APPLYING ADVANCED TECHNOLOGIES FOR ENHANCING CONSTRUCTION SAFETY MANAGEMENT: THE CONTRACTOR'S PERSPECTIVE

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

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September 2024

DECLARATION

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

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"APPLYING ADVANCED TECHNOLOGIES FOR ENHANCING CONSTRUCTION SAFETY MANAGEMENT: THE CONTRACTOR'S PERSPECTIVE"** was prepared by **CHUNG SEOW LING** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science Quantity Surveying with Honours at Universiti Tunku Abdul Rahman.

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Date : 7 Oct 2024

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Date :

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all those who have supported me throughout the completion of this research. First and foremost, I would like to extend my sincere appreciation to my supervisor, Sr Li Zi Qian, for his invaluable guidance, patience, and continuous encouragement during the course of this study. His insightful feedback and expert advice have greatly contributed to shaping this research into its final form.

I would also like to thank the lecturers and staff at Universiti Tunku Abdul Rahman for providing the resources and academic environment necessary to conduct this research. Special thanks to my peers and colleagues for their support, feedback, and encouragement throughout this journey.

Furthermore, I am deeply grateful to the industry professionals and respondents who took the time to participate in the surveys and share their insights. Their contributions were essential in shaping the findings of this study.

Lastly, I would like to express my heartfelt appreciation to my family and friends for their unwavering support, understanding, and encouragement, which helped me persevere through the challenges of this research. This accomplishment would not have been possible without their love and belief in me. Thank you all.

ABSTRACT

The construction sector is progressively integrating advanced technologies to augment safety management and optimise project efficiency. Technologies including Exoskeleton, Artificial Intelligence (AI), Sensing Technology, UAVs and drones, 3D-Printing, Building Information Modelling (BIM), Modular Construction, Internet of Thing (IoT) and YOLOv3 are instrumental in mitigating safety hazards, enhancing collaboration, and optimising construction processes. Notwithstanding these developments, numerous organisations encounter substantial obstacles, especially the elevated expenses connected with the adoption and maintenance of these technologies. Furthermore, these advanced technologies ineffectively combine with existing safety management systems as well as the gap in the construction workforce's digital literacy prevents the full utilization of these advanced technologies. This study identified the advanced technologies for managing construction safety, explores the essential of advanced technologies in managing construction safety, and evaluates the barriers of advanced technology adoption in managing construction safety. 166 responses were received for this study. The survey data analysis indicated that BIM, drones, and AI are the three most recognised and extensively utilised technology among respondents. The study ascertained that personal exposure and experience as determinant of familiarity and essential to adoption of advanced technologies. The study identified financial restrictions as the primary obstacle to adoption. Moreover, company size and CIDB grade significantly influenced perceptions of these barriers, beyond the effects of working experience or position, as larger companies and those with higher CIDB grades were more inclined to surmount these challenges. This study offered contributions to various stakeholders including policymakers and government, industry, universities and academic institutions as well as upcoming researchers to grow in their own aspects. In conclusion, although advanced technologies are becoming common, financial and logistical restrictions persist as significant obstacles.

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Chapter 1 commences with the importance of the study to describe a detailed background section. Following the problem statement, and aim and objectives is then presented. Subsequent to the aim and objectives, the study's scope and limitations are discussed. The chapter also includes a section on the contribution of the study. Ultimately, the chapter finishes by providing a succinct summary of the study.

1.2 Background of the Study

The industry of construction has long been the backbone of Malaysia's economic infrastructure, playing a key role in shaping the nation's skyline and facilitating its growth. The construction industry's substantial contribution to Malaysia's GDP at the end of 2023, which is reported to be 3.5% or 34.1 billion, underscores the industry's importance to the national economy (Gross domestic product (GDP), 2024). This percentage points to a sector that is not only thriving but also integral to the nation's development and prosperity. It is a sector with the potential to drive significant economic growth, providing employment and contributing to the country's infrastructure. However, with great economic contributions come significant responsibilities, particularly in the domain of occupational health and safety.

However, accident statistics that continue to raise concerns regarding worker safety and project security demonstrate that this industry is also associated with a high risk of workplace dangers. In line with the Department of Occupational Safety and Health Malaysia (2024), the occupational accident statistics from January to October 2023 in construction sector is recorded as a total of 159 including data of non-permanent disability, permanent disability and death, which indicates persistent safety challenges within the construction sector. These statistics suggest that despite the industry's economic importance, there are underlying issues that compromise worker welfare and efficiency. Addressing these safety challenges is not only a moral imperative but also an economic necessity, as accidents can result in project delays, increased costs, and loss of skilled labor.

It can be seen that the advent of advanced technologies offers a promising horizon for enhancing safety management within this sector. Advanced technologies facilitate a shift from traditional, reactive safety measures to more predictive and preventive strategies. By integrating safety protocols into digital project models, stakeholders can anticipate and mitigate risks before they transpire (Benjaoran & Bhokha, 2010; Guo et al., 2017). The real-time data provided by sensor-based technologies, for instance, enables immediate responses to safety threats and enhances communication across the construction site (Zhang et al., 2017). The push towards digitization in construction safety management is thus not a mere trend but a necessary evolution to foster safer work environments and more efficient project outcomes (Rey et al., 2021).

Based on National Construction Policy (NCP 2030), 2022, the third thrust 'Improve Construction Productivity' aims to boost productivity of construction with the goal of enhancing efficiency, reducing costs, and delivering infrastructure projects of greater quality. This initiative recognises the need of improving efficiency in the construction sector to stimulate economic expansion and ensure long-term viability. Through implementing construction technologies and embracing new method, organisations can notably enhance productivity through streamlined construction processes and decreased project durations.

In embracing these digital innovations, the construction industry can significantly reduce the frequency and severity of accidents, exemplifying a commitment to worker safety and sustainable construction practices (Edirisinghe, 2018; Jiang et al., 2020). The integration of these advanced technologies in the Malaysian construction industry is the focus of this research, aiming to establish a new paradigm in construction safety management that aligns with the country's vision for a safer and more innovative future in construction.

1.3 Problem Statement

The construction industry is increasingly embracing advanced technologies to enhance safety management on construction sites. As stated by Benjaoran & Bhokha (2010); Guo et al. (2017), these tools have shown potential in improving hazard identification, safety training, and risk mitigation by providing immersive and interactive environments for planning and training. However, the integration of these technologies into everyday safety practices faces significant challenges. One of the primary obstacles is the lack of comprehensive frameworks that effectively combine these advanced technologies with existing safety management systems (Zhang et al., 2017). Additionally, there is a noticeable gap in the construction workforce's digital literacy, which hampers the full utilization of these advanced technologies (Rey et al., 2021).

Previous studies have made significant strides in illustrating the potential benefits of advanced technologies in construction safety (Hou et al., 2023; Maali et al., 2024). They have documented isolated instances of success in using technologies like BIM and VR for specific safety applications, such as hazard visualization and safety training simulations. However, these studies often fall short of providing a holistic approach that integrates various advanced technologies into a cohesive safety management strategy (Hou et al., 2023; Maali et al., 2024). Furthermore, there is limited research on the long-term impact of these digital interventions on reducing accident rates and improving safety cultures within construction organizations (Zhang et al., 2017).

This study aims to bridge these gaps by developing the barriers of advanced technology adoption in managing construction safety while addressing the challenges of implementation and workforce adaptation. It seeks to provide a comprehensive understanding of how advanced technologies can be synergized with traditional safety practices to create a proactive safety management environment. By doing so, this research aspires to not only enhance immediate safety outcomes but also contribute to the establishment of a robust safety culture that embraces technological advancements. The ultimate goal is to provide actionable insights and practical guidelines that can lead to the widespread adoption of advanced technologies in managing construction safety, thereby reducing accident rates and enhancing the overall well-being of the construction workforce.

1.4 Aim and Objectives

The primary aim of this study is to investigate the application of advanced technologies in enhancing construction safety, inferring the barriers of integrating these technologies into standard safety practices within the construction industry. The objectives of this study are:

1. To identify the advanced technologies for managing construction safety.
2. To explore the essential of advanced technologies in managing construction safety.
3. To evaluate the barriers of advanced technology adoption in managing construction safety.

1.5 Research Methodology

This research employs the quantitative research method in order to identidy and evaluate the essential and barriers of advanced technologies in managing construction safety. To gather data from the target participants, the surveys were created using Google Forms and disseminated over various social media platforms such as Email, WhatsApp, and Instagram. The respondents have been selected through a planned sampling process, and they must be participants in the construction community. Table 1.1 provides a summary of the approaches employed to accomplish the objectives of this study.

Table 1.1: Overview of Research Approaches

Stage 1 **Literature Review**		*Stage 2* **Questionnaire Survey and Data Analysis**
Objective 1: To identify the advanced technologies for managing construction safety.	**Objective 2:** To explore the essential of advanced technologies in managing construction safety.	**Objective 3:** To evaluate the barriers of advanced technology adoption in managing construction safety.

1.6 Chapter Layout

The study is structured into five chapters, each fulfilling a distinct role within the research framework. In Chapter 1, Introduction, the first chapter sets the stage for the research by providing a comprehensive overview of the background, highlighting the significance of advanced technologies in enhancing construction safety. It lays out the problem statement, clearly articulating the challenges and opportunities within the application of advanced technologies for construction safety. The research aims and objectives are defined, outlining the study's primary focus and the key questions it seeks to answer. This chapter also delineates the scope and limitations of the study, setting clear boundaries for what the research will cover.

Next, Chapter 2, Literature Review shows a thorough review of existing literature related to advanced technologies in construction safety is presented. This chapter synthesizes previous research findings, theoretical frameworks, and key concepts relevant to the study's focus. It aims to identify gaps in the current body of knowledge, providing a solid foundation upon which this study builds.

For Chapter 3, Methodology, it is a methodology chapter that details the research design and approach, including the data collection methods, sampling strategies, and analysis techniques employed in the study. It justifies the choice of methods and explains how they are applied to address the research objectives. This chapter guarantees the study's integrity and validity by delineating the methodical procedure employed in collecting and analysing data.

Moreover, Chapter 4, Results and Discussion presents the findings of the research, analyzing the data in the context of the study's objectives and the broader literature on the subject. It discusses the implications of the findings, drawing connections between the data and the theoretical frameworks outlined in the literature review. This section critically examines the results, highlighting key insights and emerging themes.

The following Chapter 5, Conclusion and Recommendations is the final chapter, which concludes the study by overviewing the key findings and their implications for the field of construction safety and the application of advanced technologies. It reflects on the research aims and objectives, evaluating the extent to which they have been achieved. The chapter also provides recommendations for future research, practitioners in the field, and policy implications, suggesting ways to extend the knowledge and practical applications of advanced technologies in construction safety.

Each chapter contributes to the overall narrative of the research, guiding the reader through the investigative journey from the initial conceptualization to the final conclusions and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will dive into the subject area of construction safety, exploring the numerous advanced technologies that are being utilized more frequently to oversee safety in the construction sector. The advanced technologies in managing construction safety are reviewed. This chapter will emphasize the need of adopting advanced technologies to manage construction safety. However, there are limitations and impediments to the use of advanced technologies. Strategies for overcoming these issues will also be presented.

2.2 Safety in Construction

Construction is a physically demanding and hazardous sector that requires essential attention to worker health and safety from practitioners and academic scholars worldwide (Maali et al., 2024). Construction sites have high spatiotemporal variation in hazards, including falling, tripping, slipping, and heavy lifting due to continuous mobility of people and machines, as well as task updates throughout the construction process (Hou et al., 2023). To prevent any form of accident from happening in the construction regions, construction safety is a collection of guidelines and policies that all construction companies must adhere to (HSE Study Guide, 2023). Inadequate construction safety practices can lead to injuries and fatalities in worksite, impacting the construction process and costing the project owner both directly (e.g., medical costs and transportation expenses) and indirectly (e.g., lost of reutation, wounded worker compensation, and loss of productivity) (Maali et al., 2024).

Despite there are mandatory safety standards and practices on construction sites, worker injuries and fatalities rates remain high. Maali et al. (2024) stated that according to a recent OSHA analysis, construction workers account for approximately half of all fatal worksite injuries in the United States. In construction, common causes of accidents and fatalities include unprotected machinery, falls from heights, tripping hazards, electrical dangers, and moving machinery part. In his groundbreaking Domino Theory, Heinrich (1941) asserted that human error was directly responsible for 88% of accidents, unsafe conditions accounted for 10%, and unpreventable events accounted for 2%. Situation awareness is another concept regarding unsafe behavior of frontline employees that lead to accidents (Zhang et al., 2023). To improve construction workers' health and safety, it's crucial to execute effective risk prevention measures along with utilizing innovative technologies.

2.2.1 Situation Awareness (SA)

"The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" is the definition of situation awareness (SA) (Zhang et al., 2023). Researchers have discussed inaccurate hazard recognition and perception leads to an increase in workplace accidents (Namian et al., 2018). In addition, they further recognised that the loss of SA is a major contributing factor to human mistake rates. In fact, it can be challenging for workers who lack SA to identify, evaluate, and analyze hazards, make estimates, and develop control (Ibrahim et al., 2023). According to Zhang et al. (2023), it is critical to maintain an appropriate level of SA in order to operate safely and effectively in a dynamic workplace.

Furthermore, Weller et al. (2024) has also emphasized the dynamic process of identifying signs in the surroundings, deciphering their meaning, and projecting future developments in the scenario is known as SA. Yan et al. (2024) has further explained that SA is a reflection of how people see their surroundings and might influence their choices and behavior. Previous studies have shown within the realm of situation awareness, there are three levels that can be distinguished: perception, comprehension, and projection (Zhang et al., 2023; Yan et al., 2024). Zhang et al. (2023) found that workers frequently engage in risk-taking activity due to a lack of risk perception and response.

2.3 Advanced Technologies for Managing Construction Safety

In controlling construction safety, the innovation of advanced technologies plays an important role to prevent workplace accidents. There are numerous advanced technologies available, yet only few of them are encompassed in this chapter. For instance, Exoskeleton, Artificial Intelligence (AI), Sensing

Technologies, UAVs and Drone, 3D-Printing, Building Information Modeling (BIM), Modular Constuction, Augmented Reality (A.R.) and Virtual Reality (V.R.), Internet of Thing (IoT) as well as YOLOv3.

2.3.1 Exoskeleton

Exoskeletons, also known as exosuits, or super suits, are a type of robotics and automation that involve a system capable of generating force or motion to enhance the wearer's endurance and physical fitness during a workout (Nnaji et al., 2023). Besides that, Cai et al. (2023) asserted that exoskeletons formerly confined to the domain of science fiction, are now a tangible presence in multiple industries, such as construction. Recently, there has been an increasing interest in using exoskeletons as digital instruments to improve safety and ergonomics in construction environments. Wearable technologies can improve motion, posture, and physical activity to reduce the risk of injuries and boost safety performance on construction sites (Cai et al., 2023).

Exoskeletons can be categorised into two main types: active exoskeletons and passive exoskeletons. Active exoskeletons utilise hydraulics, electric motors, and pneumatics as actuators to offer support, whereas passive exoskeletons rely solely on mechanical actuators such as elastic energy is being stored and released by dampers and springs during the worker's body movements (Antwi-Afari et al., 2021). In addition, exoskeletons are classed into different types based on the body part they support. These types include complete body, shoulder, back, and leg-support exoskeletons. The choice of exoskeleton depends on the specific task being performed by workers and the body portion that is at risk for work-related musculoskeletal disorders (WMSD) (Gonsalves et al., 2024).

2.3.2 Artificial Intelligence (AI)

Artificial Intelligence (AI) is crucial in implementing genuine digital strategies in the sectors of engineering, construction, and management. Datta et al. (2024) emphasized that AI refers to the field of research and advancement in creating intelligent systems that possess cognitive abilities similar to humans, including intelligence, reasoning, problem-solving, and decision-making capabilities. In order to apply AI for construction safety, computer vision applications must be used to identify and assess potential safety dangers and risks on construction sites (Fang et al., 2020).

Also, Liu and T (2021) said that a combination of hardware such as cameras, sensors, and computer stations is required to act in concert with development of deep learning, machine learning, and algorithms for reinforcement learning in order to analyz image and video data. For example, from the cameras that positioned strategically around the construction workplace, the computer vision systems are capable of analyzing images or video streams (Maali et al, 2024). These algorithms also enable the identification of potential safety breaches, hazards, and unusual safety behavior patterns exhibited by workers.

2.3.3 Sensing Technology

Nguyen et al. (2022) indicated that widespread implementation of sensing technologies in the construction industry, including wearable sensors and Internet of Things devices, has proven to be an effective means of enhancing safety by providing real-time data and insights regarding the health and safety behaviours of workers. Indeed, other authors, Kanan et al. (2018) also stated that the integration of data obtained from wearable sensors with sophisticated data analytics platforms, coupled with its connection to a central monitoring system, enables the generation of significant insights pertaining to the safety measures implemented by workers.

Moreover, wearable sensors can function independently or be included into personal protective equipment (PPE) to track the essential physiological indicators of workers such as respiration rate, body temperature, heart rate, and fatigue levels (Kim et al., 2021; Lee et al., 2021). In ergonomic analysis, the utilization of wearable sensors has contributed through the detection of workers' motions and postures, hence offering valuable insights into ergonomic hazards and potential musculoskeletal injuries (Mudiyanselage et al., 2021). Wearable sensors that incorporate accelerometers and gyroscopes can detect abrupt movements, alterations in worker orientation, and the lack thereof during the construction phase, thereby mitigating the risk of falls from elevated surfaces (Hasanzadeh et al., 2018).

2.3.4 UAVs and Drone

Unmanned Aerial Vehicles (UAVs), usually called as drones, have emerged as transformative tools in the construction industry, significantly enhancing efficiency, accuracy, and safety across various project phases. The versatility of drones extends to mapping large areas, creating detailed topographic surveys, and even assisting in logistics and material handling. They excel in tasks such as site surveying, progress monitoring, and safety inspections, offering a bird's-eye view that can reveal insights not easily obtained through traditional methods (Choi et al., 2023).

Furthermore, the integration and automation of UAVs in construction processes have led to the development of workflows for structured planning and execution of inspection tasks, where UAVs can autonomously generate collision-free flight paths based on Building Information Modeling (BIM) data (Freimuth & König, 2018). According to Choi et al. (2023), drones facilitate real-time data capture and high-resolution imaging, allowing for immediate analysis and decision-making.

2.3.5 3D-Printing

In accordance with the findings of Schuldt et al. (2021), construction 3D printing is an additive manufacturing technique that involves the layer-by-layer joining of materials. Comparable to Fused Deposition Modelling 3D printers, it operates via extrusion technology and adheres to a 3D model generated through specialised software. The model is subsequently converted into G-code, a programming language that the printer can comprehend (Dávila et al. 2022). After the printer has undergone the calibration process, the G-code transmits directives to the printer that trigger the nozzle to inject concrete and deposit the material in predetermined strata of thickness, in accordance with the 3D model (Pacewicz et al. 2018).

Another author, Pan et al. (2021) stated that 3D-Printing, also known as additive manufacturing, is revolutionizing the construction industry by enabling the fabrication of complex geometries directly from digital models, offering significant advantages in terms of efficiency, waste reduction, and customization. This technology has seen various applications in construction, including the creation of intricate architectural forms, customized components, and even entire structures (Pan et al., 2021; Tay et al., 2017). From a safety standpoint, workers may encounter irradiation hazards, electrical energy hazards, thermal hazards, and entrapment (Nozar et al., 2019). Nevertheless, this building technique is implemented within a controlled setting that offers enhanced safety measures and stricter regulations, in contrast to a dynamic construction site where employees function in close proximity and may be ignorant of the hazards presented by their colleagues.

2.3.6 Building Information Modeling (BIM)

Building Information Modelling (BIM) signifies a fundamental change in the Architecture, Engineering, and Construction (AEC) sector, offering a digital representation that facilitates collaboration among stakeholders throughout the lifecycle of a building. According to Zhong et al. (2018), this digital modeling process encompasses not only geometric and spatial data but also embeds key information pertaining to the physical and functional characteristics of building elements. The adoption of BIM has been shown to significantly enhance project outcomes, delivering benefits such as improved efficiency in design and construction processes, enhanced communication among project teams, and substantial reductions in cost and time overruns. BIM's influence extends beyond traditional design and construction phases, enabling effective facility management, streamlined maintenance operations, and informed decision-making regarding building modifications or upgrades.

Other than that, in the architectural, engineering, and construction (AEC) sectors, virtual models of buildings are built digitally using BIM technology for visualisation purposes (Shukri et al., 2023). Therefore, BIM serves as a valuable tool for enhancing safety management through features such as clash detection, schedule progress, cost estimation, increased team cooperation, design consistency, and visualisations. Furthermore, BIM offers a comprehensive framework for managing and sharing information, with the potential to efficiently store vast amounts of data in BIM models (Zhong et al., 2018).

2.3.7 Modular Construction

In line with Hořínková (2021), modular construction is a construction technology that is currently widely employed and involves a high level of prefabrication. Prefabrication entails the transportation of building components or components that have already been assembled to the construction site after they have been mass-produced in specialised factories located at a location other than the future assembly site. A modular structure is a method of construction in which the desired shape is produced by assembling numerous modules. Each module represents a spatial unit that is dimensionally consistent. These modules are fabricated at off-site facilities and then brought to the building site, where they are combined into a fully integrated structure. The number of modules in the construction may vary depending on the builder's specifications regarding the size and purpose of the building (Subramanya et al., 2020).

As asserted by Thai et al. (2020), modular construction is recognized for its ability to produce structures quickly and efficiently, without necessitating the assembly resources to be located at the construction site. This construction method involves creating large modules in controlled, quality-assured environments, which are then transported to the construction site for assembly with minimal labor requirements. A notable advantage of modular construction is the rapid on-site assembly process, making it ideal for projects with tight schedules. The process is not only cost-efficient but also eco-friendly, offering sustainable construction solutions.

2.3.8 Augmented Reality (A.R.) and Virtual Reality (V.R.)

In line with Davila Delgado (2020), A.R. is a digital technology that enables users to augment their contextual perception of their surroundings by overlaying computer-generated imagery and information onto the physical environment. Augmentations are perceived through the utilisation of a head-mounted display (HMD), tablet, or mobile device. V.R., on the other hand, is a technological advancement that substitutes the user's perception of their immediate surroundings with a computer-generated virtual environment through the use of HMDs, spectacles, and multi-display configurations. Furthermore, V.R. programmes enable safety personnel, construction workers, and supervisors to digitally examine and navigate a construction site prior to commencing actual work (Shi et al., 2019). A.R. applications can be included into personal protective equipment (PPE) to provide workers with immediate notifications and reminders regarding safety rules (Moore and Gheisari, 2019).

2.3.9 Internet of Thing (IoT)

In accordance with Sabu and Kumar (2022), the IoT comprises a network of interconnected computing devices, including both digital and mechanical machinery, that are endowed with unique identifiers (UIDs) and are capable of transmitting data without the need for direct human-to-human or human-to-computer interaction. Sensors, connectivity, a platform, analytics, a governance standard, and a user interface are the primary components of the IoT (Arshad et al., 2023). Similarly, Arslan et al. (2022) described that the IoT refers to a network comprising devices, actuators, and sensors that enable instantaneous communication among these entities within the context of computer applications. In the construction industry, IoT devices are utilized to gather data via sensors and peripheral devices in order to make informed decisions on the job site (Brous et al., 2020; McCabe et al., 2017).

Besides, at the application level, IoT architecture enables semantic web-enabled interoperability, which enables sensors to communicate using low-level sensor data. The transmission of information on the construction site is made possible through the communication of wireless protocols and IoT nodes (Yang et al., 2020). Safety hazards and catastrophes have been identified on the construction site through the implementation of IoT-enabled devices. A recent investigation, Hassija et al. (2019); Javed et al. (2020) examined the utilization of wearable instruments by site workers to gather data pertaining to environmental factors including health, temperature, air quality, humidity, pulse rate, and outdoor location. Gateways and IoT security ensure the transmission of data in a secure manner, facilitating subsequent data analytics.

2.3.10 YOLOv3

Ruaz (2023) asserted that YOLO (You Only Look Once), an object detection algorithm, has undergone successful development into YOLOv2 and YOLOv3, the latter of which has demonstrated commendable speed and accuracy in detection across diverse industries, including construction and manufacturing.

A researcher has used YOLOv3 to detect objects in captured photos and determine the safe distance between surrounding workers and operating excavators/bulldozers in order to lessen the likelihood of accidents. On average, the method's absolute inaccuracy in measuring distance is less than 0.9 m (Kim et al., 2019).

Moreover, Hou et al. (2023) explained that the three primary components of YOLOv3 are the output network, the Feature Pyramid Network (FPN), and the Darknet 53 network. The Darknet-53 network is a convolutional neural network consisting of 53 layers. Its main function is to extract features from the input image. FPN manages object detection at various dimensions by integrating feature maps from many layers. The output network utilises convolutional and fully connected layers to predict the location, size, and categorization of objects. The YOLOv3 workflow consists of five main phases: image preprocessing, feature extraction, target recognition, non-maximal suppression, and output prediction results. Previous authors further described that in order to implement YOLOv3 in construction sites, it is necessary to train the model for target detection tasks.

Table 2.1: Types of Advanced Technologies

Advanced Technologies	**Related Reference**
Exoskeleton	Nnaji et al. (2023) Cai et al. (2023) Antwi-Afari et al. (2021) Gonsalves et al. (2024)
Artificial Intelligence (AI)	Datta et al. (2024) Fang et al. (2020) Liu and T (2021) Maali et al, 2024
Sensing Technology	Nguyen et al. (2022) Kanan et al. (2018) Kim et al., 2021; Lee et al. (2021) Mudiyanselage et al. (2021) Hasanzadeh et al. (2018)

UAVs and Drone	Choi et al. (2023) Freimuth & König (2018) Choi et al. (2023)
3D-Printing	Schuldt et al. (2021) Dávila et al. (2022) Pacewicz et al. (2018) Pan et al. (2021) Tay et al. (2017) Nozar et al. (2019)
Building Information Modelling (BIM)	Shukri et al. (2023) Zhong et al. (2018)
Modular Construction	Hořínková (2021) Subramanya et al. (2020) Thai et al. (2020)
Augmented Reality (A.R.) and Virtual Reality (V.R.)	Davila Delgado (2020) Shi et al. (2019) Moore and Gheisari (2019)
Internet of Thing (IoT)	Sabu and Kumar (2022) Arshad et al. (2023) Arslan et al. (2022) Brous et al. (2020) McCabe et al. (2017) Yang et al. (2020) Hassija et al. (2019) Javed et al. (2020)
YOLOv3	Ruaz (2023) Kim et al. (2019) Hou et al. (2023)

2.4 Essential of Managing Construction Safety by Using Advanced Technologies

Advanced technologies provide a diverse array of advantages that improve the overall security of construction sites and the welfare of workers. This sub-charter will examine the benefits of utilising advanced technologies for the purpose of overseeing construction safety.

2.4.1 Reducing Physical Movement by Human

A study conducted by Bilancia and Berselli (2021) examined the ways in which digital technologies can assist construction workers in carrying out repeated jobs, lifting heavy weights, and maintaining ergonomically sound postures. The study emphasised the capacity of the tools to diminish fatigue and musculoskeletal strain in construction workers, resulting in enhanced work productivity and decreased injury frequencies. For instance, according to Thamasuwan et al. (2020), using a passive back-support exoskeleton for farm work resulted in a 48% decrease in back muscle activation. In another study by Bosch et al. (2016), a passive back-support exoskeleton was found to decrease back muscle activation by 35%–38% during static forward bending assembly activities.

2.4.2 Improving Safety Concerns

Advanced technologies are intended to aid in duties such as manual material handling and rebar tasks (Zhu et al., 2021; Antwi-Afari et al., 2021; Gonsalves et al., 2021). Furthermore, Akalin et al. (2019) conducted a study on the effects of advanced technology on improving worker safety in construction when working alongside robots. The study emphasised the need to assess both the tangible and subjective safety features of the advanced technology to guarantee successful integration and user approval. Thus, construction organisations can improve worker safety and efficiency by incorporating the tools as supportive equipment.

To further explain, this study focused on three high-risk construction tasks: bricklaying, plasterboard installation, polishing, and concrete grinding. These duties involve work settings that can expose a worker's musculoskeletal system to physical risk factors, potentially leading to injuries from fatigue and excessive exertion (Inyang et al., 2012). In this way, worker health risks may be declined by applying advanced technologies in these duties. Not only that, Ahn et al. (2019) also indicated that by means of the gathered physiological and biological sensory data, possible indicators of physical tension, dehydration, and exhaustion among employees can be discerned. In order to avert health-related incidents, safety personnel and administrators can be promptly notified in the event that a worker's health is compromised through the use of real-time data on their physiological conditions.

Additionally, advanced technologies can aid in environmental monitoring by promptly notifying employees of hazardous conditions such as humidity, heat stress, pollution, and air quality, thereby enabling them to implement the required safety measures (Shakerian et al., 2021). For instance, the sensor can instantly alert safety professionals to the possibility of a potential fall, enabling them to provide medical aid. Frequently, advanced technologies are implemented in safety training to encourage safer worker conduct and provide workers with real-time feedback (Awolusi et al., 2018). The potential benefits of incorporating advanced technologies and big data analytics into construction safety include the provision of precise real-time monitoring, predictive analysis, and actionable insights pertaining to safety-related issues (Meng et al., 2022; Zhao et al., 2021).

2.4.3 Minimizing Potential Safety Risk

Advanced technologies have the ability to improve safety procedures, reduce safety risks, and oversee job site security (Maali et al., 2024). Technologies can identify potentially dangerous behaviors and anomalous motions, such as a worker approaching an exposed edge, by examining the movement patterns of the workforce. Then, providing the necessary interventions to stop the accidents before they happen. Computer vision applications can be utilized to detect potential dangers on construction sites through the capture of videos and images. These visual data can assist safety personnel in identifying any construction goods and machinery that are incorrectly positioned, blocking pathways, and posing a risk of tripping accidents (Mostafa and Hegazy, 2021).

In addition, advanced technologies can offer instantaneous surveillance of workers' adherence to wearing the mandated safety equipment, including safety goggles, high-visibility vests, protective footwear, and hard helmets

(Maali et al., 2024). Besides that, Golovina et al. (2021) explained that digital technologies can aid construction supervisors in overseeing the functioning of heavy machinery and equipment to ensure that the established safety regulations are diligently adhered to. This study further explored that in the event of any deviations from safety norms, the deployed AI algorithms can activate alarms to notify safety staff, prompting them to take immediate action to avert any potential accidents.

Moreover, advanced technologies can detect and monitor unauthorised individuals visiting the premises during non-designated hours in order to identify possible intruders and reduce the likelihood of theft and property damage (Nath et al., 2020). Lastly, advanced technologies can also aid in examining the layouts and plans of a site to detect any potential safety hazards and implement appropriate safety measures to enhance safety precautions (Mostafa and Hegazy, 2021).

2.4.4 Analyzing Hazardous Actions

A cohort of academics has concentrated on employing computer vision technology to discern hazardous actions performed by labourers at construction sites (Hou et al., 2023). Fang et al. (2019) employed advanced technologies to identify hazardous actions by workers or unsafe conditions in building structures. This allowed for real-time warnings about unsafe human behaviours, resulting in a decrease in fall incidents from elevated positions. Furthermore, the utilization of technology in construction sites primarily focuses on three key areas: ensuring proper usage of personal protective equipment by workers, monitoring their access to hazardous zones, and verifying adherence to approved construction processes. For instance, one way to detect workers who are not wearing safety lanyards or safety helmets in a work scene is by analysing 2D photos. Another method is to use semantic segmentation to track and identify workers who are in close proximity to or have entered unprotected apertures (Fang et al., 2018a; Fang et al., 2018b).

2.4.5 Boosting Efficiency

The advanced technologies used in construction are the digital representation that encompasses all aspects of a constructed object. They rely on cooperatively acquired and updated information at important stages of the project. The digital model offers comprehensive view of the building's data, resulting in enhanced efficiency in planning, design, construction, and management of the building and infrastructure. Users were able to access all technology data associated with a physical object in a virtual information window by utilising the headset's gaze and gesture controls to interact with the item. The technology enhances communication among stakeholders, automates construction administration, and ensures the timely delivery of construction projects (Ratajczak et al., 2018).

Table 2.2: Essential of Applying Advanced Technologies

Essential of Applying Advanced Technologies	**Related Reference**
Reduce Physical Movement by Human	Bilancia and Berselli (2021) Thamasuwan et al. (2020) Bosch et al. (2016)
Improving Safety Concerns	Zhu et al. (2021) Antwi-Afari et al. (2021) Gonsalves et al. (2021) Akalin et al. (2019) Inyang et al. (2012) Ahn et al. (2019) Shakerian et al. (2021) Awolusi et al. (2018) Meng et al. (2022) Zhao et al. (2021)
Minimizing Potential Safety Risk	Maali et al. (2024) Mostafa and Hegazy (2021) Maali et al. (2024) Golovina et al. (2021) Nath et al. (2020) Mostafa and Hegazy (2021)
Analyzing Hazerdous Actions	Hou et al. (2023)

	Fang et al. (2019) Fang et al. (2018a) Fang et al. (2018b)
Boosting Efficiency	Ratajczak et al. (2018)

2.5 Barriers of Applying Advanced Technologies for Construction Safety Management

2.5.1 Technogical Risks and Safety

Human-robot interactions (HRI) have the potential to raise the effect of already-existing dangers or bring novel dangers to the job site (Kim et al., 2018). While the studies about risk assessment of construction safety have their benefits, they cannot be simply applied to robotics due to the unique dangers and safety concerns that come with using digital technologies in construction activities. Furthermore, since the majority of professionals depend on job-hazard analysis as a key element of safety management, there is a crucial requirement for digital-tool-related knowledge to enhance the development of safety solutions (Nnaji et al., 2023). For instance, a safety accident investigation determined that the existence of hazardous electrical equipment at the site was one of the contributing factors to the accident. Remarkably, the equipment's potential safety risks had been identified and documented on paper during previous safety inspections.

However, due to the absence of an efficient knowledge management mechanism and safety management system, this information was not effectively utilised or promptly addressed, resulting in the occurrence of this severe accident (Junwu et al., 2024). In relation to the application of robotics in construction, recent research has revealed some dangers and elements that could potentially affect the performance of workers. Kim et al. (2019) highlighted several potential concerns, including fall risks, a false sense of safety, catch and snag risks, and hygiene issues. Additional issues involve physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation (De Looze et al., 2016; Zhu et al., 2021).

2.5.2 Professional, Costs and Expertise Shortages

Besides, the construction industry has identified a problem with the lack of adequately skilled staff to use advanced technologies. According to Aghimien et al. (2022), in order to obtain highly skilled workers, businesses must be willing to allocate resources towards the education and ongoing development of their workforce. Regrettably, this incurs a cost that most businesses are unwilling to bear (Oke et al., 2018). In addition to the expenses related to training, the expenses connected with obtaining and upkeeping digital technology have also been identified as a significant deterrent, particularly in developing countries that are burdened with financially struggling small and medium-sized companies (Aghimien et al., 2021; Golizadeh et al., 2019; Yahya et al., 2019). The construction sector has been criticised for its gradual acceptance of the necessary technologies for effectively delivering construction products (Parn and Edwards, 2019).

Apart from that, Golizadeh et al. also pointed out that certain digital technologies are intricate and necessitate specialised knowledge in order to function. In the absence of such expertise, the implementation of these technologies may present challenges. Furthermore, because of many procedure entail the exchange of information, data security and privacy will be decisive factors in a technology's adoption status. Prior research has indicated that the absence of privacy and data insecurity has hindered the implementation of certain digital technologies in construction projects (Aghimien et al., 2021; Atobishi et al., 2018). Finally, this dilemma is also associated with the legal obstacles concerning information retrieval and application that have impeded the adoption of digital technologies. Due to the ongoing evolution of legislation governing the use of digital technologies on a global scale, a number of complications may arise concerning the sharing and application of information, particularly with regard to collaborative platforms such as BIM (Golizadeh, 2019).

Barriers of Applying Advanced Technologies	**Related Reference**
Technological Risks and Safety	Kim et al. (2018)

	Nnaji et al. (2023) Junwu et al. (2024) De Looze et al. (2016) Zhu et al. (2021)
Professional, Costs and Expertise Shortages	Aghimien et al. (2022) Oke et al. (2018) Aghimien et al. (2021) Golizadeh et al. (2019) Yahya et al. (2019) Parn and Edwards (2019) Atobishi et al. (2018) Golizadeh (2019)

2.6 Strategy to Overcome Barriers

Obviously, advanced technologies have significant advantages for enhancing construction safety. Even so, proper training and education are necessary for the use of this technology to ensure that workers comprehend how to efficiently and safely utilise advanced technologies in practice (Maali et al., 2024). In order to tackle these issues and advance sustainability in construction safety management, Junwu et al. (2024) also recommended that it is crucial to methodically preserve and organise the research findings and current knowledge derived from these projects. Ontology offers a practical method by combining and summarizing real-world and specialised knowledge, hence enabling the exchange of information among different technical and managerial teams.

Several research have suggested effective ways for enhancing the safe use of tools in industrial environments. Maali et al. (2024) suggested that regular training and random checks should be carried out to prevent negative results. Also, Zhu et al. (2021) proposed simplifying work design to minimise difficult decision-making or calculations, as advanced technologies are most advantageous for repetitive tasks. Moreover, training sessions should be arranged for staff to familiarise themselves with the tools and assess their force output before utilizing them for actual duties in the workplace (Gorgey, 2018).

It is crucial to exclusively utilize advanced technologies that have been proven functional or constructed ergonomically (Hoffmann et al., 2021).

Accelerating the safe use of advanced technologies in construction operations requires practitioners and researchers to possess understanding of the hazards connected with advanced technologies use, as well as effective solutions for mitigating risks (Nnaji et al, 2023). Apart from that, Okonkwo et al. (2023) indicated that there is a requirement to promote and assess the advantages of incorporating advanced technologies in a more standardised manner into projects that have strategic objectives at the project level. In order to encourage employees to adopt digital-related methods and to optimise business processes with the support of senior management, the study also suggests that organisations implement digital applications that have brief learning curves (Okonkwo et al., 2023). Furthermore, greater emphasis should be placed on enhancing workforce training and technological advancements; this can be accomplished through the allocation of a designated portion of revenue (Okonkwo et al., 2023).

2.7 Conceptual Framework

Jabareen (2023) explained that a conceptual framework comprises an interconnected system of concepts, called "a plane," which collectively furnish an all-encompassing comprehension of a particular phenomenon or phenomena. A conceptual framework is comprised of interdependent concepts that define their respective phenomena and establish a philosophy that is unique to the framework. The proposed conceptual framework is recapped in **Error! Reference source not found.**. The foundation of this study is recognized as the applications of advanced technologies. The enhancement of construction safety management is highlighted through the assessment of digital technologies, the significance of their adoption, the obstacles encountered, and the tactics employed to overcome these obstacles.

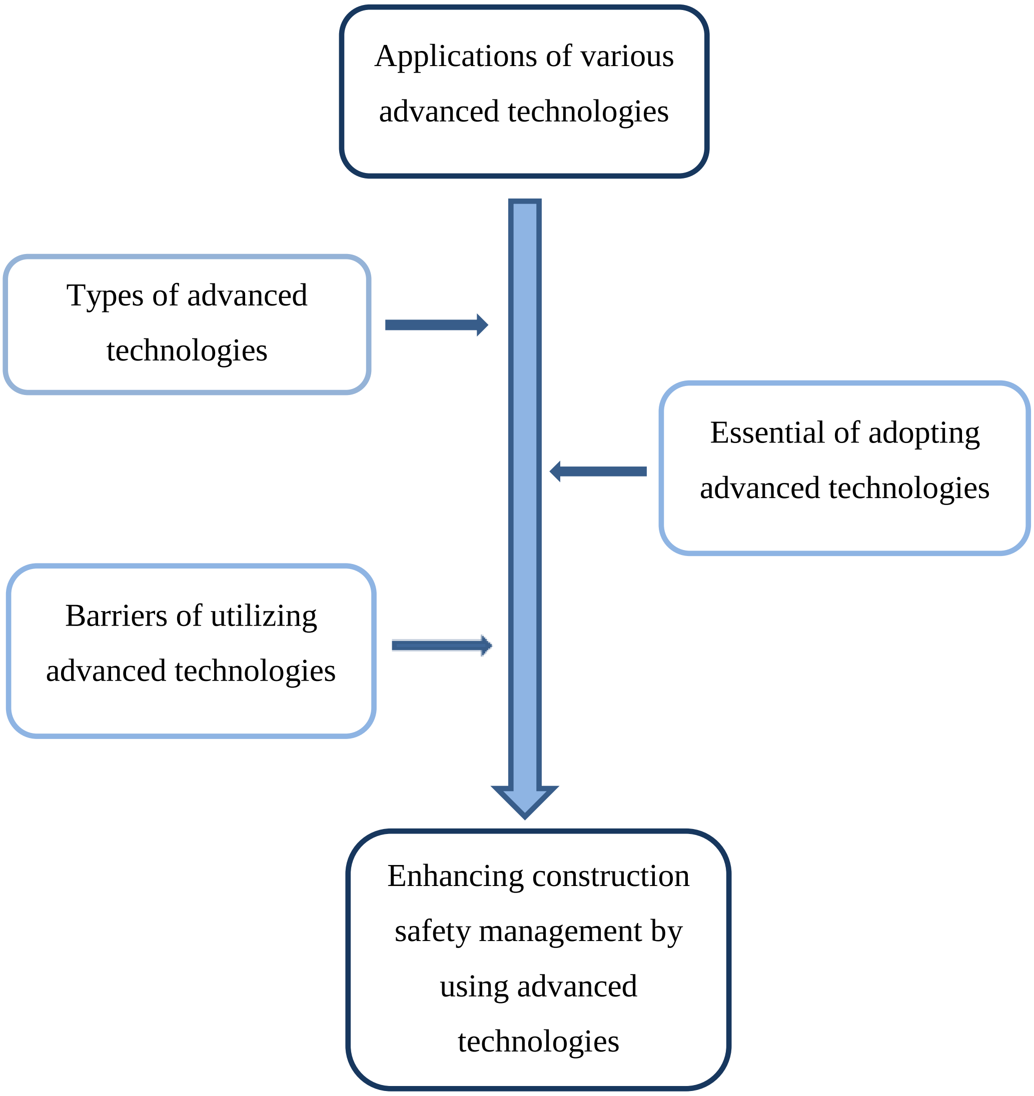

Figure 2.1: Proposed Conceptual Framework

2.8 Conclusion

In a nutshell, it is apparent that the incorporation of advanced technologies into construction safety management has the capacity to significantly enhance overall construction site safety outcomes. By enhancing data collection, analysis, and communication with the assistance of technologies such as exoskeleton, drones, Building Information Modelling (BIM), and sensing technology, proactive and effective safety measures can be implemented. Although implementation and training remain obstacles that must be surmounted, the advantages of incorporating advanced technologies into construction safety management are indisputable. Continuing technological investment and research will be essential in the future to safeguard the health and safety of construction labourers.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

Chapter 3 will delve into research methodology, which serves as the fundamental basis for any investigation. This study aims to provide a comprehensive definition of research and explore quantitative, qualitative, and mixed methods. The rationale behind selecting the research method for the investigation will also be elucidated. Finally, we will delineate the study design employed to validate our findings.

3.2 Definition of Research

Based on Patel (2019), in colloquial language, research is commonly understood as the pursuit of knowledge. Research is a systematic and scientific investigation conducted to gather pertinent knowledge on a specific topic. Similarly, Asenahabi (2019) explained that conducting research entails a methodical and meticulous approach to problem-solving and acquiring fresh insights. The purpose of research is to discover resolutions to mysteries through the application of scientific methodologies. The primary objective of research is to uncover concealed truths that have yet to be uncovered. The classification of research can be based on various factors, including time, purpose, circumstances, place, and technology (Patel, 2019).

3.3 Research Methodology

According to Patel (2019), research methodology is a scientific field that focuses on the systematic examination of how research is conducted. Creswell (2018) posits that research approaches consist of methodologies and strategies that progress from broad hypotheses to particular methods of data collection, analysis, and interpretation. The primary aim of Research Methodology is to furnish an exhaustive account and evaluation of diverse methodologies, elucidating their constraints and available resources (Patel, 2019). This includes clarifying the assumptions and implications associated with these methods, and establishing connections between their potential and the twilight zone at the forefront of knowledge. It is categorized into three methods which are quantitative method, qualitative method, and mixed method.

3.3.1 Quantitative Method

The quantitative approach entails the methodical collection and analysis of numerical data for the purpose of answering scientific research questions. The quantitative technique is employed to sum up, calculate, identify patterns, forecast, and examine causal relationships, while also extrapolating findings to broader populations (Rana et al., 2021). Moreover, Patel (2019) defined quantitative research as the process of collecting population, social, and economic data for a specific region through the conduct of surveys. Statistical analysis is applied to them. It mostly relies on primary data collection methods such as surveys and questionnaires.

3.3.2 Qualitatitive Method

Qualitative research aims to enhance comprehension of concepts, viewpoints, or personal encounters through the collection and examination of non-numerical data, including text, video, and audio. It has the capability to reveal complex intricacies regarding a given situation or to generate innovative research ideas. The primary objective of qualitative research is to get a thorough comprehension of social phenomena within their authentic settings. This approach emphasises the why rather than the what of social phenomena and is predicated on the direct experiences of individuals as agents of meaning-making in their daily lives (Ugwu and Eze, 2023).

3.3.3 Mixed Method

Mixed methods research, according to Creswell (2018), is a methodological approach that involves the gathering of qualitative and quantitative data. Integrating qualitative and quantitative data, analysis, outcomes, philosophical viewpoints, or other parts of study is a fundamental characteristic of mixed methods research. In light of multiple demands for practical guidance, the domain of mixed methods research has witnessed notable progress in the realm of integration. This progress encompasses various aspects such as the conceptualization of integration, the presentation of integrated findings, and the development of specific methodologies and protocols for integration during the planning and data collection phases (Guetterman and James, 2023).

3.4 Justificatin of Selected Research Method

This study opted for quantitative research methodologies because of their capacity to yield reliable and objective data that can be subjected to statistical analysis. When aiming to improve worker safety in construction sites, it is crucial to gather quantifiable data regarding accident rates, the influence of advanced technologies on safety matters, and the challenges encountered.

This study will utilize quantitative tools, including surveys, questionnaires, and statistical analysis, to precisely assess the success of implementing advanced technologies. For instance, through distribution of surveys to a substantial sample of chosen respondents, data relating the topic of research can readily acquired. The collected data can be analyzed to identify the obstacles hindering the adoption of advanced technologies in building projects, as well as the recommendations for enhancing their application. Quantitative methods enable the comparison of numerous variables and the identification of patterns and trends that can provide insights for future safety measures.

Figure 3.1 shows the overview of three types of research method. Instead of adopting qualitative research method, survey research in quantitative method enables to gather substantial quantities of data, typically in a statistical format, from a significant number of individuals within a short period by employing closed-ended questions. This study will not apply opene-ended questions in the qualitative method. It is control-sensitive which means that the researcher possesses greater autonomy in determining the methodology for data collection. This approach facilitates the acquisition of a broader viewpoint.

Furthermore, quantitative research methods are well-suited for this study since they allow the researcher to gather extensive data from many sources. This is essential for comprehending the complex use of advanced technologies in construction sites. This study seeks to use quantitative methodologies to generate evidence-based suggestions for enhancing workplace safety in the construction industry.

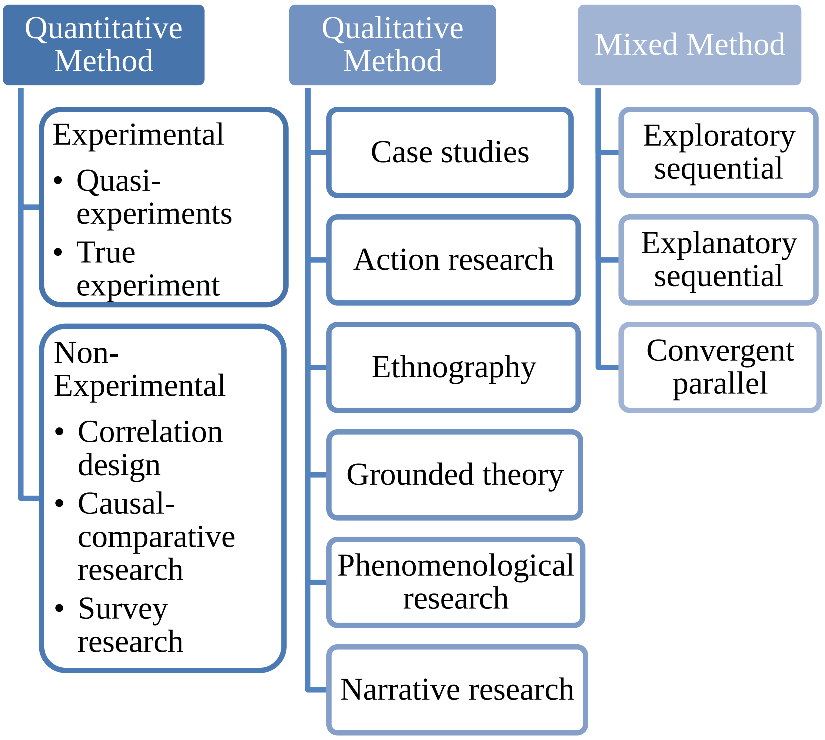

Figure 3.1 Overview of Research Design Types (Asenahabi, 2019)

3.5 Research Design

3.5.1 Choosing a Research Strategy

A strategy is, in general, an action plan designed to accomplish a particular goal. Therefore, a plan outlining the approach a researcher will take to address their research issue can be referred to as a research strategy. It is the methodological connection that exists between the philosophy and the techniques used to gather and process evidence (Saunders et al., 2016). There are several strategies such as Experiment, Survey, Case Study, Ethnography, Action Research, Grounded Theory, and Narrative Inquiry. A Survey strategy is adopted in this study. According to Saunders et al. (2016), the survey method is typically used in conjunction with a deductive research technique. In business and management research, it is a widely utilised technique that is most commonly employed to address the "what," "who," "where," "how much," and "how many" issues. As a result, exploratory and descriptive research typically uses it. Questionnaire-based survey tactics are widely used because they facilitate the cost-effective and standardised collection of data from a large population, enabling straightforward comparisons (Saunders et al., 2016).

3.5.2 Choosing a Time Horizon

Time horizon is categorized into two types which are cross-sectional and longitudinal studies. To address a research question, a study can be conducted in which data are collected only once, sometimes over the course of a few days, weeks, or months (Sekaran and Bougie, 2016). They are referred to as cross-sectional or one-shot studies. This study is defined as cross-sectional study. Survey strategy is usually employed in cross-sectional studies. Most of the research projects conducted for academic purposes are often time constrained. However, Sekaran and Bougie (2016) has explained that longitudinal studies are conducted over an extended period of time as the investigators may tend to study phenomena or human at more than one point in order to address the research issue. The researchers can control over some of the variables being studied (Saunders et al., 2016).

3.5.3 Executing the Research Design

The arrangement of conditions for data collection and analysis in a research design is intended to strike a balance between frugality and relevance to the research objective. The likelihood of achieving success in a research endeavour is significantly increased when the initial phase is accurately articulated or specified as a clear statement of objectives and rationale. Once the initial task is completed, the subsequent stages required for creating a research plan and effectively carrying out the research are encompassed in a research design (Adebiyi et al., 2016).

In line with Figure 3.2 which shows the process engaged in this study, the research design workflow commences with the identification of the study area and the selection of the research topic, in which study area was determined as “digital construction tools”. After doing research on the scope, research topic was selected as “Applying Advanced Technologies For Enhancing Construction Safety Management: The Contractor’s Perspective” as increasing rate of accidents in construction sites was founded. Subsequently, a comprehensive examination of the literature is conducted to gain insight into the current understanding within the topic. In this process, Havard style citation and reference was adopted to prevent plagiarism.

After that, the research questions were established included “What are the advanced technologies applied in construction safety?”, “What are the essential of these advanced technologies?”, and “What is the barriers of advanced technology adoption in managing construction safety?” to cover the research gap. Then, specific aim and objectives were identified to provide a clear direction for the study. Next, the methodology chosen was quantitative research method, the reason is that a large population is required to examine the adoption of advanced technologies in managing construction safety as well as to obtain information in the aspect of advanced technology types, its essentials, and barriers. Hence, in order to collect data, questionnaires were generated and distributed to a selected pool of individuals through email and social media. Sample selection has been completed before this.

After data collection was carried out, the data gathered was used to conduct data analysis. The data is then interpreted, results and findings were also presented. Ultimately, a conclusion is crafted to succinctly recapitulate the study. The study also addressed the obstacles encountered during its execution, and subsequent recommendations were provided to assist future researchers investigating the same scope or topic.

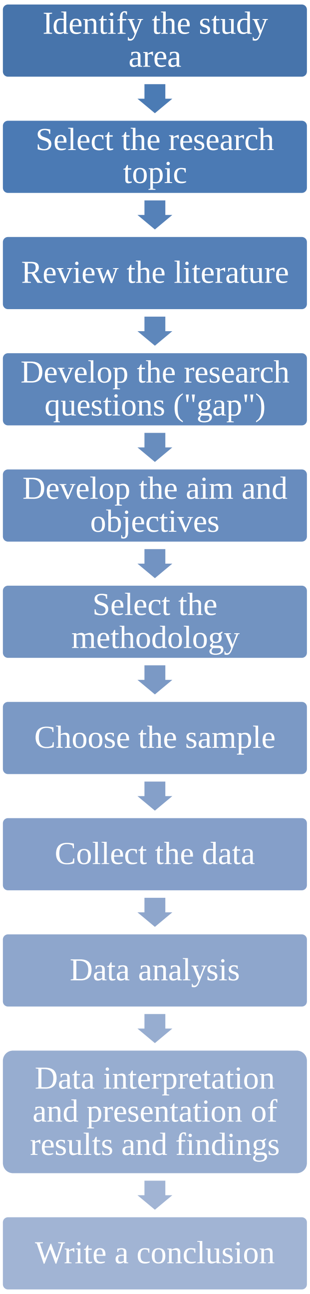

Figure 3.2 Workflow of Research Design

3.6 Designing the Questionnaire and the Structure

Before constructing the questionnaire, the study objectives were identified and ensure that the questions were aligned with them. The questionnaires were developed by following the objectives of the study below:

1. To identify the advanced technologies for managing construction safety.
2. To explore the essential of advanced technologies in managing construction safety.
3. To evaluate the barriers of advanced technology adoption in managing construction safety.

These objectives were thoroughly reflected in each section of the questionnaire. There was an introduction that offers the respondents a brief explanation of the questionnaire's purpose. The respondents were assured that their responses will remain confidential and anonymous. A clear instructions on the method of answering the questions was provided.

This questionnaire was classified into Section A, B, C, and D. Section A gathers demographic information of the repondents, which may then be applied to determine how various demographic factors affect the outcomes. The examples of the questions are shown as below:

1. How many years of your experience in the construction industry?
2. What is your current position in the organisation?
3. What is your company size?
4. What is your registered company grade in CIDB Malaysia?

In Section B, the familiarity with the distinct types of advanced technologies for enhancing construction safety management was being assessed. This is to address the first objective of the study. The questions developed are as follows:

1. To what extent you are familiar with the following advanced technologies for enhancing construction safety management?
2. To what extent these advanced technologies are used in your current / past construction project for managing construction safety?
3. What is your preference between Traditional Methods vs Advanced Technologies when it comes to the following activities?

The first question will be answered in *Not at all familiar, Slightly familiar, Somewhat familiar, Moderately familiar*, and *Extremely familiar*. And the answers of the second question will be *No Using, Planning to use in 3 years, Planning to use in 5 years, Just using,* and *Using all the while*. Lastly, *Traditional methods* and *Advanced technologies* will be the ways of answering for the last question by the respondents. There are 11 activities were selected based on the literature review of advanced technology types.

In Section C, the question of 'To what extent you agree the following is effective in ensuring workplace safety in construction sites?' was created to address the second objective of the study. The respondents were allowed to answer it by selecting the options of *Strongly disagree, Disagree, Neither agree of disagree, Agree,* and *Strongly Agree*. There are 25 statmenets derived from the literature review of essentials of advanced technologies.

To address the third objective of the study, the question of *'To what extent do you agree the following will undermine the implementation of advanced technologies for enhancing workplace safety?'* were developed in Section D. The way of answering this question is same as Section C. A literature review of barriers to the adoption of advanced technologies resulted in 9 statements indicating the extent to which respondents agree with barriers to the adoption of advanced technologies.

3.7 Research Sampling

3.7.1 Defining the Population

The process of defining the population in a research study involves the precise identification of the group of individuals or elements that the researcher intends to investigate. It is imperative to precisely define the population, as it serves as the foundation for the selection of a representative sample and the formulation of valid conclusions. The population can be defined using a variety of criteria, including demographics, geographic location, or specific characteristics that are pertinent to the research study (Trochim, Donnelly, & Arora, 2016). According to the title of this research, construction safety management only involves the role of a contractor or subcontractor, the party who is in charge of constructing building, hence the population is limited to contractor practitioners with the most relevant expertise on construction sites.

3.7.2 Determining the Sampling Frame

According to Barrie (2016), a sampling frame is a comprehensive list or representation of all the items within a specified population, from which a sample will be selected. It functions as a useful guide for choosing the sample and guarantees that every individual in the population has an equitable opportunity to be included in the sample. The process of determining the sampling frame entails creating a thorough and easily accessible list that precisely represents the population being studied. From contractor pool, sampling frame is obtained mainly from Construction Industry Development Board (CIDB) or Pusat Khidmat Kontraktor (PKK).

3.7.3 Determining the Sampling Design

The sampling design is the strategy or approach employed to select the sample from the population. Random sampling, stratified sampling, cluster sampling, and convenience sampling are among the many sampling designs, each with its own set of advantages and disadvantages. The selection of a sampling design is contingent upon the research objectives, the available resources, and the level of precision that is necessary for the study.

The various sampling methods can be broadly classified into two primary categories: (i) Probability Sampling Method and (ii) Non-Probability Sampling Method. The probability sampling method is a technique used to pick subjects from a population without any bias or prejudice. This method ensures that all units in the population have an equivalent or preset probability of being selected for the sample. On the other hand, the lack of scientific foundation in non-probability sampling method results in an increased likelihood of picking a biassed sample. Typically, such a sample does not encompass all the characteristics of the complete population. Not all units have a predetermined or defined likelihood of being selected in this procedure (Shukla, 2020)

In this research, nonprobability sampling of convenience and snowball have been applied. According to Nikolopoulou (2022), convenience sampling refers to the researcher's convenience is the primary factor that determines convenience sampling. This may encompass factors such as geographic proximity, ease of access, and existing contact with the population of interest. Meanwhile, snowball sampling is employed when the target group for study is difficult to access or when there is a lack of an established database or sample frame to facilitate their identification. To initiate a snowball sampling method, the first step is identifying an individual who is willing to actively engage in your research. Subsequently, they are requested to acquaint researcher with other individuals. In such instances, social networks can be utilized to establish contact with the target population (Nikolopoulou, 2022).

3.7.4 Determining the Sampling Size

Sampling size determination entails the selection of the appropriate number of components or individuals to be included in the sample. Calculating an adequate sample size is crucial to ensure sufficient statistical power in detecting a significant effect, while also minimising the likelihood of sampling error. As mentioned by Bluman (2014), the Central Limit Theorem (CTL) is a foundational concept in statistics that posits that the sampling distribution of the sample mean gradually approaches a normal distribution as the sample size increases (Bluman, 2014). In order to obtain demographic information from respondents, 4 questions have been designed including year of working experience, position, company size, and CIDB grade. In accordance with CTL, the minimal sample size for each group is 30, which implies that a minimum of 120 responses is required to obtain a more dependable result.

3.7.6 Executing the Sampling Process

The sampling procedure entails executing the sampling design and choosing the sample from the sampling frame. This procedure entails the identification of the sampling units, the collection of data from the chosen sample, and the verification that the sample accurately represents the specified population. Questionnaires were distributed to contractor background through Email, WhatsApp, and Instagram. Additionally, a follow-up process was implemented to improve the response rate in the event that the minimum requirement for CTL was not met. Ensuring the accurate implementation of the sampling process is essential in order to acquire dependable and legitimate research results.

3.8 Data Analysis

3.8.1 Cronbach's Alpha Reliability Test

In 1951, Lee Cronbach developed Alpha to quantify the internal consistency of a test or scale. Alpha is represented as a numerical value between 0 and 1. Internal consistency is a term that denotes the degree to which all items in a test measure the same concept or construct. Consequently, it is associated with the interrelatedness of the items within the test (Tavakol, 2011).

3.8.2 Descriptive Stastistics

The relationship between variables in a sample or population is described using descriptive statistics to summarise data in an organised manner. Descriptive statistics are an essential initial stage in research and should always be performed prior to conducting inferential statistical comparisons. Descriptive statistics encompass measures of frequency, central tendency, dispersion/variation, and position, in addition to the use of variables such as nominal, ordinal, interval, and ratio (Kaur, 2018). Mean ranking is applied to compare the sequence in each section as it offers a more reliable measure of central tendency that is less affected by outliers or extreme values.

3.8.3 Kruskal-Wallis Test

Xia (2020) has emphasized that the Kruskal-Wallis test, introduced by Kruskal and Wallis in 1952, is a nonparametric technique used to determine if samples are derived from the same underlying distribution. The Kruskal-Wallis test does not make any assumptions about the normal distribution of the underlying data. Therefore, this test is more suited for analysing data of this research. It is more suitable to use ranks rather than actual values to prevent the presence of outliers or the nonnormal distribution of data, as the data collected is frequently not normally distributed and contain some strong outliers. This test was applied in Section 4.4, 4.7 and 4.8 to address all the three objectives. This test is adopted to identify familiarity of advanced technologies from the respondents to address the first objective; to determine the level of agreement on the essential of applying advanced technologies to address the second objective; and to evaluate the level of agreement with the barriers to applying advanced technologies to address the last objective.

3.8.4 Pearson's Chi Square Test

The chi-square test is a nonparametric statistical test that serves two main purposes: (a) to assess whether there is a relationship between two or more groups, populations, or criteria, and (b) to evaluate the degree to which the observed distribution of data matches the expected distribution. This tool is specifically designed for the analysis of categorical data. It is not suitable for analysing parametric or continuous data (Rana, 2015). The purpose of conducting this test is to analyse the data collected from the questionnaire, which is classified into two categories: "Traditional Method" and "Advanced Technologies". These categories are specified as categorical data. This test is applied in Section 4.6.

3.9 Summary

In this chapter, the research methodology adopted in this study has been defined. The research method used was quantitative method, which consist of survey research. A list of questions in questionnaires was developed and distributed to targeted population. All the process involved in this study were described and presented, and they ended with a conclusion.

CHAPTER 4

FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter will include descriptive and inferential statistics by describing outcomes from a population of data collected in the study and analyzing samplings to draw conclusions and make predictions about the whole population. Based on Ruben et al. (2023), inferential statistics involves the analysis of data from a sample in order to draw conclusions and extrapolate the findings to the entire population. To answer or test the hypotheses is the aim of inferential statistics. The alternative hypothesis (H1 and Ha) asserts that there is a difference between the groups or that there is some correlation between the predictor and the result, while the null hypothesis (H0, "H-naught," "H-null") claims that there is no difference between the study group and the control (Ruben, 2023). Several tests will be executed by using SPSS to identify the adoption of advanced technologies among main contractors, contributing to the success of achieving aim and objectives of the research.

4.2 Respondent Demographic

Table 4.1 shows an overview of demographic information from 166 respondents including their working experience, position, company size, and registered company grade in CIDB Malaysia. The data collection process spanned approximately two months starting from 18 July 2024 to 18 September 2024. Throughout this period, a total of 240 questionnaires were distributed through various platforms such as WhatsApp, Email and Instagram. By 21 August 2024, 166 responses were received, resulting in a response rate of 69.17%.

Analysis presented in Table 4.1 indicates that 37 respondents reported having 6 to 10 years of work experience, representing the largest segment at 22.30%. Among the participants, 41 held manager/ project manager/ construction manager/ Head of Department positions within their organizations, reflecting the highest representation across all job roles. Additionally, the majority of responses came from company size category of 5 to 30 people, accounting for 27.10% of the total respondents. Lastly, the largest number of responses came from registered company grade in CIDB Malysia with G6, comprising 31 individuals and making up 18.70% of the total sample.

Table 4.1: Data of demographic information collected

Demographic Information	Catagories	Frequency (n)	Percentage (%)
Working experience	0-2 years	36	21.7
	3-5 years	30	18.1
	6-10 years	37	22.3
	11-20 years	30	18.1
	21 years and above	33	19.9
Current position	Junior Executive	31	18.7
	Senior Executive	30	18.1
	Assistant Manager/ Assistant Team Leader	33	19.9
	Manager/ Project Manager/ Construction Manager/ Head of Department	41	24.7
	Director/ Managing Directors/ CEO	31	18.7
Company size	Less than 5 people	37	22.3
	5 – 30 people	45	27.1
	31 – 75 people	44	26.5
	More than 75 people	40	24.1
CIDB grade	None	23	13.9
	G1	12	7.2
	G2	16	9.6
	G3	26	15.7
	G4	25	15.1
	G5	20	12.0
	G6	31	18.7
	G7	13	7.8

4.3 Reliability Test of Cronbach's Alpha

Table 4.2 shows the Reliability Test of Cronbach's Alpha results for Section B, C and D. If α is greater than 0.7, it reveals a high level of internal consistency among the items in the test. In this test, each section obtains a Cronbach's Alpha value of more than 0.7, indicating that the items from each section are highly correlated with each other.

Table 4.2: Cronbach's Alpha reliability test results

Section	Cronbach's Alpha	Number of Items
B	0.886	31
C	0.814	25
D	0.803	9

4.4 Familiarity of Advanced Technologies for Enhancing Construction Safety Management

Table 4.3 shows the mean ranking of the familiarity of advanced technologies for enhancing construction safety management. B1F – "*Building Information Modeling (BIM)*" is regarded as the most familiar advanced technology and followed by B1H – "*Augmented Reality (AR) and Virtual Reality (VR)*" and B1C – *"Sensing Technology"*. Meanwhile, the respondents are least familiar with B1J – "*YOLOv3*".

Table 4.3: Mean ranking of the familiarity of advanced technologies

Code	**Statement**	**Mean Rank**	**Chi-Square**	**Asymp. Sig.**
B1F	Building Information Modeling (BIM)	6.08	25.864	0.002
B1H	Augmented Reality (AR) and Virtual Reality (VR)	5.72		
B1C	Sensing technology	5.61		
B1D	Drone	5.60		
B1B	Artificial Intelligence (AI)	5.52		
B1G	Modular construction	5.51		
B1A	Exoskeleton	5.46		
B1I	Internet of Thing (IoT)	5.45		
B1E	3D Printing	5.37		
B1J	YOLOv3	4.67		

The Kruskal-Wallis test was implemented to investigate the correlation between the demographic profile and the level of familiarity with advanced technology. The results of Table 4.4 indicate that the null hypotheses were refuted and that there is a substantial difference ($p < 0.05$) between the demographic characteristics of the respondents and their familiarity with advanced technologies for improving construction safety management.

Table 4.4: Rejected Null Hypothesis for the Respondents' Perception on the Familiarity Level with Advanced Technology

Code	Statement	Asymp. Sig.
Working Experience		
B1A	Familiarity level with Exoskeleton is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1D	Familiarity level with Drone is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
Position		
B1D	Familiarity level with Drone is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
B1E	Familiarity level with 3D Printing is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
B1F	Familiarity level with Building Information Modeling (BIM) is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001

Table 4.4 (Cont'd)

Company Size		
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
B1C	Familiarity level with Sensing Technology is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
B1F	Familiarity level with Building Information Modeling (BIM) is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
CIDB Grade		
B1A	Familiarity level with Exoskeleton is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.001
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
B1E	Familiarity level with 3D Printing is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001

(A) The group of 21 years and above working experience agreed

(i) more towards B1A – *"Exoskeleton"* (mean rank = 108.38) as the level of familiarity with advanced technology than group of 3-5 years (mean rank = 90.10) , 6-10 years (mean rank = 82.95), 11-20 years (mean rank = 82.08) and 0-2 years (mean rank = 56.93).

(ii) more towards B1B – *"Artificial Intelligence (AI)"* (mean rank = 98.47) as the level of familiarity with advanced technology than group of 6-10 years (mean rank = 95.54), 3-5 years (mean rank = 90.37), 11-20 years (mean rank = 84.55) and 0-2 years (mean rank = 50.81).

(iii) more towards B1D – *"Drone"* (mena rank = 101.62) as the level of familiarity with advanced technology than group of 11-20 years (mean rank = 92.30), 3-5 years (mean rank = 85.78), 6-10 years (mean rank = 85.24) and 0-2 years (mean rank = 55.86).

(B) The group of Senior Executive position agreed

(i) more forwards B1D – *"Drone"* (mean rank = 106.03) as the level of familiarity with advanced technology than group of Director/ Managing Directors/ CEO (mean rank = 102.08), Assistant Manager/ Assistant Team Leader (mean rank = 77.82), Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 75.71) and Junior Executive (mean rank = 59.47).

(C) The group of Director/ Managing Directors/ CEO position agreed

(i) more forwards B1E – *"3D Printing"* (mean rank = 114.05) as the level of familiarity with advanced technology than group of Senior Executive (mean rank = 84.07), Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 82.60), Assistant Manager/ Assistant Team Leader (mean rank = 71.47) and Junior Executive (mean rank = 66.40).

(ii) more forwards B1F – *"Building Information Modeling (BIM)"* (mean rank = 103.97) as the level of familiarity with advanced technology than group of Senior Executive (mean rank = 97.77), Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 90.62), Assistant Manager/ Assistant Team Leader (mean rank = 64.26) and Junior Executive (mean rank = 60.29).

(D) The group of Medium-sized (31-75 people) company agreed

(i) more towards B1B – *“Artificial Intelligence (AI)”* (mean rank = 102.86) as the level of familiarity with advanced technology than group of Large-sized (>75 people) (mean rank = 98.13), Small-sized (5-30 people) (mean rank = 74.83) and Micro-sized (<5 people) (mean rank = 55.20).

(ii) more towards B1F – *“Building Information Modeling (BIM)”* (mean rank = 98.98) as the level of familiarity with advanced technology than group of Large-sized (>75 people) (mean rank = 92.56), Small-sized (5-30 people) (mean rank = 85.86) and Micro-sized (<5 people) (mean rank = 52.43).

(D) The group of Large-sized (>75 people) company agreed

(i) more towards B1C – *“ Sensing Technology”* (mean rank = 100.09) as the level of familiarity with advanced technology than group of Medium-sized (31-75 people) (mean rank = 99.65), Small-sized (5-30 people) (mean rank = 74.67) and Micro-sized (<5 people) (mean rank = 57.11).

(E) The group of G5 CIDB Grade agreed

(i) more towards B1A – *“Exoskeleton”* (mean rank = 118.20) as the level of familiarity with advanced technology than group of G7 (mean rank = 91.31), G4 (mean rank = 88.78), G6 (mean rank = 88.19), None (mean rank = 85.17), G2 (mean rank = 72.59), G1 (mean rank = 66.00) and G3 (mean rank = 55.54).

(ii) more towards B1B – *“Artificial Intelligence (AI)”* (mean rank = 103.30) as the level of familiarity with advanced technology than group of G4 (mean rank = 101.12), G6 (mean rank = 99.08), G7 (mean rank = 96.62), None (mean rank = 81.78), G2 (mean rank = 65.66), G3 (mean rank = 62.88) and G1 (mean rank = 31.08).

(F) The group of G4 CIDB Grade agreed

(i) more towards B1E – *"3D Printing"* (mean rank = 106.38) as the level of familiarity with advanced technology than group of G5 (mean rank = 101.90), G6 (mean rank = 98.44), G7 (mean rank = 85.65), G3 (mean rank = 72.19), None (mean rank = 68.98), G1 (mean rank = 59.92) and G2 (mean rank = 51.00).

4.5 Implementation of Advanced Technologies in Current/ Past Construction Project

The mean rankings of the implementation levels of advanced technologies in current/ past construction project are summarized in Table 4.5. The highest mean rank of advanced technology implementation is B2D – "*Drone*", while B2C – *"Sensing Technology"* and B2F – "*BIM*" are the second highest mean rank. Furthermore, the least use technology among the respondents is B2J – "*YOLOv3*".

Table 4.5: Mean ranking of implementation of advanced technologies

Code	Statement	Mean Rank	Chi-Square	Asymp. Sig.
B2D	Drone	5.96	36.972	<0.001
B2C	Sensing technology	5.88		
B2F	Building Information Modeling (BIM)	5.88		
B2B	Artificial Intelligence (AI)	5.76		
B2G	Modular construction	5.54		
B2H	Augmented Reality (AR) and Virtual Reality (VR)	5.48		
B2E	3D Printing	5.45		
B2I	Internet of Thing (IoT)	5.24		
B2A	Exoskeleton	5.02		
B2J	YOLOv3	4.79		

4.6 Preference of Traditional Methods and Advanced Technologies from the Respondents

Table 4.6 shows the preference of the respondents between traditional methods and advanced technologies in managing construction safety. In all construction events, advanced technologies made up the majority of choices. Among them, B3F – *"Offering comprehensive view of building's data"* received the highest number of votes, and followed by B3D – *"Mapping large areas and create detailed topographic surveys"* and B3E – *"Site surveying and offering a bird's-eye view of plan"*.

Table 4.6: Preference of Traditional Methods and Advanced Technologies

Code	Statements	Traditional Methods		Advanced Technology	
		Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)
B3A	Execution in construction works	61	36.7	105	63.3
B3B	Problem-solving and decision-making	60	36.1	106	63.9
B3C	Identifying potential safety dangers by detecting workers' motions, postures and physiological indicators	49	29.5	117	70.5
B3D	Mapping large areas and create detailed topographic surveys	47	28.3	119	71.7
B3E	Site surveying and offering a bird's-eye view of plan	48	28.9	118	71.1
B3F	Offering comprehensive view of building's data	41	24.7	125	75.3
B3G	Reducing cost and time overruns	51	30.7	115	69.3
B3H	Prefabricating building components	63	38.0	103	62.0
B3I	Examining and navigating construction site	50	30.1	116	69.9
B3J	Gathering and transmitting data	60	36.1	106	63.9
B3K	Detecting objects in captured photos	57	34.3	109	65.7

Table 4.7: Pearson's Chi Square for Preference of Traditional Methods and Advanced Technologies among Respondents based on Demographic

Code	Statements	Categories	Traditional Methods		Advanced Technology		Asymp. Sig.
			Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Year of Working Experience							
B3F	Offering comprehensive view of building's data	0-2 years	19	11.4	17	10.2	<0.001
		3-5 years	1	0.6	29	17.5	
		6-10 years	10	6.0	27	16.3	
		11-20 years	5	3.0	25	15.1	
		21 years and above	6	3.6	27	16.3	
B3D	Mapping large areas and create detailed topographic surveys	0-2 years	20	12.0	16	9.6	0.002
		3-5 years	6	3.6	24	14.5	
		6-10 years	8	4.8	29	17.5	
		11-20 years	6	3.6	24	14.5	
		21 years and above	7	4.2	26	15.7	
B3H	Prefabricating building components	0-2 years	22	13.3	14	8.4	0.003
		3-5 years	11	6.6	19	11.4	
		6-10 years	7	4.2	30	18.1	
		11-20 years	8	4.8	22	13.3	
		21 years and above	15	9.0	18	10.8	
Current Position							
B3A	Execution in construction works	Junior Executive	13	7.8	18	10.8	0.001

		Senior Executive	11	6.6	19	11.4	
		Assistant Manager	21	12.7	12	7.2	
		Manager	11	6.6	30	18.1	
		Director	5	3.0	26	15.7	
B3J	Gathering and transmitting data	Junior Executive	15	9.0	16	9.6	0.001
		Senior Executive	5	3.0	25	15.1	
		Assistant Manager	20	12.0	13	7.8	
		Manager	10	6.0	31	18.7	
		Director	10	6.0	21	12.7	
B3H	Prefabricating building components	Junior Executive	10	6.0	21	12.7	0.002
		Senior Executive	12	7.2	18	10.8	
		Assistant Manager	22	13.3	11	6.6	
		Manager	9	5.4	32	19.3	
		Director	10	6.0	21	12.7	
Company Size							
B3B	Problem-solving and decision-making	Less than 5	18	10.8	19	11.4	0.002
		5-30	14	8.4	31	18.7	
		31-75	22	13.3	22	13.3	
		More than 75	6	3.6	34	20.5	
B3D	Mapping large areas and create detailed topographic surveys	Less than 5	17	10.2	20	12.0	<0.001
		5-30	17	10.2	28	16.9	
		31-75	4	2.4	40	24.1	
		More than 75	9	5.4	31	18.7	

CIDB Grade							
B3D	Mapping large areas and create detailed topographic surveys	None	7	4.2	16	9.6	<0.001
		G1	6	3.6	6	3.6	
		G2	8	4.8	8	4.8	
		G3	13	7.8	13	7.8	
		G4	7	4.2	18	10.8	
		G5	1	0.6	19	11.4	
		G6	2	1.2	29	17.5	
		G7	3	1.8	10	6.0	
B3E	Site surveying and offering a bird's-eye view of plan	None	3	1.8	20	12.0	0.002
		G1	7	4.2	5	3.0	
		G2	5	3.0	11	6.6	
		G3	14	8.4	12	7.2	
		G4	3	1.8	22	13.3	
		G5	8	4.8	12	7.2	
		G6	6	3.6	25	15.1	
		G7	2	1.2	11	6.6	
B3A	Execution in construction works	None	9	5.4	14	8.4	0.003
		G1	7	4.2	5	3.0	
		G2	10	6.0	6	3.6	
		G3	15	9.0	11	6.6	
		G4	6	3.6	19	11.4	
		G5	4	2.4	16	9.6	

	G6	5	3.0	26	15.7
	G7	5	3.0	8	4.8

4.7 Level of Agreement on the Essential of Applying Advanced Technologies

The mean ranking of advanced technologies essential in managing construction safety is outlined in Table 4.8. The top three essentials of advanced technologies that most of the respondents agree are C112 – *"My company used drone to execute inspection tasks"*, C110 – *"My company used drone to oversee job site security"*, and C111 – *"My company used drone to map large areas and create detailed topographic surveys".* Besides, C125 – *"My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers"* and C11 - *"My company used exoskeleton to reduce physical movement by humans"* ranked the last two.

Table 4.8: Mean Ranking of Level of Agreement on the Essential of Applying Advanced Technologies

Code	Statement	Mean Rank	Chi-Square	Asymp. Sig.
C112	My company used drone to execute inspection tasks.	14.83	85.873	<0.001
C110	My company used drone to oversee job site security.	14.67		
C111	My company used drone to map large areas and create detailed topographic surveys.	14.19		
C14	My company used artificial intelligence (AI) to solve problems and make decisions.	13.94		
C12	My company used exoskeleton to carry out repeated jobs.	13.82		
C116	My company used BIM to reduce time overruns and cost overruns.	13.69		
C117	My company used BIM to enhance communication among stakeholders.	13.59		
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites.	13.55		
C19	My company used sensing technology to detect and monitor unauthorised individuals visiting the premises.	13.29		
C18	My company used sensing technology to notify the event regarding a worker's health.	13.27		
C13	My company used exoskeleton to lift heavy weights.	13.14		
C114	My company used 3D-printing to offer comprehensive view of the building's data.	13.12		
C121	My company used VR to digitally examine and navigate a construction site.	13.01		
C118	My company used modular construction to produce structures quickly and efficiently.	13.00		
C113	My company used 3D-printing to boost efficiency in planning, designing, construction and management of the building.	12.92		
C115	My company used 3D-printing to reduce waste from construction.	12.81		
C16	My company used AI to expose a worker's musculoskeletal system to physical risk factors.	12.59		
C17	My company used sensing technology to gather physiological and biological sensory data.	12.52		

C124	My company used YOLOv3 to detect objects.	12.32
C122	My company used IoT to transmit data.	12.29
C119	My company used modular construction to provide sustainable construction solutions.	12.27
C120	My company used AR to augment contextual perception of the surroundings.	11.85
C123	My company used IoT to gather data via sensors and peripheral devices.	11.76
C125	My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers.	11.36
C11	My company used exoskeleton to reduce physical movement by humans.	11.20

This study examines the correlation between the demographic characteristics of respondents and their level of agreement with the essentials of applying advanced technologies, using the Kruskal-Wallis test. The findings presented in Table 4.9 demonstrate that the null hypothesis has been rejected, suggesting a statistically significant distinction ($p < 0.05$) between the demographic characteristics of the respondents and the essentials of applying advanced technologies.

Table 4.9: Rejected Null Hypothesis for the Respondents' Perception on the Essentials of Applying Advanced Technologies

Code	Statement	Asymp. Sig.
Working Experience		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C13	My company used exoskeleton to lift heavy weights is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
Position		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction	<0.001

	Manager/ Head of Department and Director/ Managing Directors/ CEO.	
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C117	My company used BIM to enhance communication among stakeholders is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
Company Size		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.001
C112	My company used drone to execute inspection tasks is similar from the respondents with company size of Micro (<5 people), Small (5-30	<0.001

	people), Medium (31-75 people) and Large (>75 people).	
CIDB Grade		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
C116	My company used BIM to reduce time overruns and cost overruns is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
C125	My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.001

(A) The group of 21 years and above working experience agreed

(i) more towards C12 – *"My company used exoskeleton to carry out repeated jobs"* (mean rank = 111.45) as the essentials of applying advanced technologies than group of 6-10 years (mean rank = 89.35), 0-2 years (mean rank = 84.58), 11-20 years (mean rank = 75.03) and 3-5 years (mean rank = 72.12).

(ii) more towards C13 – *"My company used exoskeleton to lift heavy weights"* (mean rank = 108.41) as the essentials of applying advanced technologies than group of 3-5 years (mean rank = 92.73), 6-10 years (mean rank = 83.85), 11-20 years (mean rank = 80.67) and 0-2 years (mean rank = 54.97).

(iii) more towards C15 – *"My company used AI to identify and assess potential safety dangers and risks on construction sites"* (mena rank = 103.08) as the essentials of applying advanced technologies than group of 6-10 years (mean rank = 90.58), 3-

5 years (mean rank = 87.07), 11-20 years (mean rank = 81.50) and 0-2 years (mean rank = 56.97).

(B) The group of Manager/ Project Manager/ Construction Manager/ Head of Department position agreed

(i) more forwards C15 – *"My company used AI to identify and assess potential safety dangers and risks on construction sites"* (mean rank = 101.89) as the essentials of applying advanced technologies than group of Director/ Managing Directors/ CEO (mean rank = 93.03), Senior Executive (mean rank = 85.85), Assistant Manager/ Assistant Team Leader (mean rank = 75.68) and Junior Executive (mean rank = 55.69).

(ii) more forwards C117 – *"My company used BIM to enhance communication among stakeholders"* (mean rank = 100.79) as the essentials of applying advanced technologies than group of Senior Executive (mean rank = 93.68), Director/ Managing Directors/ CEO (mean rank = 92.16), Assistant Manager/ Assistant Team Leader (mean rank = 63.85) and Junior Executive (mean rank = 63.03).

(C) The group of Director/ Managing Directors/ CEO position agreed

(i) more forwards C12 – *"My company used exoskeleton to carry out repeated jobs"* (mean rank = 101.66) as the essentials of applying advanced technologies than group of Senior Executive (mean rank = 99.02), Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 82.38), Assistant Manager/ Assistant Team Leader (mean rank = 80.79) and Junior Executive (mean rank = 54.69).

(D) The group of Large-sized (>75 people) company agreed

(i) more towards C12 – *" My company used exoskeleton to carry out repeated jobs"* (mean rank = 100.46) as the essentials of applying advanced technologies than group of Medium-sized (31-75 people) (mean rank = 96.47), Small-sized (5-30 people) (mean rank = 70.03) and Micro-sized (<5 people) (mean rank = 66.12).

(ii) more towards C15 – *" My company used AI to identify and assess potential safety dangers and risks on construction sites"* (mean rank = 100.33) as the essentials of applying advanced technologies than group of Medium-sized (31-75 people) (mean rank = 89.34), Small-sized (5-30 people) (mean rank = 82.74) and Micro-sized (<5 people) (mean rank = 59.28).

(E) The group of Medium-sized (31-75 people) company agreed

(i) more towards C112 – *" My company used drone to execute inspection tasks"* (mean rank = 102.85) as the essentials of applying advanced technologies than group of Large-sized (>75 people) (mean rank = 89.35), Small-sized (5-30 people) (mean rank = 76.59) and Micro-sized (<5 people) (mean rank = 62.57).

(F) The group of G5 CIDB Grade agreed

(i) more towards C12 – *"My company used exoskeleton to carry out repeated jobs"* (mean rank = 100.55) as the essentials of applying advanced technologies than group of G4 (mean rank = 96.72), G6 (mean rank = 95.55), G2 (mean rank = 91.34), G7 (mean rank = 83.31), None (mean rank = 79.97), G3 (mean rank = 64.79) and G1 (mean rank = 33.58).

(ii) more towards C116 – *"My company used BIM to reduce time overruns and cost overruns"* (mean rank = 127.83) as the essentials of applying advanced technologies than group of G7 (mean rank = 95.88), G6 (mean rank = 87.42), None (mean rank = 86.78), G4 (mean rank = 76.58), G2 (mean rank = 67.69), G3 (mean rank = 63.98) and G1 (mean rank = 57.58).

(G) The group of G4 CIDB Grade agreed

(i) more towards C125 – *"My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers"* (mean rank = 107.02) as the essentials of applying advanced technologies than group of G6 (mean rank = 101.66), G5 (mean rank = 88.58), None (mean rank = 85.48), G3 (mean rank = 68.65), G2 (mean rank = 65.00), G7 (mean rank = 64.81) and G1 (mean rank = 52.42).

4.8 Level of Agreement with Barriers to Applying Advanced Technologies by the Respondents

Table 4.10 shows the mean ranking of the level of agreement with barriers to using advanced technology. D1G - "*My company feels struggle with the expenses connected with obtaining and upkeeping digital technology"*, emerges as the statement that most respondents agree with, and followed by the statement D1F - *"My company is unwilling to bear the cost of training"*.

Table 4.10: Mean Ranking for the Level of Agreement with Barriers to Applying Advanced Technologies

Code	Statement	Mean Rank	Chi-Square	Asymp. Sig.
D1G	My company feels struggle with the expenses connected with obtaining and upkeeping digital technology.	5.97	155.259	<0.001
D1F	My company is unwilling to bear the cost of training.	5.87		
D1H	My company is not using advanced technologies due to the process of exchanging information, data security and privacy.	5.35		
D1D	My company lacks adequately skilled staff to use advanced technologies.	5.3		
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions.	5.17		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns.	4.83		
D1E	My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers.	4.5		
D1C	Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation.	4.26		
D1I	My company thinks that legal obstacles concerning information retrieval and application have impeded the adoption of digital technologies.	3.75		

The Kruskal-Wallis test was utilised to examine the association between the demographic characteristics and the level of agreement with barriers to applying advanced technologies. The findings from Table 4.11 demonstrate that the null hypotheses were rejected, indicating a significant difference ($p < 0.05$) between the demographic characteristics of the respondents and their level of agreement with barriers to applying advanced technologies for enhancing construction safety management.

Table 4.11: Rejected Null Hypothesis for the Respondents' Perception on the Barriers to Applying Advanced Technologies

Code	Statement	Asymp. Sig.
Working Experience		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.001
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
D1C	Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.013
Position		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with position of Junior Executive,	0.027

	Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.004
D1E	My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers is similar from the respondents with position of Junior Executive, Senior Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.024
Company Size		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.003
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
D1E	My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled	0.008

	workers is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	
CIDB Grade		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
D1C	Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.012

(A) The group of 21 years and above working experience agreed

(i) more towards D1A – *"My company simply applied advanced technologies causing unique dangers and safety concerns"* (mean rank = 102.47) as the essentials of applying advanced technologies than group of 11-20 years (mean rank = 97.15), 6-10 years (mean rank = 86.88), 3-5 years (mean rank = 67.97) and 0-2 years (mean rank = 64.21).

(ii) more towards D1C – *"Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation"* (mena rank = 95.15) as the essentials of applying advanced technologies than group of 6-10 years (mean rank = 91.64), 11-20 years (mean rank = 89.25), 3-5 years (mean rank = 82.90) and 0-2 years (mean rank = 60.17).

(B) The group of 6-10 years and above working experience agreed

(i) more towards D1B – *"My company requires digital-tool-related knowledge to enhance the development of safety solutions"* (mean rank = 103.68) as the essentials of applying advanced technologies than group of 11-20 years (mean rank = 91.45), 21 years and above (mean rank = 89.33), 3-5 years (mean rank = 86.93) and 0-2 years (mean rank = 47.93).

(C) The group of Director/ Managing Directors/ CEO position agreed

(i) more forwards D1A – *"My company simply applied advanced technologies causing unique dangers and safety concerns"* (mean rank = 102.73) as the essentials of applying advanced technologies than group of Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 88.59), Senior Executive (mean rank = 83.80), Assistant Manager/ Assistant Team Leader (mean rank = 73.08) and Junior Executive (mean rank = 68.35).

(ii) more forwards D1B – *"My company requires digital-tool-related knowledge to enhance the development of safety solutions"* (mean rank = 105.16) as the essentials of applying advanced technologies than group of Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 89.91), Senior Executive (mean rank = 85.43), Assistant Manager/ Assistant Team Leader (mean rank = 71.00) and Junior Executive (mean rank = 64.79).

(iii) more forwards D1E – *"My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers"* (mean rank = 108.16) as the essentials of applying advanced technologies than group of Manager/ Project Manager/ Construction Manager/ Head of Department (mean rank = 80.61), Senior Executive (mean rank = 80.37), Assistant Manager/ Assistant Team Leader (mean rank = 75.20) and Junior Executive (mean rank = 74.53).

(D) The group of Medium-sized (31-75 people) company agreed

(i) more towards D1A – *" My company simply applied advanced technologies causing unique dangers and safety concerns"* (mean rank = 95.67) as the essentials of applying advanced technologies than group of Small-sized (5-30 people) (mean rank = 91.74), Large-sized (>75 people) (mean rank = 82.40) and Micro-sized (<5 people) (mean rank = 60.19).

(ii) more towards D1B – *" My company requires digital-tool-related knowledge to enhance the development of safety solutions"* (mean rank = 104.11) as the essentials of applying advanced technologies than group of Large-sized (>75 people) (mean rank = 88.88), Small-sized (5-30 people) (mean rank = 87.41) and Micro-sized (<5 people) (mean rank = 48.42).

(E) The group of Large-sized (>75 people) company agreed

(i) more towards D1E – *" My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers"* (mean rank = 95.25) as the essentials of applying advanced technologies than group of Medium-sized (31-75 people) (mean rank = 87.99), Small-sized (5-30 people) (mean rank = 86.97) and Micro-sized (<5 people) (mean rank = 61.24).

(F) The group of G5 CIDB Grade agreed

(i) more towards D1A – *"My company simply applied advanced technologies causing unique dangers and safety concerns"* (mean rank = 117.48) as the essentials of applying advanced technologies than group of G4 (mean rank = 107.82), G2 (mean rank = 85.75, None (mean rank = 74.07), G6 (mean rank = 72.44), G3 (mean rank = 71.94), G7 (mean rank = 65.42) and G1 (mean rank = 64.50).

(G) The group of G4 CIDB Grade agreed

(i) more towards D1B – *"My company requires digital-tool-related knowledge to enhance the development of safety solutions"* (mean rank = 107.60) as the essentials of applying advanced technologies than group of G6 (mean rank = 103.16), G5 (mean rank = 94.85), G7 (mean rank = 86.46), G2 (mean rank = 73.47), None (mean rank = 71.15), G3 (mean rank = 63.96) and G1 (mean rank = 39.75).

(ii) more towards D1C – *"Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation"* (mean rank = 112.14) as the essentials of applying advanced technologies than group of G2 (mean rank = 96.47), G5 (mean rank = 87.40), None (mean rank = 81.04), G6 (mean rank = 80.34), G7 (mean rank = 73.85), G1 (mean rank = 70.00) and G3 (mean rank = 61.98).

4.9 Discussion

4.9.1 Familiarity and Implementation of BIM and YOLOv3

(A) The Widespread Implementation of BIM

As shown in Table 4.3 and 4.5, the recognition of BIM as the most familiar (with a mean rank of 6.08) and widely utilised technology (ranked second highest with a mean rank of 5.88) can be attributed to various causes. BIM has been utilised since the early 2000s, establishing itself as one of the most well-established digital technologies in the construction industry. Based on Shukri et al. (2023), BIM's extensive history has facilitated its widespread adoption across many areas of the building industry. Over time, professionals have found the characteristics of this software, such as 3D modelling, data management, and real-time collaboration, to be crucial in improving accuracy, reducing errors, and facilitating communication within project teams. Furthermore, the incorporation of BIM into government rules and regulations, particularly in extensive projects, has rendered it a vital tool for ensuring adherence. Contractors and consultants are frequently required to include BIM into their workflows in order to fulfil specific project requirements, hence promoting its extensive utilisation.

The capacity of BIM to encourage collaboration among a variety of stakeholders renders it indispensable. BIM facilitates communication by offering a shared platform that enables architects, engineers, and contractors to collaborate more efficiently. Its widespread acceptance is substantially influenced by the reduction in conflicts and rework that results from improved coordination. Furthermore, the adoption of BIM is contingent upon its ability to mitigate project risks through enhanced visualisation and decision-making, which enables stakeholders to identify and resolve issues at the outset of the project lifecycle as noted by Azhar (2011).

Moreover, the adaptability of BIM, which encompasses many tasks such as design coordination and facility management, has rendered it indispensable across the whole building lifecycle. The efficient storage and management of data enhances the decision-making process for stakeholders, leading to improved project outcomes in terms of time, cost, and quality. The prevalence of BIM systems and the abundance of training resources have also played a role in its widespread adoption, facilitating the smooth transfer of construction companies into digital workflows.

(B) Limited Familiarity and Low Adoption of YOLOv3

The review of the study's results, specifically in Table 4.3 and 4.5, demonstrates that YOLOv3 is the technology that is least known and least utilized by the respondents. In comparison to more established tools such as BIM and drones, its implementation in the industry of construction is still relatively new and niche.

(I) Insufficient Knowledge and Specialized Nature

YOLOv3 is a highly specialised technology that is primarily employed in fields such as computer vision, robotics, and AI. These fields have not yet been completely integrated into mainstream construction workflows. The utilization of real-time object detection algorithms may be unfamiliar to numerous construction professionals, as they necessitate sophisticated computational resources and an understanding of AI, which are not frequently encountered in conventional construction firms. The exposure and utilization of YOLOv3 among industry professionals are restricted by its affiliation with disciplines that are not typically associated with construction operations.

Additionally, the technology's adoption may be hindered by its complexity and the necessity for specialised training. Drones and sensing technologies are relatively straightforward to comprehend and implement; however, according to Zhou (2012), YOLOv3 necessitates a more profound understanding of AI algorithms and data processing concepts. This presents a challenge for numerous construction companies, particularly those that are lesser and may not possess the necessary technical expertise to effectively implement such technologies. Respondents who have had less exposure to advanced technologies are less likely to be acquainted with or embrace complex AI systems such as YOLOv3, as shown in Table 4.5.

(II) Cost and Resource Obstacles

The substantial resource investment necessary to effectively implement YOLOv3 is another factor that restricts its adoption. As indicated in Table 4.10, the statement of “My company feels struggle with the expenses connected with obtaining and upkeeping digital technology” ranked the highest with a mean rank of 5.97. Thus, financial constraints are a significant impediment to the adoption of advanced technologies. In addition to the computing capacity required to process real-time video data, YOLOv3 necessitates the installation of cameras and sensors, as well as the training of personnel to interpret and manage the results. In comparison to more affordable and readily applicable technologies such as drones, which can provide immediate value with reduced financial and technical entry points, these costs may be prohibitive for smaller firms. Additionally, companies with smaller project scopes may not perceive the necessity of real-time object detection, as they can mitigate the safety risks they confront through less sophisticated technological means.

4.9.2 Higher Position and Working Experience have an Impact on Driving Digitalization

The significance of leadership in digital transformation is emphasised by the substantial correlation between working experience, position, and familiarity with advanced technologies as illustrated in Table 4.4, where 8 statements of both demographic characteristics exhibited an Asymptotic Significance of < 0.05. Director, managing directors or CEO, who are accountable for strategic decision-making, frequently occupy positions that enable them to influence the adoption of technologies such as BIM, AI, and drones within their organizations. These individuals typically possess a greater understanding of both traditional and advanced methodologies, as they have observed the construction industry undergo significant changes over the years.

For instance, professionals with over 21 years of experience frequently possess the ability to contrast the efficiency of conventional methods (such as manual data transmittion and physical site navigation) with the precision and productivity that advanced technologies provide. They possess a profound comprehension of the potential of technology to address operational requirements, which is the foundation of their capacity to lead digitalization initiatives. Furthermore, their leadership positions enable them to make well-informed decisions regarding the integration of new systems, resource allocation, and training. Additionally, these professionals are frequently more exposed to industry trends and innovations, which further influences their decision to advocate for digitalization within their organizations.

4.9.3 Personal Exposure and Experience as Determinant of Familiarity and Essentials

From Table 4.6 and 4.7, the results reveal that, due to the substantial essentials that advanced technologies provide, the majority of respondents prefer them. These results imply that because of their effectiveness, precision, and capacity to handle complicated data, respondents are more likely to prefer them over more conventional approaches. Drones, for instance, provide topographical surveys that are quicker and more detailed than those conducted manually, while BIM facilitates better team collaboration.

(A) Intermediate-Level Positions and High-Experienced Professions Favor Advanced Technologies

The result in Table The results in Table 4.4 and 4.9 indicate that individuals in middle-to-higher management positions, particularly managers with 21 years or more of experience, are more likely to implement and perceive advanced technologies as indispensable tools for project success. This is primarily due to the fact that these individuals have spent the early stages of their careers utilising conventional methods. In the years that have followed, they have either experienced or facilitated the adoption of digital tools such as BIM, AI, and sensing technologies.

For example, a manager with 10 to 20 years of experience likely relied on manual processes during the first ten years, such as physical site inspections or traditional project documentation. As advanced technologies became more widespread, they were compelled to adapt, recognising the benefits of tools such as BIM, which facilitate more efficient project coordination and error reduction. This exposure to both traditional and digital methods allows them to make well-informed decisions about which technology to adopt. They are better equipped to assess the potential for risk reduction, cost-effectiveness, and efficiency in construction projects that advanced technologies offer.

(B) Company Size does not Determine the Perceived Essentials

Curiously, the study indicates that the scale of a corporation does not have a major impact on how advantageous new technology are regarded to be. This is apparent in the statistics from Table 4.9, as respondents from both small and large organizations exhibited little disparities in their opinion of the benefits of advanced technologies. Despite their limited resources, smaller company can nonetheless utilize technology to enhance their productivity. For instance, the utilization of Building Information Modelling (BIM) or unmanned aerial vehicles (drones) can effectively minimize the duration of tasks and decrease the requirement for considerable manual work, thereby rendering it a financially efficient alternative, even for smaller-scale projects.

In contrast, larger companies with plenty of resources and well-established operational processes may not experience as significant an advantage from using these technologies, as they likely already possess robust systems in operation. This implies that the way individuals perceive the benefits of technology is more affected by their personal experience and receptivity to adopting new tools, rather than the size or CIDB grade level of the organization. Within both large and small organizations, individuals with extensive expertise and elevated positions are usually the primary drivers of digital transformation. This suggests that familiarity with advanced technologies and effective leadership are more significant factors than the size of the company.

4.9.4 Financial Issues was Cited as the Most Higgest Hurdle

A major obstacle for organisations in adopting advanced technology is the substantial expense associated with procurement and upkeep. Table 4.10 illustrates that the expenses connected with obtaining and upkeeping digital technology (with mean rank of 5.97), including BIM software, drones, AI, and sensing technology, pose significant challenges for numerous construction organisations. As mentioned as Azhar (2011), the upfront expense of acquiring these technologies can be excessive, particularly for small- and medium-sized firms that frequently function under constrained financial limits. Moreover, the continuous expenses related to the maintenance and enhancement of these technologies further deplete financial resources.

Advanced technologies necessitate frequent upgrades, software licensing costs, and, in certain instances, specialised hardware that requires enhancement as the technology advances. BIM software entails not just the initial acquisition cost but also necessitates annual license payments, employee training, and modifications to computer systems to accommodate the substantial data volumes required by BIM models (Azhar, 2011). Drones and AI systems require ongoing software updates and routine calibration to maintain accuracy, hence increasing maintenance expenses.

Many organisations, particularly smaller ones, may not instantly perceive the return on investment (ROI) for these technologies, leading to reluctance in allocating substantial amounts of their budget for such expenditures. This financial limitation is frequently intensified by the competitive character of the sector, where profit margins are already narrow. Consequently, numerous firms perceive the expenses associated with the adoption and maintenance of digital technologies as a high-risk investment, perhaps lacking quick or tangible rewards, thereby impeding general adoption (Ghaffarianhoseini et al., 2017).

4.9.5 Company Size and CIDB Grade have an Impact on Perceptions of Barriers

Table 4.11 shows that the company size and CIDB grade on the barriers to applying advanced technologies possess have a rejected null hypothesis of 5 and 6, respectively, which is substantially greater than the demographic information of indicates that the company's size and the CIDB grade substantially influence organizations’ perceptions of the obstacles to adopting advanced technology. Companies of greater size and elevated CIDB grades typically possess more resources, resulting in an increased capacity to absorb the expenses related to the adoption of advanced technology. These organisations generally possess broader project scopes, enhanced access to money, and superior in-house knowledge, thereby alleviating the effects of financial constraints (Pärn and Edwards, 2019).

Conversely, smaller enterprises and those with inferior CIDB grades encounter greater difficulties regarding both the original capital investment and the continuous upkeep of these technology. Smaller enterprises frequently function with limited resources, and the expense of advanced technology might constitute a significantly greater proportion of their operational budget relative to larger corporations. This elucidates why SMEs and lower-tier CIDB enterprises are more prone to identify cost as a substantial impediment to adoption (Arayici et al., 2011).

Moreover, larger corporations are more inclined to own specialised teams for IT support, software administration, and technology training, facilitating the seamless integration of sophisticated technologies without interrupting their activities. Smaller enterprises, however, may lack this internal support, rendering the adoption and maintenance of digital tools more arduous and expensive. Pärn and Edwards (2019) highlight that the deficiency of proficient staff to oversee these technologies is a significant obstacle for smaller enterprises, exacerbating the problem.

The perceived benefits of advanced technologies are also a reflection of the divide between large and small companies. Larger organisations may attain a more evident ROI through enhanced project efficiencies and risk management, however smaller companies may encounter difficulties in swiftly realizing these advantages to justify the investment.. The disparity in resources and perceived benefits is a significant factor influencing how company size and CIDB grade affect companies’ perception of cost as an obstacle.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The last chapter of this study will present a thorough assessment of the principal findings and their implications. 5.2 will reiterate the research objectives and examine how the analysis of outcomes has fulfilled these objectives. Furthermore, 5.3 will delineate the contributions this research has rendered to the construction sector, academia, and policymakers. 5.4 will delineate the limits faced during the study and propose recommendations for subsequent research in the domain.

5.2 Accomplishment on Research Aim and Objectives

The research aim and objectives have been accomplished, as evidenced by the following justification.

Research Objective 1: To identify the advanced technologies for managing construction safety

The advanced technologies discussed include Exoskeleton, AI, Sensing Technology, UAVs and Drone, 3D-Printing, BIM, Modular Construction, A.R. and V.R., IoT and YOLOv3. BIM appeared as the most familiar technology, with the highest mean rank among these. The other technologies, including A.R. and V.R. and Sensing Technology, also achieved high rankings in terms of familiarity. Other than that, Drone emerged as the most extensively utilized technology, followed by Sensing Technology and BIM. There are relatively minor differences in mean rankings of all the advanced technologies, which signifies that each of these technologies is becoming increasingly prominent in the building sector. To prove this, respondents indicated a preference for new technologies over conventional methods for their construction safety management. Respondents with higher positions and work experience are more likely to apply advanced technologies than those with lower positions and work experience.

Research Objective 2: To explore the essential of advanced technologies in managing construction safety.

This objective investigated the perspectives of contractors within the construction industry regarding the significance of advanced technologies. The 25 statements were derived from the Literature Review in Chapter 2, specifically section 2.4. These statements were developed according to the main concepts found in the literature review as critical considerations for managing construction safety with advanced technologies. For example, several statements that evaluate the impact of minimizing manual intervention on safety were straightly delivered by Section 2.4.1, *'Reducing Physical Movement by Human'*. Next, Section 2.4.2, *'Improving Safety Concerns'* led to statements relating to the respondents' view on how advanced technologies such as sensing technology and AI enhance rish identification. The questions on how the technologies streamline building operations and create a safer working environments were also developed by Section 2.4.3, *'Minimizing Potential Safety Risks'*. The findings of Chapter 4.7 demonstrated that the majority of the p-values were less than 0.05, suggesting that there are substantial disparities in the perspective of different professionals regarding the fundamentals of these technologies. These discrepancies are the result of the unique duties and responsibilities that are associated with each profession, which in turn affect their expectations and requirements for technology. For instance, surveyors may employ drones to accurately measure progress and calculate completed tasks, while architects may exclusively employ drones for design visualisation. In the same vein, engineers may prioritise AI for safety planning and risk assessment, while project managers may consider BIM more essential for coordination and documentation. These distinctions underscore the necessity of suited technology solutions that are tailored to the unique requirements of each profession. From the result, personal exposure and experience are the determinants of familiarity and essentials. On the contrary, company size will not determine the perceived essentials. Smaller businesses can still benefit from using technology to increase productivity despite limited resources.

Research Objective 3: To evaluate the barriers of advanced technology adoption in managing construction safety.

The study sought to evaluate the barriers of advanced technology implementation in construction safety management. A principal conclusion indicated that expenses associated with obtaining and upkeeping technology constituted the most substantial barrier to adoption, as concurred by the majority of respondents. The expense associated with acquiring technology like BIM, drones, and AI systems, in addition to continuous maintenance and updates, was seen as a significant barrier, especially for small- and medium-sized firms (SMEs). The second and third highest barriers that agreed by the respondents are "*My company is unwilling to bear the cost of training" and "My company is not using advanced technologies due to the process of exchanging information, data security and privacy*". Furthermore, Table 4.11 indicated that firm size and CIDB grade exerted a more significant influence on the consensus on barriers than working experience and position. The null hypotheses regarding firm size and CIDB grade were more frequently rejected, suggesting that these characteristics significantly affect organisations' perceptions of barriers to technology adoption. The main purpose is that smaller companies and those with lower CIDB grade have more trouble investing in and maintaining technology due to limited resources.

5.3 Contribution of the Study

This research has provided multiple substantial contributions to various stakeholders including policymakers and government, industry, universities and academic institutions as well as upcoming researchers.

The results offer valuable insights for policymakers who are striving to encourage the digitalisation of the construction industry. Governments can develop more effective incentive programs to encourage the adoption of technology in small- and medium-sized enterprises (SMEs) by comprehending the obstacles, including financial constraints. Furthermore, this investigation underscores the significance of establishing legal frameworks that address privacy and data security concerns in cutting-edge technologies such as AI and BIM.

Furthermore, the study's results are especially pertinent to construction companies that are seeking to enhance safety and efficiency through digitalisation. The identification of widely adopted tools such as drones and BIM offers a roadmap for companies that are seeking to incorporate advanced technologies into their workflows. Additionally, the study underscores the necessity of overcoming internal obstacles, including training and cost, to guarantee the successful implementation of these tools. It also assists to rise the awareness and readiness of applying advanced technologies for enhancing construction safety management for the industry related personnels, especially the Contractor.

Other than that, this study provides academic institutions with valuable data for the development of curricula for construction management, engineering, and architecture programs. The results can be used to inform the incorporation of digital technology training into university programs, thereby preparing future professionals for a digitally-driven industry.

Ultimately, this study provides a foundation for the further investigation of advanced technologies in construction for future researchers. The methodology of the study, particularly the quantitative approach employed to evaluate technology adoption, has the potential to be adapted and expanded in future research. By investigating the long-term effects of digitalisation on construction safety and productivity or researching new technologies, researchers can expand upon this work.

5.4 Limitations

This investigation encountered numerous constraints that necessitated recognition. The sample size was restricted by time constraints, which was one of the primary constraints. Although the study sought to collect data from all regions of Malaysia, the majority of the responses were from the Klang Valley region, which restricted the generalisability of the findings to the entire country. Furthermore, the study did not extensively explore the applications of emerging technologies, such as blockchain or 5G, in the construction sector, as a result of time constraints. This could have offered a more comprehensive perspective on the industry's digital transformation. Besides, one limitation was the dependence on self-reported data, which may introduce bias as respondents may overestimate or underestimate their familiarity or utilisation of advanced technologies. This may compromise the precision of the results, as the responses may not accurately represent the industry's actual practices. In general, contractors have the most influence in enhancing building safety. Whenever they act carelessly and fail to actively contribute to the industry, building safety will not be enhanced in general.

5.5 Recommendations and Future Works

Subsequent study should seek to overcome the aforementioned constraints by increasing the sample size and geographic scope to encompass additional regions in Malaysia. Research may also investigate the incorporation of emerging technologies, such as blockchain for project management and 5G for improved connection on building sites. Moreover, subsequent research might examine targeted training programs and policies that may aid SMEs in transitioning to digital tools, as they encounter significant financial and technical obstacles. Besides, researchers could investigate the potential for advanced technologies to be tailored to the specific needs of various professions within the construction industry in order to optimise their benefits. For example, research may focus on architects as their principal respondents, as architects are integral to the design phase and are expected to utilize these technologies for visualisation, design collaboration, and project planning. This would offer a deeper understanding of the manner in which these tools optimise workflows during the initial stages of a project.

Furthermore, subsequent research might concentrate exclusively on those who have already implemented advanced technology for safety management. This would focus on respondents including safety managers, site supervisors, or contractors who utilise AI, drones, or IoT-based sensors to oversee site safety and mitigate hazards. By concentrating on these respondents, researchers can investigate the ways in which real-time data from these technologies is employed to prevent catastrophes, improve communication, and guarantee regulatory compliance on construction sites. This method would enable a more sophisticated comprehension of the practical obstacles and advantages of implementing advanced technologies specifically for construction safety, providing valuable insights that could be implemented by organizations seeking to enhance their safety management practices through digitalization.

Last but not least, contractors can improve safety by establishing a thorough safety culture, emphasising managerial commitment, and guaranteeing compliance across all workgroups. Effective safety communication at supervisory levels is critical to sustaining a strong safety culture. Supervisory communication has been shown to positively influence worker behaviour, ensuring adherence to safety regulations (Zhang et al., 2020). Furthermore, contractors must guarantee that personal protection equipment (PPE) is accepted and used consistently, which can be accomplished by implementing the technology acceptance model (Man et al., 2021). Another substantial contribution comes from advanced technologies like the Sensing Technology, AI, Drone, and IoT. This framework promotes better task planning and execution, resulting in significantly lower accident rates by recognizing possible dangers at the start of the project (Lim & Latief, 2020).

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APPENDICES

Appendix A: Tables

Table 4.6: Rejected Null Hypothesis for the Respondents' Perception on the Familiarity Level with Advanced Technology

Code	Statement	Asymp. Sig.
Working Experience		
B1A	Familiarity level with Exoskeleton is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1C	Familiarity level with Sensing Technology is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.024
B1D	Familiarity level with Drone is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1E	Familiarity level with 3D printing is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1F	Familiarity level with Building Information Modeling (BIM) is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
B1G	Familiarity level with Modular Construction is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.005
B1H	Familiarity level with Augmented Reality (AR) and Virtual Reality (VR) is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.010

B1I	Familiarity level with Internet of Thing (IoT) is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
Position		
B1A	Familiarity level with Exoskeleton is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.002
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.003
B1D	Familiarity level with Drone is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
B1E	Familiarity level with 3D Printing is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
B1F	Familiarity level with Building Information Modeling (BIM) is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
B1G	Familiarity level with Modular Construction is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/	0.012

	Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	
B1I	Familiarity level with Internet of Thing (IoT) is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
Company Size		
B1A	Familiarity level with Exoskeleton is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.020
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
B1C	Familiarity level with Sensing Technology is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
B1D	Familiarity level with Drone is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.002
B1E	Familiarity level with 3D Printing is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.002
B1F	Familiarity level with Building Information Modeling (BIM) is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
B1G	Familiarity level with Modular Construction is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
B1H	Familiarity level with Augmented Reality (AR) and Virtual Reality (VR) is similar from the respondents with company size of Micro (<5	0.026

	people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	
B1I	Familiarity level with Internet of Thing (IoT) is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
CIDB Grade		
B1A	Familiarity level with Exoskeleton is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.001
B1B	Familiarity level with Artificial Intelligence (AI) is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
B1C	Familiarity level with Sensing Technology is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.011
B1D	Familiarity level with Drone is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.004
B1E	Familiarity level with 3D Printing is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
B1F	Familiarity level with Building Information Modeling (BIM) is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.003
B1G	Familiarity level with Modular Construction is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.027
B1H	Familiarity level with Augmented Reality (AR) and Virtual Reality (VR) is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.026
B1I	Familiarity level with Internet of Thing (IoT) is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.002
B1J	Familiarity level with YOLOv3 is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.012

Table 4.1: Pearson's Chi Square for Preference of Traditional Methods and Advanced Technologies among Respondents based on Demographic

Code	Statements	Categories	Traditional Methods		Advanced Technology		Asymp. Sig.
			Frequency (N)	Percentage (%)	Frequency (N)	Percentage (%)	
Year of Working Experience							
B3A	Execution in construction works	0-2 years	23	13.9	13	7.8	0.005
		3-5 years	9	5.4	21	12.7	
		6-10 years	12	7.2	25	15.1	
		11-20 years	8	4.8	22	13.3	
		21 years and above	9	5.4	24	14.5	
B3B	Problem-solving and decision-making	0-2 years	21	12.7	15	9.0	0.005
		3-5 years	5	3.0	25	15.1	
		6-10 years	14	8.4	23	13.9	
		11-20 years	7	4.2	23	13.9	
		21 years and above	13	7.8	20	12.0	
B3D	Mapping large areas and create detailed topographic surveys	0-2 years	20	12.0	16	9.6	0.002
		3-5 years	6	3.6	24	14.5	
		6-10 years	8	4.8	29	17.5	
		11-20 years	6	3.6	24	14.5	
		21 years and above	7	4.2	26	15.7	
B3E	Site surveying and offering a bird's-eye view of plan	0-2 years	18	10.8	18	10.8	0.018
		3-5 years	6	3.6	24	14.5	

		6-10 years	6	3.6	31	18.7	
		11-20 years	8	4.8	22	13.3	
		21 years and above	10	6.0	23	13.9	
B3F	Offering comprehensive view of building's data	0-2 years	19	11.4	17	10.2	<0.001
		3-5 years	1	0.6	29	17.5	
		6-10 years	10	6.0	27	16.3	
		11-20 years	5	3.0	25	15.1	
		21 years and above	6	3.6	27	16.3	
B3H	Prefabricating building components	0-2 years	22	13.3	14	8.4	0.003
		3-5 years	11	6.6	19	11.4	
		6-10 years	7	4.2	30	18.1	
		11-20 years	8	4.8	22	13.3	
		21 years and above	15	9.0	18	10.8	
B3I	Examining and navigating construction site	0-2 years	18	10.8	18	10.8	0.023
		3-5 years	4	2.4	26	15.7	
		6-10 years	9	5.4	28	16.9	
		11-20 years	9	5.4	21	12.7	
		21 years and above	10	6.0	23	13.9	
B3J	Gathering and transmitting data	0-2 years	19	11.4	17	10.2	0.008
		3-5 years	5	3.0	25	15.1	
		6-10 years	13	7.8	24	14.5	
		11-20 years	15	9.0	15	9.0	
		21 years and above	8	4.8	25	15.1	

Current Position							
B3A	Execution in construction works	Junior Executive	13	7.8	18	10.8	0.001
		Senior Executive	11	6.6	19	11.4	
		Assistant Manager	21	12.7	12	7.2	
		Manager	11	6.6	30	18.1	
		Director	5	3.0	26	15.7	
B3B	Problem-solving and decision-making	Junior Executive	16	9.6	15	9.0	0.048
		Senior Executive	12	7.2	18	10.8	
		Assistant Manager	15	9.0	18	10.8	
		Manager	10	6.0	31	18.7	
		Director	7	4.2	24	14.5	
B3E	Site surveying and offering a bird's-eye view of plan	Junior Executive	11	6.6	20	12.0	0.024
		Senior Executive	7	4.2	23	13.9	
		Assistant Manager	15	9.0	18	10.8	
		Manager	5	3.0	36	21.7	
		Director	10	6.0	21	12.7	
B3F	Offering comprehensive view of building's data	Junior Executive	13	7.8	18	10.8	0.041
		Senior Executive	5	3.0	25	15.1	
		Assistant Manager	9	5.4	24	14.5	
		Manager	11	6.6	30	18.1	
		Director	3	1.8	28	16.9	
B3G	Reducing cost and time overruns	Junior Executive	15	9.0	16	9.6	0.045
		Senior Executive	5	3.0	25	15.1	

		Assistant Manager	13	7.8	20	12.0	
		Manager	11	6.6	30	18.1	
		Director	7	4.2	24	14.5	
B3H	Prefabricating building components	Junior Executive	10	6.0	21	12.7	0.002
		Senior Executive	12	7.2	18	10.8	
		Assistant Manager	22	13.3	11	6.6	
		Manager	9	5.4	32	19.3	
		Director	10	6.0	21	12.7	
B3J	Gathering and transmitting data	Junior Executive	15	9.0	16	9.6	0.001
		Senior Executive	5	3.0	25	15.1	
		Assistant Manager	20	12.0	13	7.8	
		Manager	10	6.0	31	18.7	
		Director	10	6.0	21	12.7	
B3K	Detecting objects in captured photos	Junior Executive	11	6.6	20	12.0	0.02
		Senior Executive	9	5.4	21	12.7	
		Assistant Manager	19	11.4	14	8.4	
		Manager	12	7.2	29	17.5	
		Director	6	3.6	25	15.1	
Company Size							
B3B	Problem-solving and decision-making	Less than 5	18	10.8	19	11.4	0.002
		5-30	14	8.4	31	18.7	
		31-75	22	13.3	22	13.3	
		More than 75	6	3.6	34	20.5	

B3D	Mapping large areas and create detailed topographic surveys	Less than 5	17	10.2	20	12.0	<0.001
		5-30	17	10.2	28	16.9	
		31-75	4	2.4	40	24.1	
		More than 75	9	5.4	31	18.7	
B3I	Examining and navigating construction site	Less than 5	14	8.4	23	13.9	0.046
		5-30	15	9.0	30	18.1	
		31-75	6	3.6	38	22.9	
		More than 75	15	9.0	25	15.1	
B3K	Detecting objects in captured photos	Less than 5	11	6.6	26	15.7	0.034
		5-30	23	13.9	22	13.3	
		31-75	10	6.0	34	20.5	
		More than 75	13	34.3	27	16.3	
CIDB Grade							
B3A	Execution in construction works	None	9	5.4	14	8.4	0.003
		G1	7	4.2	5	3.0	
		G2	10	6.0	6	3.6	
		G3	15	9.0	11	6.6	
		G4	6	3.6	19	11.4	
		G5	4	2.4	16	9.6	
		G6	5	3.0	26	15.7	
		G7	5	3.0	8	4.8	
B3D	Mapping large areas and create detailed topographic surveys	None	7	4.2	16	9.6	<0.001
		G1	6	3.6	6	3.6	

		G2	8	4.8	8	4.8	
		G3	13	7.8	13	7.8	
		G4	7	4.2	18	10.8	
		G5	1	0.6	19	11.4	
		G6	2	1.2	29	17.5	
		G7	3	1.8	10	6.0	
B3E	Site surveying and offering a bird's-eye view of plan	None	3	1.8	20	12.0	0.002
		G1	7	4.2	5	3.0	
		G2	5	3.0	11	6.6	
		G3	14	8.4	12	7.2	
		G4	3	1.8	22	13.3	
		G5	8	4.8	12	7.2	
		G6	6	3.6	25	15.1	
		G7	2	1.2	11	6.6	
B3F	Offering comprehensive view of building's data	None	3	1.8	20	12.0	0.005
		G1	7	4.2	5	3.0	
		G2	5	3.0	11	6.6	
		G3	11	6.6	15	9.0	
		G4	6	3.6	19	11.4	
		G5	5	3.0	15	9.0	
		G6	4	2.4	27	16.3	
		G7	0	0	13	7.8	
B3G	Reducing cost and time overruns	None	4	2.4	19	11.4	0.025

		G1	8	4.8	4	2.4	
		G2	7	4.2	9	5.4	
		G3	11	6.6	15	9.0	
		G4	5	3.0	20	12.0	
		G5	5	3.0	15	9.0	
		G6	6	3.6	25	15.1	
		G7	5	3.0	8	4.8	
B3J	Gathering and transmitting data	None	4	2.4	19	11.4	0.027
		G1	5	3.0	7	4.2	
		G2	7	4.2	9	5.4	
		G3	15	9.0	11	6.6	
		G4	6	3.6	19	11.4	
		G5	5	3.0	15	9.0	
		G6	10	6.0	21	12.7	
		G7	8	4.8	5	3.0	

Table 4.9: Rejected Null Hypothesis for the Respondents' Perception on the Essentials of Applying Advanced Technologies

Code	Statement	Asymp. Sig.
Working Experience		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C13	My company used exoskeleton to lift heavy weights is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C14	My company used artificial intelligence (AI) to solve problems and make decisions is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.017
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C16	My company used AI to expose a worker's musculoskeletal system to physical risk factors is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C17	My company used sensing technology to gather physiological and biological sensory data is	0.019

	similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	
C18	My company used sensing technology to notify the event regarding a worker's health is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.025
C19	My company used sensing technology to detect and monitor unauthorised individuals visiting the premises is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C110	My company used drone to oversee job site security is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.003
C111	My company used drone to map large areas and create detailed topographic surveys is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.017
C112	My company used drone to execute inspection tasks is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.008
C113	My company used 3D-printing to boost efficiency in planning, designing, construction and management of the building is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.014

C114	My company used 3D-printing to offer comprehensive view of the building's data is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.009
C116	My company used BIM to reduce time overruns and cost overruns is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C117	My company used BIM to enhance communication among stakeholders is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
C118	My company used modular construction to produce structures quickly and efficiently is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.028
C119	My company used modular construction to provide sustainable construction solutions is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.037
C121	My company used VR to digitally examine and navigate a construction site is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.006
C124	My company used YOLOv3 to detect objects is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.004

C125	My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.035
Position		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C13	My company used exoskeleton to lift heavy weights is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C14	My company used artificial intelligence (AI) to solve problems and make decisions is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.002
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/	<0.001

	Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	
C16	My company used AI to expose a worker's musculoskeletal system to physical risk factors is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.002
C17	My company used sensing technology to gather physiological and biological sensory data is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.016
C18	My company used sensing technology to notify the event regarding a worker's health is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.011
C19	My company used sensing technology to detect and monitor unauthorised individuals visiting the premises is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction	0.002

	Manager/ Head of Department and Director/ Managing Directors/ CEO.	
C110	My company used drone to oversee job site security is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.004
C111	My company used drone to map large areas and create detailed topographic surveys is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.032
C112	My company used drone to execute inspection tasks is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C113	My company used 3D-printing to boost efficiency in planning, designing, construction and management of the building is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.009
C114	My company used 3D-printing to offer comprehensive view of the building's data is	0.012

	similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	
C115	My company used 3D-printing to reduce waste from construction is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C116	My company used BIM to reduce time overruns and cost overruns is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C117	My company used BIM to enhance communication among stakeholders is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	<0.001
C118	My company used modular construction to produce structures quickly and efficiently is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/	0.001

	Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	
C119	My company used modular construction to provide sustainable construction solutions is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.008
Company Size		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
C13	My company used exoskeleton to lift heavy weights is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.007
C14	My company used artificial intelligence (AI) to solve problems and make decisions is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.005
C15	My company used AI to identify and assess potential safety dangers and risks on construction sites is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.001

C16	My company used AI to expose a worker's musculoskeletal system to physical risk factors is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.005
C17	My company used sensing technology to gather physiological and biological sensory data is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.014
C18	My company used sensing technology to notify the event regarding a worker's health is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.003
C19	My company used sensing technology to detect and monitor unauthorised individuals visiting the premises is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.045
C110	My company used drone to oversee job site security is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.021
C111	My company used drone to map large areas and create detailed topographic surveys is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.010
C112	My company used drone to execute inspection tasks is similar from the respondents with	<0.001

	company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	
C115	My company used 3D-printing to reduce waste from construction is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.033
C116	My company used BIM to reduce time overruns and cost overruns is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.002
C118	My company used modular construction to produce structures quickly and efficiently is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.015
C120	My company used AR to augment contextual perception of the surroundings is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.047
C123	My company used IoT to gather data via sensors and peripheral devices is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.003
CIDB Grade		
C12	My company used exoskeleton to carry out repeated jobs is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001

C13	My company used exoskeleton to lift heavy weights is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.004
C14	My company used artificial intelligence (AI) to solve problems and make decisions is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.013
C16	My company used AI to expose a worker's musculoskeletal system to physical risk factors is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.007
C19	My company used sensing technology to detect and monitor unauthorised individuals visiting the premises is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.018
C111	My company used drone to map large areas and create detailed topographic surveys is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.032
C113	My company used 3D-printing to boost efficiency in planning, designing, construction and management of the building is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.021
C114	My company used 3D-printing to offer comprehensive view of the building's data is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.023
C116	My company used BIM to reduce time overruns and cost overruns is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001

C117	My company used BIM to enhance communication among stakeholders is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.002
C118	My company used modular construction to produce structures quickly and efficiently is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.010
C121	My company used VR to digitally examine and navigate a construction site is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.041
C123	My company used IoT to gather data via sensors and peripheral devices is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.013
C125	My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.001

Table 4.11: Rejected Null Hypothesis for the Respondents' Perception on the Barriers to Applying Advanced Technologies

Code	Statement	Asymp. Sig.
Working Experience		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.001
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	<0.001
D1C	Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.013
D1E	My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers is similar from the respondents with working experience of 0-2 years, 3-5 years, 6-10 years, 11-20 years, and 21 years and above.	0.019
Position		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction	0.027

	Manager/ Head of Department and Director/ Managing Directors/ CEO.	
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with position of Junior Executive, Senoir Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.004
D1E	My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers is similar from the respondents with position of Junior Executive, Senr Executive, Assistant Manager/ Assistant Team Leader, Manager/ Project Manager/ Construction Manager/ Head of Department and Director/ Managing Directors/ CEO.	0.024
Company Size		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.003
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	<0.001
D1E	My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers is similar from the respondents with company	0.008

	size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	
D1F	My company is unwilling to bear the cost of training is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.008
D1G	My company feels struggle with the expenses connected with obtaining and upkeeping digital technology is similar from the respondents with company size of Micro (<5 people), Small (5-30 people), Medium (31-75 people) and Large (>75 people).	0.033
CIDB Grade		
D1A	My company simply applied advanced technologies causing unique dangers and safety concerns is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
D1B	My company requires digital-tool-related knowledge to enhance the development of safety solutions is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	<0.001
D1C	Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.012
D1D	My company lacks adequately skilled staff to use advanced technologies is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.019
D1F	My company is unwilling to bear the cost of training is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.027

D1I	My company thinks that legal obstacles concerning information retrieval and application have impeded the adoption of digital technologies is similar from the respondents with CIDB grade of None, G1, G2, G3, G4, G5, G6 and G7.	0.023

Appendix B: Google Form

Advanced Technologies for Enhancing Construction Safety Management: The Contractor's Perspective

Dear Sir / Madam,

I am Chung Seow Ling, a final year undergraduate student pursuing a Bachelor of Science (Honours) Quantity Surveying at the Department of Surveying, Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman (UTAR).

I am conducting a survey regarding my Final Year Project titled “Advanced Technologies for Enhancing Construction Safety Management: The Contractor’s Perspective”. This research is to gather insights and perspectives on the adoption of advanced technologies in enhancing construction safety management in the Malaysian construction industry.

This questionnaire is divided into FOUR (4) sections which will take approximately 10 - 15 minutes to complete. Your response to this questionnaire will significantly contribute to achieving the research aim. All information provided is strictly confidential and used solely for academic purposes.

I would be very grateful if you could devote a few minutes to filling out this questionnaire. Thank you for your time and cooperation. If you have any queries, please do not hesitate to contact me at seowling0409@1utar.my.

Many thanks.

Yours faithfully,

Chung Seow Ling

Bachelor of Science (Honours) Quantity Surveying

Universiti Tunku Abdul Rahman

seowling0409@gmail.com 切换账号

未共享的内容

Appendix B: Google Form (Cont'd)

SECTION A: RESPONDENT DEMOGRAPHIC

Direction: Please circle or fill in your answers for each question.

1. How many years of your experience in the construction industry?

- ○ 0-2 years
- ○ 3-5 years
- ○ 6-10 years
- ○ 11-20 years
- ○ 21 years and above

2. What is your current position in the organisation?

- ○ Junior Executive
- ○ Senior Executive
- ○ Assistant Manager/ Assistant Team Leader
- ○ Manager/ Project Manager/ Construction Manager/ Head of Department
- ○ Director/ Managing Directors/ CEO

Appendix B: Google Form (Cont'd)

3. What is your company size?

- ◯ Less than 5 people
- ◯ 5 – 30 people
- ◯ 31 – 75 people
- ◯ More than 75 people

4. What is your registered company grade in CIDB Malaysia?

- ◯ None
- ◯ G1
- ◯ G2
- ◯ G3
- ◯ G4
- ◯ G5
- ◯ G6
- ◯ G7

Appendix B: Google Form (Cont'd)

SECTION B

Please indicate one level of your understanding on the advanced technologies for managing construction safety.

1. To what extent you are familiar with the following advanced technologies for enhancing construction safety management? *

	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
Exoskeleton	○	○	◉	○	○
Artificial Intelligence (AI)	○	○	◉	○	○
Sensing Technology	○	○	◉	○	○
UAVs and Drone	○	○	◉	○	○
3D-Printing	○	○	○	◉	○
Building Information Modeling	○	○	◉	○	○

Appendix B: Google Form (Cont'd)

Modular Construction	○	○	◉	○	○
Augmented Reality (AR) and Virtual Reality (VR)	○	○	◉	○	○
Internet of Thing (IoT)	○	○	○	◉	○
YOLOv3	○	○	◉	○	○

2. To what extent these advanced technologies are used in your current / past construction project for managing construction safety? *

	No using	Planning to use in 3 years	Planning to use in 5 years	Just using	Using all the while
Exoskeleton	○	○	◉	○	○
Artificial Intelligence (AI)	○	○	◉	○	○
Sensing Technology	○	○	◉	○	○

Appendix B: Google Form (Cont'd)

UAVs and Drone	○	○	◉	○	○
3D-Printing	○	○	○	◉	○
Building Information Modeling (BIM)	○	◉	○	○	○
Modular Construction	○	◉	○	○	○
Augmented Reality (AR) and Virtual Reality (VR)	○	◉	○	○	○
Internet of Thing (IoT)	○	◉	○	○	○
YOLOv3	○	○	◉	○	○

Appendix B: Google Form (Cont'd)

3. What is your preference between Traditional Methods vs Advanced Technologies when it comes to the following activities? *

	Traditional Methods	Advanced Technologies
Execution in construction works	○	◉
Problem-solving and decision-making	◉	○
Identifying potential safety dangers by detecting workers' motions, postures and physiological indicators	◉	○
Mapping large areas and create detailed topographic surveys	○	◉
Site surveying and offering a bird's-eye view of plan	○	◉
Offering comprehensive view of building's data	◉	○
Reducing cost and time overruns	◉	○
Prefabricating building components	○	◉
Examining and navigating construction site	○	◉
Gathering and transmitting data	○	◉
Detecting objects in captured photos	◉	○

Appendix B: Google Form (Cont'd)

SECTION C

Please indicate one level of your understanding on the advanced technologies for managing construction safety.

1. To what extent you agree the following is effective in ensuring workplace safety in construction sites? *

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
My company used exoskeleton to reduce physical movement by humans.	○	○	○	◉	○
My company used exoskeleton to carry out repeated jobs.	○	○	○	◉	○
My company used exoskeleton to lift heavy weights.	○	○	○	◉	○
My company used artificial intelligence (AI) to solve problems and make decisions.	○	○	○	◉	○

Appendix B: Google Form (Cont'd)

My company used AI to identify and assess potential safety dangers and risks on construction sites.	○	○	○	◉	○
My company used AI to expose a worker's musculoskeletal system to physical risk factors.	○	○	○	○	◉
My company used sensing technology to gather physiological and biological sensory data.	○	○	○	○	◉
My company used sensing technology to notify the event regarding a worker's health.	○	○	○	○	◉
My company used sensing technology to detect and monitor unauthorised individuals visiting the premises.	○	○	○	○	◉

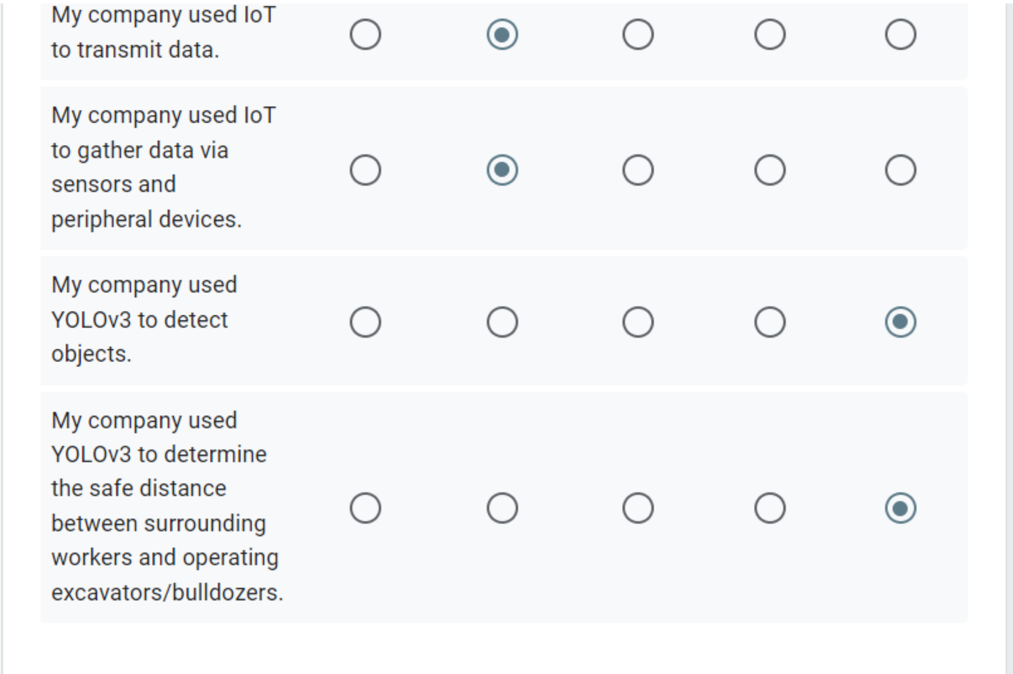
Appendix B: Google Form (Cont'd)

My company used drone to oversee job site security.	○	○	○	○	◉
My company used drone to map large areas and create detailed topographic surveys.	○	○	○	○	◉
My company used drone to execute inspection tasks.	○	○	○	○	◉
My company used 3D-printing to boost efficiency in planning, designing, construction and management of the building.	○	◉	○	○	○
My company used 3D-printing to offer comprehensive view of the building's data.	○	◉	○	○	○
My company used 3D-printing to reduce waste from construction.	○	◉	○	○	○

Appendix B: Google Form (Cont'd)

My company used BIM to reduce time overruns and cost overruns.	○	○	○	◉	○
My company used BIM to enhance communication among stakeholders.	○	○	○	◉	○
My company used modular construction to produce structures quickly and efficiently.	○	○	○	◉	○
My company used modular construction to provide sustainable construction solutions.	○	○	○	◉	○
My company used AR to augment contextual perception of the surroundings.	○	○	○	○	◉
My company used VR to digitally examine and navigate a construction site.	○	○	○	○	◉

Appendix B: Google Form (Cont'd)



My company used IoT to transmit data.	○	◉	○	○	○
My company used IoT to gather data via sensors and peripheral devices.	○	◉	○	○	○
My company used YOLOv3 to detect objects.	○	○	○	○	◉
My company used YOLOv3 to determine the safe distance between surrounding workers and operating excavators/bulldozers.	○	○	○	○	◉

Appendix B: Google Form (Cont'd)

SECTION D

Please indicate one level of your understanding on the advanced technologies for managing construction safety.

1. To what extent do you agree the following will undermine the implementation of advanced technologies for enhancing workplace safety? *

	Strongly disagree	DIsagree	Neither agree or disagree	Agree	Strongly agree
My company simply applied advanced technologies causing unique dangers and safety concerns.	○	○	○	◉	○
My company requires digital-tool-related knowledge to enhance the development of safety solutions.	○	○	○	◉	○

Appendix B: Google Form (Cont’d)

Physical discomfort and potential harm resulting from the pressure exerted by exoskeletons on the body during operation.	○	○	○	◉	○
My company lacks adequately skilled staff to use advanced technologies.	○	◉	○	○	○
My company must be willing to allocate resources towards the education and ongoing development of their workforce in order to obtain highly skilled workers.	○	○	○	◉	○

Appendix B: Google Form (Cont'd)

My company is unwilling to bear the cost of training.	○	○	○	◉	○
My company feels struggle with the expenses connected with obtaining and upkeeping digital technology.	○	◉	○	○	○
My company is not using advanced technologies due to the process of exchanging information, data security and privacy.	○	○	○	◉	○
My company thinks that legal obstacles concerning information retrieval and application have impeded the adoption of digital technologies.	○	○	○	◉	○