement (Printed or CAD drawings / Microsoft Excel vs BIM)	☐	☐
b) Planning and management of construction activities	☐	☐

(Physical site visit vs BIM)		
c) Data Transfer/Sharing (Pendrive/ Email vs Cloud Computing)	☐	☐
d) Data Storage (Pendrive/ Email/ Hard disk vs Cloud Computing)	☐	☐
e) Meeting (Physical meeting vs Cloud Computing [eg: Cloud-based Google meet, Zoom, Microsoft Team, Skype])	☐	☐
f) On-site real time data collection/site surveillance (Physical site visit/ On-site video and photos capturing vs Internet of Things (IoT))	☐	☐
g) Body temperature checking (Temperature screener with manual recording vs Internet of Things (IoT))	☐	☐
h) Monitoring and supervising site activities (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	☐	☐
i) Topographic survey (Physical site visit vs Unmanned Aerial Vehicle (UAV)/ Drone)	☐	☐
j) Construction tasks such as concreting,	☐	☐

bricklaying, finishing-laying (Manual workforce vs Autonomous Robotics)		
k) Material and equipment tracking and checking (Manual recording/ barcodes vs Radio Frequency Identification Device (RFID))	☐	☐
l) Worker identification / attendance checking (Manual recording/ ID card scanning vs Radio Frequency Identification Device (RFID))	☐	☐
m) Pre-construction building design concept (Printed or CAD drawings vs Augmented Reality (AR) and Virtual Reality (VR))	☐	☐
n) Employee Training Programs (Physical site visit vs Augmented Reality (AR) and Virtual Reality (VR))	☐	☐
o) Procurement (Printed drawings and documents vs Blockchain)	☐	☐
p) Interim payment/supply chain payment (Manual payment/ banking vs Blockchain)	☐	☐

q) Health or safety condition checking (Self-reporting vs Smart Wearables)	☐	☐
r) Manufacturing and installation of construction elements (Off-site manufacturing, transportation and on-site manual construction vs 3D printing)	☐	☐

Section C: Potentials of leveraging digital tools in construction project during the pandemic (Including the Transition to Endemic)

C1) In your opinion, to what extent you agree the listed potentials of digital technologies incur in your construction project during the pandemic, including the transition to endemic?

Potentials of leveraging digital tools in construction project during the pandemic	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**
a) I adopt BIM, AR and VR to enhance my project design	☐	☐	☐	☐	☐
b) I adopt BIM to enhance my project's site planning and management	☐	☐	☐	☐	☐
c) I adopt RFID to enhance my project's material supply chain and inventory management	☐	☐	☐	☐	☐

d)	I adopt UAV/drone and IoT (sensors) to enhance my project’s site inspection	☐	☐	☐	☐	☐
e)	I adopt UAV/drone and IoT (sensors) to improve my project’s Covid-19 virus infection identification	☐	☐	☐	☐	☐
f)	I adopt cloud computing to promote my project’s communication and collaboration	☐	☐	☐	☐	☐
g)	I adopt autonomous robotics and 3D printing to efficiency of repetitive task and monotonous workflows of my project	☐	☐	☐	☐	☐
h)	I adopt BIM, AR and VR to enrich my project members’ education and training	☐	☐	☐	☐	☐
i)	I adopt blockchain to enhance my project’s	☐	☐	☐	☐	☐

procurement contracting management					
j) I adopt blockchain to enhance my project's payment claim	☐	☐	☐	☐	☐
k) I adopt autonomous robotics, UAV/drone and smart wearables to enhance my project's safety and risk management	☐	☐	☐	☐	☐

Section D: Barriers of Leveraging Digital Tools in Construction Project During the Pandemic (Including the Transition to Endemic)

D1) In your viewpoint, to what degree you agree the following barriers undermine the leverage of digital technologies in my construction project during the pandemic, including the transition to endemic?

Barriers of Leveraging Digital Tools in Construction Project During the Pandemic	**Strongly disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly agree (5)**
a) Substantial Initial Investment	☐	☐	☐	☐	☐
b) Shortage of Professionals	☐	☐	☐	☐	☐
c) Lack of Training Level of Workers	☐	☐	☐	☐	☐
d) Lack of Top Management Support	☐	☐	☐	☐	☐
e) Poor Internet Connectivity	☐	☐	☐	☐	☐

f)	Lack of Government Regulations and Financial Assistance	☐	☐	☐	☐	☐
g)	Lack of Individual Privacy	☐	☐	☐	☐	☐
h)	Unproven Reliability of Digital Tools	☐	☐	☐	☐	☐
i)	Organization Culture (eg: resistance to change and prefer to adopt traditional method)	☐	☐	☐	☐	☐
j)	Legal and Contractual Uncertainties	☐	☐	☐	☐	☐
k)	Cybersecurity Risk	☐	☐	☐	☐	☐

End of Questionnaire Survey

Thank you very much for your time and effort in filling out this survey.