THE POTENTIAL OF EMERGING TECHNOLOGIES FOR SAFETY AND HEALTH MANAGEMENT IN THE MALAYSIAN CONSTRUCTION INDUSTRY

LIM KAR FAI

UNIVERSITI TUNKU ABDUL RAHMAN

THE POTENTIAL OF EMERGING TECHNOLOGIES FOR SAFETY AND HEALTH MANAGEMENT IN THE MALAYSIAN CONSTRUCTION INDUSTRY

LIM KAR FAI

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

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

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DECLARATION

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

Signature	:	
Name	:	Lim Kar Fai
ID No.	:	18UEB07153
Date	:	08 September 2022

APPROVAL FOR SUBMISSION

I certify that this project report entitled **"THE POTENTIAL OF EMERGING TECHNOLOGIES FOR SAFETY AND HEALTH MANAGEMENT IN THE MALAYSIAN CONSTRUCTION INDUSTRY"** was prepared by **LIM KAR FAI** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman.

Approved by,

Signature :

Supervisor : Dr Lew Yoke Lian

Date : 30/9/2022

Signature : -

Co-Supervisor : -

Date : -

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ABSTRACT

Traditional safety management was no longer adequate for modern and complex construction projects. In addition, construction workers were exposed to higher health risks than in other industries. Therefore, the objective of this study was to identify the adoption benefits, adoption barriers and willingness to use emerging technologies for safety and health management, which further exposed the potential of implementing emerging technologies for safety and health management in the Malaysian construction industry. Besides, this study used a questionnaire survey and quantitative research methods to complete the data collection and analysis. Moreover, the target respondents were the Grade 7 main contractors in Malaysia, with 392 respondents participating in this study, achieving a response rate of 49%. According to the results of the mean ranking, the most significant benefits contractors perceive to be gained from using emerging technologies for safety and health management were Enhance Hazard Identification, Improve Safety Planning and Intensify Safety Inspection. Beyond that, the most prominent barriers to using emerging technologies in safety management were Extra Costs, Additional Training and Lack of Top Management Support. Furthermore, the top emerging technologies that G7 contractors were willing to use to improve safety and health management were Building Information Model, Wearable Safety Technology and Unmanned Safety Technology. The correlation and regression analysis results further revealed that the adoption benefits of emerging technologies were more influential than the adoption barriers of emerging technologies, thus confirming that the implementation of emerging technologies for safety and health management in the Malaysian construction industry had positive potential. Finally, the findings of this study provided an impetus for the public and private sectors to offer incentives and initiate action to remove any barriers to the generalisation of emerging technologies in safety and health management. Meanwhile, the results of this study extended the existing literature, which could increase awareness and knowledge of construction practitioners in the use of emerging technologies for safety and health management.

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LIST OF SYMBOLS / ABBREVIATIONS

e	Margin of error
N	Population size
n	Sample size
R^2	R-squared
Rs	Size of correlation coefficient
α	Cronbach's alpha coefficient
β	Regression coefficient
2D	Two dimensions
3D	Three dimensions
AFS	Accident forewarning system
AI	Artificial intelligence
AR	Augmented reality
BCA	Building and construction authority
BIM	Building information modelling
CDC	Centers for disease control and prevention
CIDB	Construction industry development board
G7	Grade 7
GIS	Geographic information systems
GPS	Global positioning system
IoT	Internet of things
LiDAR	Light detection and ranging
R&A	Robotics and automation
RFID	Radio-frequency identification
PPE	Personal protective equipment
S&H	Safety and health
SPSS	Statistical package for the social sciences
TAM	Technology acceptance model
UAV	Unmanned aerial vehicle
VR	Virtual reality

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Construction is one of the most significant contributors to employment in Malaysia. Between 2012 and 2018, the value of construction works increased by about RM10 billion annually (Alaloul, et al., 2021). As of December 2020, Malaysia's labour market was about 15.99 million, of which 1.399 million workers, 8.75% of the labour market powered the construction industry (Statista, 2022; Department of Statistics Malaysia, 2021). However, construction workers still face higher health risks than most industries. In particular, respiratory diseases, noise-induced hearing loss and musculoskeletal diseases are more prevalent, with the prevalence of musculoskeletal diseases among construction workers being 77% in the United States, 76% in Malaysia and 68% in Taiwan (Anwer, et al., 2021). These has caused substantial economic costs to individuals, employers and society, and construction workers may be at increased risk of construction accidents due to illness.

Hence, these safety demands allow the construction industry to transform by introducing innovative technologies to meet safety and health goals. With the Fourth Industrial Revolution, new technologies were also discovered, and a series of digital technologies emerged in the construction industry (Torrecilla-Garcia, et al., 2021). Digital technologies, also known as emerging technologies, refer to new tools, devices, products and applications to achieve specified goals, perform specific functions and solve related problems. Technology improves productivity in the construction industry and responds to the increasing demand for safety performance (Holt, Benham and Bigelow, 2015). Safety technology management in the construction industry is considered to integrate any combination of resources, processes and conditions of a construction project (Tatum, 1988). Technology is the foundation of the construction industry, and it provides solutions to practical problems in construction projects (Khudzari, Rahman and Ayer, 2021). Therefore, emerging safety and health management technology is defined as the informatization and digitization of management technology or equipment to enhance safety performance (Nnaji, et al., 2019). These emerging technologies could protect workers from physical harm while identifying and eliminating hazards. Edirisinghe (2019) elaborated that automated safety technology can save managers time while decreasing errors and providing intelligent security solutions. The construction industry needs emerging safety and health technologies to change the status quo to create a safe construction environment.

Besides that, Martinez-rojas, Marin and Vila (2016) stated that the construction industry is a labour-intensive and information-intensive industry, and the complexity of construction projects is also increasing with modernization. Therefore, traditional construction safety management can no longer meet the needs of a safety strategy. The biggest challenge facing by the construction industry today is safety performance (Qi, et al., 2022). However, the traditional safety and health management approaches are not only weak in safety assurance, but also inefficient and time-consuming (Zhang, et al., 2015). For example, it is difficult to monitor and identify unsafe behaviour by all workers in construction site through manual observation. Thus, emerging technologies have become a trend to help improve construction safety and health issues (Guo, et al., 2017).

From the point of work safety, the construction industry was ranked third in terms of casualty rates in 2020, with 3,958 accidents and 81 deaths (Department of Statistics Malaysia, 2021). It has been criticized for being a high-risk sector (Rahman, 2015). These risks can lead to injury, permanent disability, and even death due to long-term exposure to high-pressure work conditions for construction workers. Therefore, the government implements safety policies within a legal framework, such as the Occupational Safety and Health Act 1994 or the Occupational Safety and Health Act (OSHA) (Awang and Kamil, 2014). However, the construction industry still has many labour force accidents, illnesses and death. This is because human behaviour is difficult to predict, and the construction industry has a low degree of control, so the construction industry needs to improve the safety process by integrating emerging technologies (Malekitabar, 2016). Generally, safety managers use experience and professional knowledge to identify and deal with safety risks, but it is still difficult to predict potential hazards, which will quickly lead to safety plan failure (Mo, et al., 2018). Security risks can be reduced if security managers have the technology to help identify potential threats. Practical implementation of the technology and case study evidence shows that building information modelling and sensing technology can visualize and simulate the construction situation on site, which can effectively improve the hazard identification ability and safety planning ability of managers (Riaz, et al., 2017). In addition, Zhao and Lucas (2015) explored that virtual reality technology can enhance construction workers' hazard judgment ability on site, because workers can experience real dangerous scenes before actual construction and get feedback on safety awareness from them, thus reducing on-site errors. Moreover, other emerging technologies that can be used for security management include but are not limited to geographic information systems (GIS), radio-frequency identification (RFID), robotics, sensing technology and the internet of things (IoT).

1.2 Problem Statement

Studies have been conducted on emerging technologies in safety and health management. Yap, Lee, and Wang (2021) mainly explored the emerging technologies related to safety management and the factors that promote the use of technologies. The results showed that the most effective technologies used are building information modelling (BIM), wearable safety technology and robotics and automation (R&A). Therefore, related enterprises in the construction industry promote the development of emerging technologies to predict construction hazards, strengthen safety planning, and improve safety awareness. Moreover, Chen, et al. (2021) reviewed all the available technologies in the construction industry. These technologies can be divided into five major categories according to their functions in the construction process, including data acquisition, analysis, visualization, communication and design and construction automation.

In addition, Yap, et al. (2022) analysed barriers to adopting emerging technologies in safety and health management. Although emerging technologies are regarded as practical safety management tools, the construction industry in most developing countries is less active in emerging technologies than other industries. This is due to the high cost of investment in emerging technologies, lack of relevant occupational safety and health regulations, limited safety culture and lack of support and commitment from the organization's management. Besides that, Kamaruddeen, et al. (2022); Khudzari, Rahman and Ayer (2021) showed the influencing reasons and obstacles in adopting safety technology management in the Malaysian construction industry.

Furthermore, Nnaji and Karakhan (2020) provided an overview of emerging technologies adopted in the U.S. construction industry and listed the benefits and limitations. In addition, the study also identified the barriers that contractors face to adopting safety and health technologies and relevant solutions. The benefits of emerging technology are two-fold. It can raise awareness of hazards and provide warnings to construction workers. It can also eliminate hazards for employers or contractors at the design stage.

Next, Arabshahi, et al. (2022) observed the effectiveness of various types of sensing technology in construction safety and the influencing factors of technology adoption. Sensing technologies include global positioning system (GPS), radio-frequency identification (RFID) or ultra-wideband (UWB). The influencing factors of technology adoption are mainly divided into six categories: affordability, effectiveness, organizational culture and supplier characteristics, technical constraints, and user-friendliness. Furthermore, the study also confirmed that the adoption of new technologies in construction projects is lagging behind, even though the technology has great potential.

Last but not least, Afzal, Shafiq and Jassmi (2021) found that virtual-design construction (VDC) technologies also belong to the category of emerging technologies. These include virtual reality (VR), augmented reality (AR), geographic information system (GIS) and gaming technology. The study focused on the adoption and related challenges of VDC technology in construction safety to transform traditional document-oriented safety procedures into digital safety management.

According to the above studies, the variables related to safety and health management can be mainly divided into six types, namely the type, effectiveness, influence factors, obstacles, benefits and limitations of emerging technology. It can be inferred from previous studies that there is a missing link between the various variables, which means that the variables are analysed separately.

The construction industry, though, remains optimistic about the potential of safety technology. Nevertheless, there is still a lack of practical application in the construction of Malaysia. Despite the effectiveness of emerging safety technologies for construction safety and the emergence of many viable safety technologies on the market, the safety management methods and techniques used in the construction industry remain unchanged, which contributes to the poor safety record of the Malaysian construction industry. Furthermore, past studies have only highlighted the benefits, limitations or barriers to the safety management of various emerging technologies. Besides, previously published studies and databases on the potential of adopting emerging safety technologies in the construction industry are lacking. In order to supplement this research gap, the scope of this study was formed.

Firstly, this study will focus on the contractor's willingness regarding the use of safety emerging technologies and establish a linkage between adoption benefits, adoption barriers and willingness to use. Secondly, this linkage ultimately leads to emerging technologies that have great potential in safety and health management and apply to the construction industry in Malaysia. Therefore, this study will identify emerging safety technologies applicable to the Malaysian construction industry that improve site safety management performance. It is also expected that the relevant technology will be widely used in the construction industry. Furthermore, this study will elaborate the adoption benefits and adoption barriers of implementing emerging technologies in safety and health management, which can serve as a benchmark for safety managers to consider when choosing safety technologies.

1.3 Aim

This study aims to investigate the potential of emerging technologies for safety and health management in the Malaysian construction industry.

1.4 Objectives

The objectives of this study are: -

(i) To identify the adoption benefits of emerging technologies for safety and health management in the construction industry.

(ii) To identify the adoption barriers of emerging technologies for safety and health management in the construction industry.

(iii) To identify the willingness to use emerging technologies for safety and health management in the construction industry.

1.5 Research Hypotheses

The hypotheses of this study are: -

H_1: Adoption benefits positively affects willingness to use emerging technologies for safety and health management.

H_2: Adoption barriers negatively affects willingness to use emerging technologies for safety and health management.

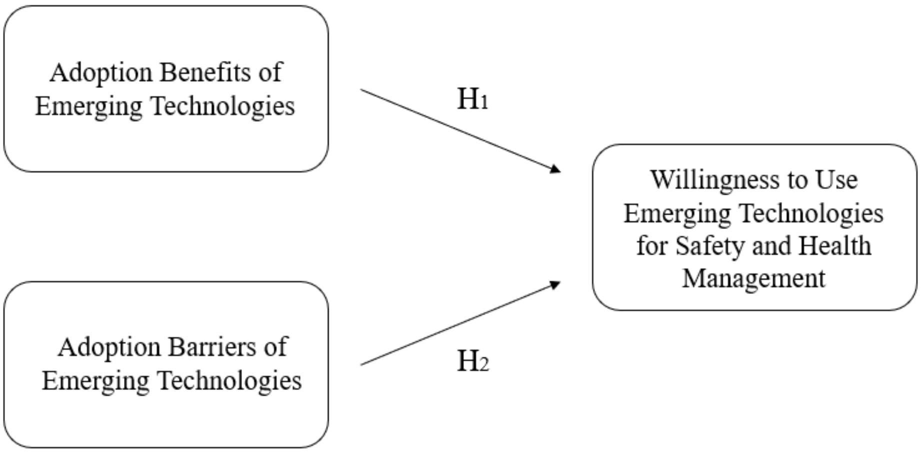

Figure 1.1: Research Hypotheses Diagram

1.6 Research Methodology

Research methodology refers to the process of gathering information and data when conducting research. This study will use an attitudinal approach to analyse the potential of emerging technologies for safety and health management in the Malaysian construction industry. In addition, in order to obtain a large number of respondents in a short period, the quantitative method of questionnaire survey is adopted to achieve the aim of the study. The data collected by the questionnaire will be analysed through different data analysis techniques to identify the relationship between variables. Beyond that, a comprehensive series of literature reviews are conducted to enhance understanding of the research area through research-related topics from various reading materials such as articles, journals, papers, government publications, websites, and books. The research approaches used to achieve the research objectives are shown in Figure 1.2.

Phase 1 Questionnaire Survey	**Phase 2** Data Analysis and Discussion with Literature Reviews	
Objective 1 To identify the adoption benefits of emerging technologies for safety and health management in the construction industry.	**Objective 2** To identify the adoption barriers of emerging technologies for safety and health management in the construction industry.	**Objective 3** To identify the willingness to use emerging technologies for safety and health management in the construction industry.

Figure 1.2: Research Approaches

1.7 Research Scope

The study is limited to local contractors in Malaysia. Contractors are more involved in the construction phase than developers and consultants, so contractors have more opportunities to adopt emerging technologies to improve safety and health performance on the construction site. In addition, the target respondents of this study are Grade 7 (G7) contractors in Malaysia. Because G7 contractors are entitled to undertake construction projects worth more than RM10 million, there is more budget to implement emerging technologies in safety and health management.

1.8 Research Significance

The findings of this study drive the widespread use of emerging technologies for safety and health management in the construction industry, accelerating the construction industry to become a safer industry. Moreover, using these emerging technologies can improve the safety environment on construction sites, where safety hazards such as falls, electrocution or being struck by objects often occur. This can reduce the number of work-related injuries and deaths because emerging technologies can assist safety managers in the development process by eliminating possible hazards on site or warning workers of the threats they are exposed to in their daily activities. Besides, the study results can be used as an indicator to help construction practitioners select the most appropriate safety technology for their construction projects based on the type of emerging technology, adoption benefits and adoption barriers.

1.9 Outline of the Report

Chapter 1 summarized the research background of this study. It also covers the problem statement of the study. Next, the aim, objective, hypothesis, method, scope and significance of the research will be presented. Finally, the outline of each chapter is summarized.

Chapter 2 focused on the current safety and health management information with emerging technologies collected from websites, journals, articles, and other published public resources. This chapter reveals the current safety and health management situation in the construction industry. It also reviews the types, adoption benefits and adoption barriers of emerging technologies for safety and health management. In addition, it showed the global and local willingness and attitude towards the adoption of emerging technologies and the theoretical framework of the technology acceptance model (TAM).

Chapter 3 presented the research methodology and design of the study. Moreover, it describes data collection methods, sampling methods, sampling frameworks and sampling sizes. Finally, this chapter reviews the data analysis methods used.

Chapter 4 discussed in detail the findings of the study to assess the potential of implementing emerging technologies for safety and health management in the Malaysian construction industry. The data collected from the questionnaire were analysed and discussed using statistical analysis and compared with the relevant literature review.

Chapter 5 concluded the findings and results of this study. In addition, this chapter identified limitations and provided recommendations to improve the quality of future related research. Finally, the importance of the study was identified to increase the implementation rate of emerging technologies for safety and health management in the Malaysian construction industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section explained the current state of safety and health management in the construction industry. In addition, it summarized the different types of technologies from past studies and their benefits for safety and health management. Furthermore, it described the barriers that influence the adoption of emerging technologies for safety and health management. Beyond that, this section demonstrated the willingness and attitude of the global and local construction industry to adopt emerging technologies. Finally, this chapter applied the technology acceptance model (TAM) to the willingness to use emerging technologies.

2.2 Safety and Health Management in Construction

Effective implementation of safety and health management is a significant factor in the success of any construction project. Safety and health management are gradually integrated with project management, which helps safety and health management in the early stage of the project be more comprehensive planning, it significantly improves the safety performance (Xu and Wang, 2020). If an accident frequently occurs on the construction site, it will affect the company's reputation, project schedule, construction quality and employee morale (Asanka and Ranasinghe, 2015). The system structure of safety and health management encompasses different levels of hazard control, from the most effective to the least effective for elimination, substitution, engineering control, administrative control and personal protective equipment (Popov, Lyon and Hollcroft, 2016). These significantly reduce the construction site safety risks. According to Centers for Disease Control and Prevention (CDC), elimination and substitution refer to the physical removal of all or part of the hazard, for example, identifying potential safety risks in initial safety planning and providing appropriate measures to eliminate the occurrence of the hazard. In addition, engineering control representatives use guardrails, barriers, or fall-proof systems to separate workers from site hazards (CDC, 2020). Besides that, CDC (2020) explained that administrative control does not eliminate physical hazards, but it increases workers' safety awareness and thus avoids accidents, such as safety training. Moreover, the use of personal protective equipment, such as hard hats and safety shoes, does not affect the hazard but only minimizes the impact of the hazard.

The high accident rate and risk in the construction industry have led to regulations that have been introduced to curb the dangerous expansion of the industry, examples include the Occupational Safety and Health Act 1994 or the Occupational Safety and Health Act (OSHA) (Awang and Kamil, 2014). This puts the onus on all stakeholders to ensure the safety of construction workers on site, so all parties involved must contribute to the safety and health of the project (Gheisari and Esmaeili, 2019). The responsibility for safety and health management rests primarily with contractors, consultants and clients, followed by subcontractors or specialist contractors (Gheisari and Esmaeili, 2019). In addition to promoting safety regulations, management practices also contribute significantly to safety and health management. Azmy and Zain (2016) mentioned that management practices can be divided into safety planning in the pre-construction stage and implementation and monitoring in the construction stage. Effective management practices, such as the ability to identify potential hazards on construction sites, risk assessment of worker behaviour or worker training, can influence the ultimate performance of safety management.

Traditional safety management methods cannot effectively control the on-site safety problems due to the complexity and high dynamic of the construction industry (Xu and Wang, 2020). Traditional safety measures mainly rely on workers' perception, safety knowledge, experience and hazard identification ability. Therefore, emerging technology in the construction industry is increasingly valued. Emerging technologies can significantly reduce safety hazards in the construction industry, leading to safer working conditions (Yap, Lee and Wang, 2021).

2.3 Emerging Technologies for Safety and Health Management

Initially, emerging technologies were used in the construction industry to improve the construction process's efficiency and ultimately reduce costs or increase profits. However, more and more emerging technologies are being used in safety and health management to reduce workplace hazards to workers (Nnaji and Karakhan, 2020). Various emerging technologies revolutionize safety in the construction industry in different ways. This section introduces the different types of emerging technologies for safety and health management.

2.3.1 Building Information Model (BIM)

Building information model (BIM) is most widely used in safety and health management. This is because most safety risks are related to the implementation of the wrong decisions in the safety planning stage (Afzal, Shafiq and Al Jassmi, 2021). BIM is mainly implemented in the stage of safety planning (Qi, Qian and Costin, 2020). It enables construction practitioners to visualize the site from a three-dimensional perspective, which helps safety managers identify potential threats (Azmy and Zain, 2016). An effective safety plan can advance proactive safety measures and reduce predictable and unpredictable safety hazards. In addition, several BIM-based safety systems are integrated into it, such as an intelligent risk assessment system or safety design knowledge base (Hossain, et al., 2018). Therefore, the automatic algorithm of BIM can predict risks and design better preventive measures for managers more accurately.

2.3.2 Wearable Safety Technology

Wearable safety technology effectively monitors workers performing high-risk construction work. Compared with other emerging technologies, it has advantages in terms of portability and cost (Yap, Lee and Wang, 2021). Wearable safety technology comes in various device types, including wristbands, connected hardhats, work boots or eyewear (Borhani, 2016). Among them, connected hardhats are widely used, which can continuously track construction workers' site location, movement tracking, and temperature (Cai, et al., 2020). For example, if a worker is dizzy or overheated, it will immediately notify workers and safety personnel. Beyond that, the technology can sense when a worker falls and trigger an emergency call to a manager (Yap, Lee and Wang, 2021).

2.3.3 Unmanned Aerial Vehicle (UAV)

An unmanned aerial vehicle (UAV) is a flying device equipped with cameras and motion sensors (Jeelani and Gheisari, 2021). In terms of safety, it mainly performs tasks related to supervision and inspection (Okpala, Nnaji and Karakhan, 2020). Its remote operation allows workers to avoid contact with potential hazards, such as hazardous structural inspections or land feasibility observations (De Melo, et al., 2017). The UAV can transmit 360-degree and real-time actual information on the site, making it easy for workers to carry out inspection and supervision tasks at any time.

2.3.4 Virtual Reality (VR)

Virtual Reality (VR) is a technology that visualises the digital world and allows users to immerse in a 3D virtual world by equipping themselves with a virtual reality headset (Chen, et al., 2021). If VR is used in construction industry, it will allow safety planners to visualize construction sites at the planning stage and identify threat sources through virtual reality models (Zhao and Lucas, 2015). In addition, VR allows workers to rehearse high-risk tasks and develop safety plans accordingly. Alam, et al. (2017) showed that VR could also be used in safety training. Compared with traditional lectures, it is difficult to instil in participants the need to remember safety measures to avoid accidents. However, VR allows workers to immerse themselves in dangerous construction environments and visualize the dangers. Realistic feeling and fun interactive training can stimulate awareness of danger (Eiris, Gheisari and Esmaeili, 2018). Concurrently, it allows workers to accumulate relevant experience during the training process.

2.3.5 Augmented Reality (AR)

Augmented reality (AR) is another visualization technology that is the opposite of VR. It projects virtual information into a real-world environment (Yap, Lee and Wang, 2021). AR can also provide risk-free safety training to improve workers' ability to identify hazards. Furthermore, the panoramic image function of AR can also enhance the risk judgment ability of workers, such as the prevention awareness of slip danger and contact danger (Haupt, Akinlolu and Raliile, 2019).

2.3.6 Sensing Technology

Sensors are one of the technologies that belong to the internet of things (IoT), such as radio frequency identification (RFID), light detection and ranging (LiDAR) or global positioning system (GPS). Sensing technology can precisely track the location of a person or object (Kereri and Adamtey, 2019). Therefore, it can be used to prevent falling incidents on the site by embedding pulse sensors in fall-prone items such as hand tools and personal protective equipment (PPE) worn by workers (Martínez-Rojas, et al., 2021). Besides, when workers enter the safety monitoring area, once workers approach dangerous equipment or locations, alarms will be triggered to prevent accidents (Arabshahi, et al., 2021).

2.3.7 Camera Network Systems

Camera network systems are similar to traditional closed-circuit television (CCTV). In addition to monitoring construction sites live, it can also record videos to collect all the actions of workers for the purpose of hazard identification and unsafe behaviour detection (Okpala, Nnaji and Karakhan, 2020). If the construction site is covered by camera network systems, it can provide a complete view to supervise the site and its record and track all the prerequisites for an accident (Nnaji, et al., 2020).

2.3.8 Others

In addition to the emerging technologies mentioned above, other technologies for safety and health management include robotics and automation (R&A). Aghimien, et al. (2020) agreed that R&A is particularly suitable for highly repetitive tasks, and it can replace humans for high-intensity, high-risk and complex tasks, which avoids safety risks for workers. Moreover, 3D laser scanning allows users to obtain 3D data without touching surfaces, eliminating the risk of workers taking on-site measurements in hazardous areas (Arabshahi, et al., 2021). Furthermore, digital signage attracts the attention of surrounding staff and visitors more than traditional safety signboards, enhancing the on-site warnings, cautions and safety reminders that managers desire to convey (Yap, Lee and Wang, 2021). Besides that, the exoskeleton is another wearable technology that users can use to reduce physical stress and injury (Kim, et al., 2019). Different versions of exoskeletons have their features, such as the whole bodysuit, which helps workers lift and carry heavy tools or materials. Finally, artificial intelligence (AI) can automatically perform safety monitoring tasks for safety managers, such as detecting if construction workers are wearing personal protective equipment through image recognition to reduce the incidence of under-viewing (Yang, et al., 2021).

Table 2.1: Type of Emerging Technologies for Safety and Health Management

Type	**References**								
	Azmy and Zain, 2016	Borhani, 2016	Haupt, Akinlolu and Raliile, 2019	Nnaji, et al., 2020	Nnaji,and Karakhan , 2020	Qi, Qian, and Costin, 2020	Afzal, Shafiq, and Al Jassmi, 2021	Chen, et al., 2021	Yap, Lee, and Wang, 2021
1. Building Information Model	✓	✓	✓	✓	✓	✓	✓	✓	✓
2. Wearable Safety Technology	✓	✓	✓	✓	✓				✓
3. Unmanned Aerial Vehicle		✓		✓	✓		✓	✓	✓
4. Virtual Reality		✓	✓	✓	✓	✓	✓	✓	✓
5. Augmented Reality			✓	✓	✓	✓	✓	✓	✓
6. Sensing Technology	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 2.1 (Continued)

Type		References								
		Azmy and Zain, 2016	Borhani, 2016	Haupt, Akinlolu and Raliile, 2019	Nnaji, et al., 2020	Nnaji,and Karakhan , 2020	Qi, Qian, and Costin, 2020	Afzal, Shafiq, and Al Jassmi, 2021	Chen, et al., 2021	Yap, Lee, and Wang, 2021
7.	Camera Network Systems				✓	✓				✓
8.	Robotics and Automation			✓	✓	✓	✓		✓	✓
9.	Digital Signage					✓				✓
10.	3D Laser Scanning								✓	✓
11.	Exoskeleton					✓				
12.	Artificial Intelligence					✓			✓	

2.4 Adoption Benefits of Emerging Technologies for Safety and Health Management

The construction industry was known as one of the most dangerous industries, with the development of emerging technology having a massive impact on safety and health management, which achieved a high safety workplace on the construction site. Therefore, this section discussed the adoption benefits of emerging technologies for safety and health management in the construction industry, which drove confidence in the adoption of emerging technologies by the construction industry.

2.4.1 Enhance Hazard Identification

Hazard identification, also known as risk prediction, is the most basic and vital part of safety and health management. To achieve accident control in the construction industry, practitioners must identify safety errors and potential hazards during the design and planning stages (Newaz, et al., 2022). Since the construction industry still relies on 2D drawings, this also creates an inefficient ability to identify and analyse potential hazards (Zhang, et al., 2015). Traditional hazard identification methods mainly rely on the experience and knowledge of safety managers and formulate corresponding prevention strategies by holding safety meetings (Choe and Leite, 2017). However, the traditional hazard identification cannot accurately reflect the actual situation of the construction site, so the safety designer cannot effectively implement preventive measures against the related hazards.

Therefore, the development of hazard identification requires technology for in-depth prediction and analysis (Guo, et al., 2021). This is because emerging technologies, such as BIM or sensing technology, can more effectively identify hazards on the construction site. These technologies automate hazard identification, which also avoids human error. For instance, real-time sensor technology can take advantage of the device in hazardous construction areas to collect data and track safety hazards (Hou, et al., 2020). Furthermore, compared with traditional 2D drawings, BIM provides 3D models that allow safety designers to intuitively identify potential safety hazards and eliminate or mitigate the risk of hazards on site (Cortés-Pérez, Cortés-Pérez and Prieto-Muriel, 2020).

2.4.2 Improve Safety Planning

Safety planning decisions at the beginning of a project have a significant impact on the project's success (Chen, et al., 2021). Safety planning provides an appropriate safety precaution strategy based on the identified hazards to prevent accidents on site. Effective safety planning runs through the life cycle of a construction project so that it can be divided into two phases: planning and implementation (Khalid, Sagoo and Benachir, 2021). Safety designers conduct risk assessments and safety measures for each task in the planning phase. Safety planning is complicated by the diversity of construction projects and labour-intensive work patterns (Kim, Cho and Zhang, 2016). If safety planning is carried out according to individual tacit knowledge, organizational cultures and safety policies, it is not enough to cover all aspects of emergencies (Zhang, et al., 2015).

In order to achieve the goal of zero accidents, practitioners can enhance safety planning capabilities through BIM. For instance, BIM can visualize the layout and dynamics of a construction site to support on-site logistics analysis (Zhang, Cao and Zhao, 2017). Safety route planning is one of the critical parts of construction safety management. The combination of BIM and sensor technology can predict the trajectory of machinery or workers (Zhang, Cao and Zhao,2017). Thus, it can prevent the occurrence of collision accidents. In addition, BIM is based on the development of automated safety rule checking (ASRC) system, it assists safety designers to complete the hazard prediction and puts forward the corresponding safety measures, which helps safety managers to make decisions (Kim, Lee and Choi, 2020).

2.4.3 Intensify Safety Inspection

A safety inspection is also regarded as a site inspection and is a core part of implementing safety and health management. Safety planning cannot remain unchanged until the completion of construction. Thus, it needs to seek and rectify safety errors on site through a safety inspection in time to prevent the occurrence of safety hazards (Zailani, Abdullahi and Auwal, 2021). Traditional safety inspection procedures typically involve a safety officer personally surveying the construction site, but there are also manageable problems, including lack of labour efficiency, data loss, communication barriers and difficulties in implementing corrective action in real-time (Yap, Lee and Wang, 2021). As a result, new technologies are emerging to solve these problems and replace or supplement the inspection work of safety officers. For example, Ashour, et al. (2016) suggested that the UAV is a reliable inspection tool that can replace safety officers by entering dangerous or inaccessible areas to observe and record safety manifestations of working conditions and worker behaviour.

2.4.4 Strengthen Safety Monitoring

Medium to large construction projects usually involve many construction workers, equipment and materials and are often required to continuously monitor the site (Yap, Lee and Wang, 2021). If the primary use of staffing is to monitor the construction site, this is a very ineffective monitoring strategy. This is because human monitoring capabilities are limited (Zhou, Irizarry and Lu, 2018). For instance, it is difficult for safety managers to visit several locations simultaneously or to supervise large numbers of workers, resulting in a deterioration in the safety performance of construction projects.

However, this situation has improved with the emergence of a camera network system or wearable safety technology. These safety technologies can provide real-time on-site information for safety managers, especially camera network systems (Borhani, 2016). It makes safety managers easier to monitor from a bird's eye view, allowing safety executives to understand the situation on the ground better and catch any workers who violate safety precautions. When working at height, the camera network system can automatically identify workers who are not wearing safety helmets, safety belts and anchors (Hou, et al., 2020). In addition, construction workers are exposed to high temperatures and humidity for a long time, directly affecting the workers' physiological state and work behaviour. Therefore, wearable safety technology can detect the physiological state of workers to track their health performance of workers. If the health performance does not fulfil the criteria, the task will be immediately suspended (Kiani, Salman and Riaz, 2014).

2.4.5 Improve Safety Training

The success of construction projects depends on regular safety training for workers, which has a positive effect on reducing the occurrence of accidents. Safety training refers to improving workers' safety knowledge and awareness before construction tasks so that workers' interests and safety goals are consistent (Bavafa, Mahdiyar and Marsono, 2018). Traditional safety training, such as lectures or demonstrations have shortcomings, such as failing to stimulate students' interest or lack of reasonable practices (Hou, et al., 2020). Li, et al. (2018) believed that the above problems could be solved if VR or game technology was combined with safety training. This innovative way of training creates a virtual environment that allows users to interact with objects. There is no occupational hazard because the virtual environment simulates and generates a virtual scene of construction activities (Hou, et al., 2020). VR provides an immersive experience that allows users to get the same feedback as the physical world. For example, users can behave in a virtual world that does not conform to safety norms. Once the users experience the negative consequences, who will consciously abide by the safety regulations and avoid that type of behaviour in the physical task (Hou, et al., 2020). If the new technology does not offer a user-friendly experience or convenience, safety training may be more challenging (Zhang, et al.,2022).

2.4.6 Boost Safety Awareness

Safety awareness is promoted through the participation of upper management and site staff in maintaining site safety (Zhang, et al., 2015). The safety awareness of site workers is directly related to safety performance. Safety awareness refers to the construction individual's values, attitudes and behaviour on construction safety (Khalid, Sagoo and Benachir, 2021). When workers have sufficient safety awareness and experience, the risk of accidents on site will also be reduced (Khawam and Bostain, 2019). Safety awareness can be divided into two types, namely psychological and behavioural. The psychological aspect involves personal values, attitudes and perception of danger, while the behavioural aspect describes the individual's code of conduct for safety (Khalid, Sagoo and Benachir, 2021).

Moreover, such safety awareness can be cultivated. For example, the adoption of new technologies can enhance the safety awareness of construction workers. Although the ultimate goal of most emerging technologies is to improve construction safety directly, it can indirectly improve the safety awareness of construction operators through the process of technology adoption. Some studies have confirmed this theory. For example, Cheng and Teizer (2013) verified that visualization technology could improve workers' safety awareness while conducting real-time safety monitoring. In addition, Kim, Kim and Kim (2017) also proved the effectiveness of AR for construction workers in enhancing safety awareness. At the same time, another study also proposed that BIM can enhance architects' or structural engineers' awareness of building safety (Yap, Lee and Wang, 2021).

2.4.7 Reinforce Accident Warning

The best method to avoid accidents is to take active action rather than a passive reaction. Thus, real-time information is crucial to preventing accidents from happening (Borhani, 2016). An accident forewarning system (AFS) is to discover the potential cause of an accident before it occurs (Zhang, Cao and Zhao, 2017). The accident forewarning system can detect and identify workers' unsafe behaviours in real-time and prevent accidents by triggering alarms to construction workers or managers. Limited manpower on site does not ensure that every unsafe situation is detected.

Therefore, sensing technology can be used to monitor the construction environment automatically. Due to the rapid development of new technology, AFS based on sensor technology has a breakthrough (Zhang, Cao and Zhao, 2017). Position sensing technology is used for the automatic prevention of construction accidents, such as GIS, GPS or RFID in AFS (Kim, et al., 2014). Installing RFID tags on each heavy equipment can prevent machinery or workers from colliding with each other. Because RFID based AFS can calculate the dynamic distance between individual equipment or workers, which assess collision risk based on real-time positioning (Akinlolu, et al., 2020). Besides, safety managers demarcate some site areas as hazardous areas, such as construction machinery workplaces or areas prone to falling objects, and sensors are installed in the relevant areas (Park, Kim and Cho, 2017). As soon as a worker approaches a danger zone, the system broadcasts an alert to the worker because location sensors can capture the worker's real-time location on the site.

Table 2.2: Adoption Benefits of Emerging Technologies for Safety and Health Management

Adoption Benefits	**References**								
	Zhang, et al., 2015	Borhani, 2016	Zhang, Cao and Zhao, 2017	Nnaji and Karakhan, 2020	Chen, et al., 2021	Khalid, Sagoo and Benachir, 2021	Yap, Lee and Wang, 2021	Hou, et al., 2022	Newaz, et al., 2022
1. Enhance Hazard Identification	✓			✓	✓	✓	✓	✓	✓
2. Improve Safety Planning	✓	✓	✓	✓	✓	✓	✓	✓	✓
3. Intensify Safety Inspection		✓		✓		✓	✓		
4. Strengthen Safety Monitoring		✓	✓			✓	✓	✓	
5. Improve Safety Training		✓	✓	✓		✓	✓	✓	✓
6. Boost Safety Awareness	✓			✓	✓	✓	✓		
7. Reinforce Accident Warning			✓	✓				✓	✓

2.5 Adoption Barriers of Emerging Technologies for Safety and Health Management

The construction industry remains resistant to change. There is resistance to emerging technology changing traditional ways of working in the construction industry. Therefore, this section addressed the barriers that influence the adoption of emerging technologies in safety and health management. Adoption barriers can be divided into three aspects, including technological, organizational and environmental factors (Nnaji, et al., 2020).

2.5.1 Technological Factors

The technological factors are the impact of the technology and the users themselves. According to the previous research, four technological factors have been identified, which are explained in detail below.

2.5.1.1 Time Need for Learning and Adoption

Time is a limited resource, and it can exacerbate the impact of other factors, such as the complexity and effectiveness of safety technologies (Borhani, 2016). The complexity of using technology or the fact that its safety value is not recognised by the industry makes safety executives more sensitive and, therefore, less willing to take the time to learn and adopt emerging technologies (Tulenheimo, 2015). Hence, if emerging technologies are adopted, safety managers will need more time to master the operation of emerging technologies to maximise their safety performance.

2.5.1.2 Ineffectiveness of Technology

The effectiveness of technology shapes the willingness of potential users to adopt emerging technologies. In terms of effectiveness, it is one of the technical characteristics that can provide users with higher efficiency and benefits, thus attracting potential users to adopt a particular technology (Hamid, et al., 2016). While the technology is still immature, it does not provide absolute safety value, so it can be swayed by construction practitioners to decide on the introduction of new technology (Rui, Khai and Alzoubi, 2022). For instance, when new technology does not show significant benefits or is used as a marketing tool, its safety performance is not proven. Uncertainty about its effectiveness leads the construction industry to refuse the new technology.

2.5.1.3 Inadaptability of Technology

The adaptability of technology is related to the user's ease of operation and friendliness (Borhani, 2016). Khudzari, Rahman and Ayer (2021) mentioned that if the equipment is easy to use on the site and the interface of software or systems is user-friendly, the system attracts the user to access it. This will speed up the implementation of safety technologies. Once the use of the technology is complex, the time required to learn and adopt the technology increases difficulties, and the chances of deploying the technology are low, even if it has a positive impact on on-site safety (Borhani, 2016).

2.5.1.4 No Assurance of Data Privacy

Data from most emerging technologies are stored in cloud services and on the internet, meaning that relevant parties with access can access the data (Tulenheimo, 2015). However, some employers are reluctant to provide the business information of the project to a third party, such as the project plan (Bello, et al., 2021). On top of that, the weakest part of the data chain is on the user side, which means vulnerabilities can compromise data as workers process work on mobile devices because these mobile devices are vulnerable to virus infection or hacker attacks (Bello, et al., 2021).

2.5.2 Organizational Factors

The organizational factors are the influence at the firm level. This study discovered five organizational factors, which are discussed in the following.

2.5.2.1 Small Organizational Size

The organizational size will influence managers' decisions on adopting emerging technologies. The size of an organization can be determined by the business turnover and the number of employees (Rui, Khai and Alzoubi, 2022). Generally, the larger the construction enterprise, the more inclined to adopt new technology. This is because construction companies can increase the cost-effectiveness of adopting new technologies through economies of scale (Rui, Khai and Alzoubi, 2022). In addition, large organizations have more resources to invest in new technologies to replace old safety methods (Borhani, 2016). In contrast, small businesses do not prioritise safety improvements, whose goal is to survive among many competitors. However, with the emergence of low initial cost technologies, such as UAV, there are opportunities for small organisations to implement emerging technologies to improve safety and health management (Zhang, et al., 2022).

2.5.2.2 Closed Organizational Culture

Closed organizational culture will affect the value and attitude of safety management practices of organization members (Gao, et al., 2018). Khalid, Sagoo and Benachir (2021) explain that if the organizational culture of the construction enterprise is supportive and open to the adoption of new safety technology. Once a construction enterprise deploys emerging technologies in safety and health management to improve safety status, organization members generally remain optimistic about new changes. Therefore, the open organizational culture enables the organization members to adapt to the new technology in the construction industry more promptly. However, a closed organisational culture will stifle a culture of innovation to spread safety awareness among its members and encourage and support the adoption of new technologies. (Rui, Khai and Alzoubi, 2022).

2.5.2.3 Extra Costs

In any industry, adopting new technologies will face cost issues (Yap, et al., 2022). High initial costs will hinder the implementation of emerging technologies in safety and health management (Nnaji, Gambatese and Eseonu, 2018). In addition to initial costs, emerging technologies also require maintenance costs to maintain day-to-day operations and training costs to support trainees to become safety experts to achieve a safe workplace (Khudzari, Rahman and Ayer, 2021). Therefore, the construction manager should consider the economic and financial risks undertaken. Moreover, managers also analyse the cost-effectiveness and investment value of replacing old methods with new technologies (Bademosi and Issa, 2021). Besides that, most contractors tender as low as possible to be selected among many competitors. Nevertheless, it also means that contractors' budgets will be curtailed, which limits the opportunity to adopt emerging technologies (Yap, et al., 2022).

2.5.2.4 Lack of Top Management Support

Managerial decisions have a significant impact on the deployment of emerging technologies. Since top management has ownership of decisions, such as resource allocation, financial provision, or safety training, all reside at the management level (Nnaji and Karakhan, 2020). If top management refuses to provide any support for new technologies, this also affects adoption. Due to the weak safety culture of the construction industry, most leaders have less safety awareness, and only profit is the focus of the leadership (Yap, et al., 2022). Hence, leadership must recognise that emerging technology has technical and safety benefits to be reused across multiple construction projects (Nnaji, 2020).

2.5.2.5 Additional Training

Lack of operational experience and skills will affect confidence in adopting emerging technologies. Thus, a successful technology will be complemented by training courses for operators' technical knowledge (Yap, et al., 2022). In addition, to achieve the best safety performance of emerging technologies, management must provide additional training to ensure that safety managers and operators have the required technology (Khudzari, Rahman and Ayer, 2021). In addition to the higher cost of additional training, it also requires a longer training time for safety managers and operators to understand the practicality of the technology, so it is difficult for organizations to provide adequate training for everyone. Older safety executives, in particular, are slower to absorb knowledge about the use of emerging technologies and therefore require more additional training (Zakari, et al., 2014).

2.5.3 Environmental Factors

The environmental factors refer to the social or governmental impact. Based on previous studies, three environmental factors are summarised below.

2.5.3.1 Lack of Occupational Safety and Health Regulations

Government support for occupational safety and health regulations is one of the decisive factors in adopting emerging technologies. This is because safety regulations are used as guidelines for safety planning to achieve favourable construction safety (Khalid, Sagoo and Benachir, 2021). If the construction industry adopts basic standards for emerging technologies, this should involve relevant regulations and policies. In addition, outdated safety regulations are responsible for the high number of accidents at construction sites (Okpala, Nnaji and Awolusi, 2019). Therefore, the government should develop safety standards for construction safety with the progress of technology. New regulations or safety laws will influence the construction industry to promote the adoption of new technologies for safety purposes. For instance, The Ministry of Works in Malaysia launched the National Construction Policy (NCP) 2030 in 2021. Under the policy, the department will develop new measures to enhance site supervision and safety assessment through the Safety and Health Assessment System in Construction (SHASSIC). In addition, the department's enhanced use of emerging technologies such as BIM in infrastructure projects, combined with the SHASSIC assessment tool, ensured overall productivity and safety improvements to the project throughout the development process (Ministry of Works, 2021). Nonetheless, current safety and health regulations or standards do not cover the full range of emerging technologies, which are often limited to BIM, thus limiting the types of emerging technologies used by construction practitioners.

2.5.3.2 Lack of Government Incentives and Promotion

Most traditional construction enterprises are unwilling to carry out safety management innovations due to the lack of awareness of new technologies and high costs, thus, most enterprises prefer to maintain the status quo (Rui, Khai and Alzoubi, 2022). However, the government has the ability to improve the situation to promote the adoption of new safety technologies. Government incentives such as free training and tax breaks can encourage traditional firms to experiment with new technologies in construction projects (Khudzari, Rahman and Ayer, 2021). For example, 168 construction firms in Singapore currently benefited from the BIM fund launched by the Building and Construction Authority (BCA), which provides financial incentives to cover the cost of implementing BIM (BCA, 2011). However, Malaysia's Construction Industry Development Board (CIDB) promoted specific emerging technologies and their endless benefits to the construction industry, which will refresh traditional companies' perception of emerging technologies (Yap, et al., 2022). Nevertheless, there is still a lack of government incentives, which could reduce the driver for Malaysian builders to adopt new technologies.

2.5.3.3 Lack of Competitive Pressure

In order to improve safety standards and safety problems, a small number of construction enterprises first introduce emerging technologies to control safety, which also provides enterprises with competitive advantages in the construction industry (Ghazal, et al., 2021). Competitive advantage can also be considered competitive pressure, which is two-sided. Competitive pressures will catalyse construction companies' decisions to implement emerging technologies in safety and health management in the long run. When most companies adopt emerging technologies, it puts competitive pressure on other companies (Roger, Chong and Preece, 2015). If the remaining enterprises are still unwilling to adopt emerging technologies, they may face the risk of being eliminated. However, in most cases, no construction company is willing to implement emerging technologies for safety and health management in the first place, resulting in a lack of competitive pressure in the construction environment as a whole.

Table 2.3: Adoption Barriers of Emerging Technologies for Safety and Health Management

Adoption Barriers			**References**								
			Borhani, 2016	Nnaji, Gambatese and Eseonu, 2018	Nnaji, et al., 2020	Bademosi and Issa, 2021	Khalid, Sagoo and Benachir, 2021	Khudzari, Rahman, and Ayer, 2021	Nnaji and Karakhan, 2022	Rui, Khai and Alzoubi, 2022	Yap, et al., 2022
Technological Factors	1.	Time Needed for Learning and Adoption	✓					✓		✓	
	2.	Ineffectiveness of Technology	✓	✓	✓	✓		✓	✓	✓	✓
	3.	Inadaptability of Technology	✓	✓	✓	✓		✓	✓	✓	✓
	4.	No Assurance of Data Privacy				✓					✓
Organizational Factors	1.	Small Organizational Size				✓				✓	
	2.	Closed Organizational Culture			✓	✓	✓			✓	✓
	3.	Extra Costs	✓	✓	✓	✓		✓	✓	✓	✓

Table 2.3 (Continued)

Adoption Barriers			**References**								
			Borhani, 2016	Nnaji, Gambatese and Eseonu, 2018	Nnaji, et al., 2020	Bademosi and Issa, 2021	Khalid, Sagoo and Benachir, 2021	Khudzari, Rahman, and Ayer, 2021	Nnaji and Karakhan, 2022	Rui, Khai and Alzoubi, 2022	Yap, et al., 2022
Organizational Factors	4.	Lack of Top Management Support	✓	✓	✓		✓	✓	✓	✓	✓
	5.	Additional Training	✓	✓	✓	✓	✓	✓	✓	✓	✓
Environmental Factors	1.	Lack of Occupational Safety and Health Regulations	✓		✓	✓	✓			✓	✓
	2.	Lack of Government Incentives and Promotion						✓	✓	✓	✓
	3.	Lack of Competitive Pressure			✓					✓	

2.6 Willingness to Use Emerging Technologies for Safety and Health Management

The adoption rate of BIM can reflect a country's willingness to embrace emerging technologies because BIM is one of the first emerging technologies adopted by the construction industry (Zhang, et al., 2020). When a country's construction industry begins to use BIM, other emerging technologies will be embraced to help improve safety performance. Furthermore, BIM is mandatory in some countries' construction industries and projects to improve productivity and safety performance (Enshassi, Ayyash and Choudhry, 2016). For example, Statista (2022) found that BIM adoption in the UK construction industry rose from 13% in 2011 to 73% in 2020. On the side, in terms of company size, Mohammad, et al. (2018) revealed that 91% of large construction companies in North America (the US and Canada) have adopted BIM, while only 49% of small and medium businesses have.

Moreover, Juszczyk, Výskala and Zima (2015) discovered that the type of construction business also influences the BIM adoption rate, with 93% of consultants in Finland accepting BIM compared to only 60% of engineering firms. Next, Hosseini, et al. (2016) investigated that the adoption of BIM in Australia is still scattered, with few private enterprises participating in the adoption of BIM, but BIM has been successfully implemented in public projects in Australia. Finally, Enshassi, Ayyash and Choudhry (2016) showed that the government of Singapore is one of the few countries in Asia to mandate the use of BIM in construction projects. Singapore's building and construction authority (BCA) plans to implement BIM in all public projects in 2015 to promote productivity and safety performance in Singapore's construction industry.

On the other hand, the BIM penetration rate in developing countries is lower compared with the developed countries mentioned above. For example, most countries in the Middle East or Southeast Asia have not adopted measures to at least use BIM in public projects. Because approximately 60% of consultants and 69% of contractors in the Middle East consider the commitment to implementing new technologies to improve construction safety performance to be very low, there are no plans to adopt new technologies in future construction projects (Enshassi, Ayyash and

Choudhry, 2016). This may be due to a lack of in-depth knowledge and the positive changes in the safety performance of emerging technologies, thus resulting in the infrequent use of new technologies in buildings. Besides, the Public Works Department (PWD) has been aiming to adopt BIM in more than 10% of Ranancangan Malaysia KE-11 (RMK11) projects in Malaysia since 2007 (CIDB, 2018). In 2018, BIM was authorised to be used in public construction projects with a budget of over RM100 million, such as the Malaysian Anti-Corruption Commission (MACC) Office, Selangor, which will launch a renovation program for the Malaysian construction industry and promote the application of emerging technologies (CIDB, 2018). According to Othman, et al. (2021), the level of BIM implementation in Malaysia is deficient, with only 8.2% of the public sector and 4.9% of the private sector using BIM technology. The main reasons why most organizations refuse to use new technologies are lack of awareness, high cost and difficulty in changing the traditional methods.

Beyond that, the British construction industry has started to move towards institutionalisation by adopting new technologies (Noruwa, 2020). That study showed that 81% of UK (United Kingdom) contractors believe the use of new technology can reduce the risk of project complexity (Noruwa, 2020). Contractors can predict and solve site problems through virtual environments and drones to capture and evaluate construction site management in real-time. In addition, 77% of new technology from UK contractors meets industry standards (Noruwa, 2020). The term standard refers to an official document issued by a country or industry to ensure the quality, compatibility and compliance of the relevant technology defined by the specification. An emerging technological standard recognised in the UK begins with BIM, which will develop a unified framework that will allow UK practitioners to access models with complete data as all parties meet specified information requirements and documentation to comply with the ISO 19650 (Ajayi, Oyebiyi and Alaka, 2021). Besides that, 99% of UK contractors will be willing to continue to use new and tried technologies, as new technologies improve contractors' safety performance on the site (Noruwa, 2020). These contractors can more effectively collect and manage site data on safety and operational processes by using artificial intelligence to analyse the data and quickly solve site problems.

Last but not least, Nnaji and Karakhan (2020) identified the top five emerging technologies currently and in the future that United States (U.S.) contractors will use for safety and health construction management, including BIM, wearable sensing devices, mobile devices on-site, radio frequency identification and LiDAR to improve worker safety and health as the primary function. Furthermore, Qi, et al. (2020) analysed the utilisation level and future investment level of technology and finally showed that BIM, GIS and sensing technology are the three technology types with the highest utilisation level and future investment level in the United States. This also shows that these three technologies are the most widely used safety and health management technologies in construction projects.

2.7 Technology Acceptance Model (TAM)

Initially, the technology acceptance model (TAM) proposed the theoretical framework of information technology acceptance based on the basic theory of reasoning action (TRA) (Katebi, Homami and Najmeddin, 2022). At present, TAM is one of the standard theories, which is mainly used to measure users' acceptance of specific technologies (Liu, Lu and Niu, 2018). The original TAM concept was explained below, as well as a discussion of how the TAM was modified for the theoretical framework based on the study.

2.7.1 Original TAM

According to Figure 2.1, perceived ease of use, perceived usefulness, and attitude toward using the technology are key factors to explain the adoption of technology by the industry (Davis, 1989). Thus, the intention or attitude of an individual or organization to use an emerging technology is determined by its perceived usefulness and ease of use. In other words, if a technology makes it more efficient while at the same time making it less challenging to use, its acceptance will increase. It is also worth noting that perceived usefulness will be affected by perceived ease of use and external variables, while perceived applicability will be affected by external variables.

From the previous studies, for instance, Sanchís Pedregosa, Vizcarra Aparicio and Leal Rodríguez (2020) used TAM to investigate the acceptance degree of BIM technology in the construction industry. Moreover, Man, et al. (2021) supported TAM's interpretation of Hong Kong construction workers' acceptance of PPE use. Besides that, Zhang, et al. (2022) provided TAM with a decision-making perspective on VR technology in safety training. Therefore, TAM can be used to demonstrate the willingness to use emerging technologies in safety and health management.

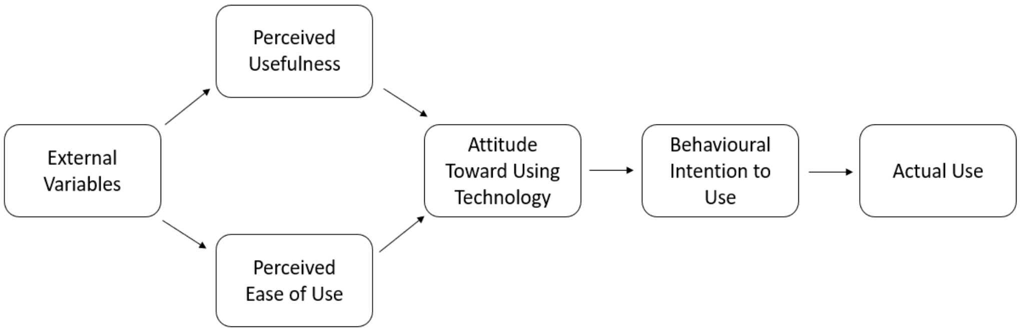

Figure 2.1: Original Technology Acceptance Model (Source: Davis, 1989)

2.7.2 Modified TAM

This section introduces the modified TAM framework and proposed hypotheses. Although TAM is a general and robust model, some scholars suggested that the model could be extended or modified by other factors to support the acceptance of technology in a particular field (Wong, Man and Chan, 2021; Shin, et al., 2022). Therefore, TAM will be taken as the basis of this study, and the definitions of perceived usefulness and perceived ease of use will be modified to apply this theory to the acceptance model of willingness to use emerging technologies in safety and health management. Figure 2.2 demonstrated the theoretical framework for emerging technologies in safety and health management and related variables.

First, the willingness to use is the endpoint of TAM, which means that the acceptance of technology is driven by the willingness to use specific emerging technologies, which is directly determined by the adoption benefits and adoption barriers. It represents how an individual or organization is willing to experiment with emerging technology (Ajzen and Driver, 1991). In addition, if an individual or organization has a positive attitude toward the relevant emerging technology (such as BIM, AR, UAV or R&A), it will affect the actual use of the technology. Therefore, this study will investigate the relationship between adoption benefits and willingness to use emerging technologies and adoption barriers and willingness to use emerging technologies, which would assist in measuring the strength of the willingness to use specific emerging technologies.

Secondly, adoption benefit is equivalent to the perceived usefulness in the original TAM, which means that an individual can achieve specific performance and efficiency improvement to the construction project by using a particular technology (Davis, 1989). In this study, adoption benefits refers to the belief that emerging technologies can enhance the safety performance on construction sites (Yap, Lee and Wang, 2021). In particular, emerging technologies have much adoption benefits in some aspects of safety and health management, including safety planning, hazard prediction or safety training, which can directly improve the safety assurance of construction projects. Based on this model, adoption benefits will directly affect the willingness to adopt technology because emerging technologies can bring positive safety performance compared to traditional safety methods, thus, individuals or organizations will have a greater willingness to use technology (Katebi, Homami and Najmeddin, 2022). For example, technology could automate safety monitoring or accident warning systems for safety managers.

Finally, the adoption barriers in the original TAM refer to the perceived ease of use, which relates to how difficult it is for individuals to operate with emerging technologies, such as the need for professional training or effortless (Davis, 1989). This study will incorporate perceived ease of use into the adoption barriers of emerging technologies in safety and health management, namely technological, organizational and environmental aspects. Other adoption barriers also play a crucial part in the decision-making process of emerging technologies (Katebi, Homami and Najmeddin, 2022). In other words, ease of use is only one of the factors that affect the willingness to use emerging technologies, and it does not fully reflect the level of acceptance of emerging technologies. According to this model, if the adoption of emerging technologies encounters barriers, the willingness to use will be reduced, resulting in a lack of sufficient willingness of construction safety operators to use the emerging technologies (Katebi, Homami and Najmeddin, 2022). For instance, the adoption of technology in safety and health management is easily affected by high-cost budget or closed organisation culture. Hence, this study proposed the following hypotheses:

H_1: Adoption benefits positively affect willingness to use emerging technologies for safety and health management.

H_2: Adoption barriers negatively affect willingness to use emerging technologies for safety and health management.

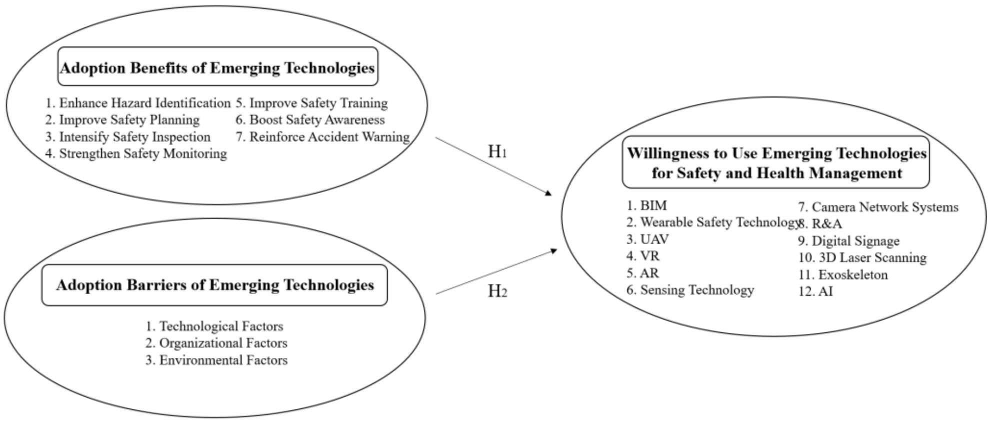

Figure 2.2: Theoretical Framework for Emerging Technologies in Safety and Health Management

2.8 Summary of Chapter

This chapter summarised past research on applying emerging technologies to safety and health management, including BIM, VR, AR, sensing technology, UAV or camera network systems. In addition, the adoption benefits of emerging technologies was reflected in safety planning, safety inspection, safety monitoring, safety training and other aspects. Moreover, the impact of adoption barriers on emerging technologies is divided into technological, organizational and environmental factors. It also identified the current and future state of willingness to use emerging technologies from a global and Malaysian perspective. Finally, TAM was used to measure the willingness of Malaysia's construction industry to use emerging technologies for safety and health management.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter introduced the research methodology of this study, which explained in detail the attitudinal study, research framework, research method, research design, data collection, sampling and data analysis.

3.2 Attitudinal Study

This is an attitudinal study to explore the potential of adopting emerging technologies for safety and health management in the Malaysian construction industry. Typically, an attitudinal study is used to evaluate respondents' subjective 'opinions', 'views' or 'ideas' about a particular subject (Gregar, 1994). It helps to measure whether respondents' perceptions of using emerging technologies in safety and health management are positive or negative.

3.3 Research Method

A research method is an approach that is used to answer the research aim and objectives, and different studies require different technical strategies (Kothari, 2004). However, the mainstream research methods are divided into quantitative and qualitative research. The quantitative research method is systematic research that collects quantifiable data and performs statistics and analysis (Pajo, 2017). In other words, it quantifies specific research topics by obtaining the required numerical data from a larger population and performing statistics and data analysis. The quantitative research method can also be expressed as a deductive approach, so it relies on the statistical data in the research to test the theory (Pajo, 2017).

On the other hand, qualitative research is research within the limited scope of knowledge and theory in the field of study. It emphasises quality, meaning, description, perception and experience (Hennink, Hutter and Bailey, 2020). It is considered a form of inductive reasoning, where experimental research methods such as interviews are used to gain an in-depth understanding and knowledge. It is usually unstructured or open-ended questions, encouraging respondents to contribute more ideas, but the number of targeted respondents is limited.

Hence, this study used quantitative research methods to collect data. Since the theoretical framework is clear and sufficient and the questionnaire is well-structured and comprehensive. Furthermore, in analysing the data obtained, quantitative research methods allow for the systematic application of mathematical and statistical techniques to test and explain the relationships between the dependent and independent variables, thus evaluating the potential of emerging technologies for safety and health management in the construction industry.

Beyond that, this method usually involves logic and statistics, thus, the results obtained by researchers are logical, objective and fair. Furthermore, the advantages of the quantitative research method are reliable. Since it collects a wide range of samples, it can eliminate personal bias (Cresswell, 2009). Besides that, another advantage is fast execution and low cost, as it requires less time to collect data such as questionnaires.

Finally, the quantitative research method allows a single data collection technique (Cresswell, 2009). For example, this study will collect and analyse data through a questionnaire survey. In order to ensure that the data collected is valid and reliable, it is necessary for all respondents to clearly understand the questions and answer questions in a standard manner. Therefore, a pre-test is used to test the integrity and grammar of the questionnaire.

3.4 Research Design

The research design is constructed to describe how the research process is conducted. It is crucial to determine the research topic, so this study begins with selecting the appropriate research area. Once the research topic is determined, the previous studies or cases related to the topic should be investigated to define the problem statement. Next, corresponding research objectives are set according to the problem statement to ensure the feasibility of the study (Kothari, 2004). Then, more relevant data and information are collected from existing theories and concepts proposed by different researchers through detailed literature reviews, including journals, articles, books, government publications and other reliable resources.

In addition, quantitative research is adopted to collect data from target respondents by distributing questionnaires. The next stage is to conduct data analysis with appropriate research analysis techniques. The analysis results are discussed in detail, and previous literature is used to support or justify the achievement of the research objectives. Moreover, the conclusion discusses the implications of the findings and relate them to previously set goals and objectives. Finally, suggestions for future research are put forward by reviewing this study. Figure 3.1 showed the various processes of this research design, which were modified and customised based on Kothari (2004).

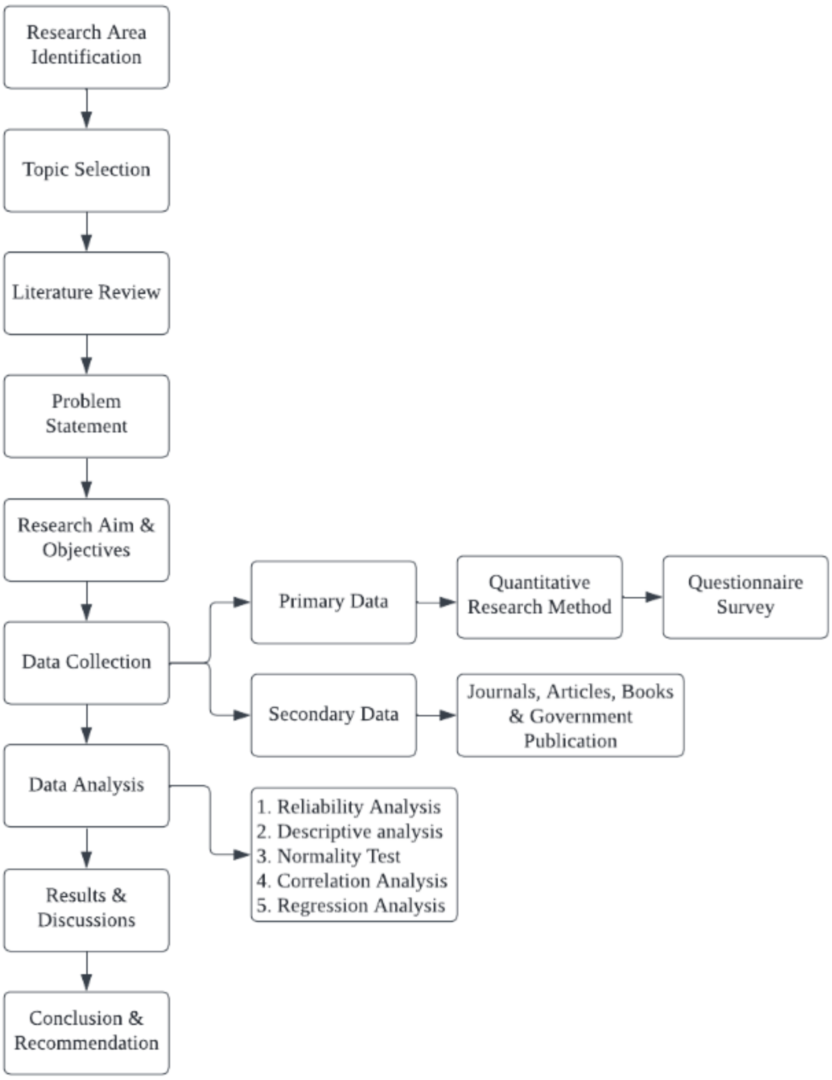

Figure 3.1: Research Design Workflow (Source: Kothari, 2004)

3.5 Data Collection

In this study, data collection can be divided into two forms, namely primary data and secondary data, which will be used for statistical analysis (Naoum, 2012). First of all, there are four primary data collection instruments, including experiments, questionnaires, polls and controlled observation. These are raw data collected directly from the original source, such as users or respondents. This study distributed online questionnaires to target respondents through Internet platforms as the primary data source, such as Google Form. Online questionnaires can obtain a large number of respondents and a high response rate from a large sample group quickly (Pajo, 2017). Links generated by Google Form will be sent to targeted respondents via email, Facebook or LinkedIn.

In contrast, secondary data are information obtained through a review of relevant studies that have been collected and analysed by other researchers. Generally, secondary data is relatively easy to obtain for researchers, for example, through open sources such as journals, books, magazines, news, or government publications. These data helped to generate new understandings in this study. The secondary data collection method for this study was collected through the online library of the Universiti Tunku Abdul Rahman's (UTAR).

3.5.1 Questionnaire Design

The questionnaire consists of a series of questions related to the research objectives. Therefore, preliminary questions should be identified from the literature review when designing the questionnaire. Next, the preliminary questions are divided into several sections (Naoum, 2012).

This questionnaire begins with a concise explanation of the study topic and goal before the respondents answer the main section of the questionnaire. The questionnaire of this study mainly consists of four sections, as shown in Table 3.1. First of all, section A of the questionnaire collects respondents' demographic information, including basic information such as highest academic qualification, job title, work experience and the nature of the project involved. Moreover, section B asks respondents about the adoption benefits of adopting emerging technologies in safety and health management. Next, section C requires respondents to reveal barriers influencing the adoption of emerging technologies in safety and health management. Finally, section D prompts respondents to identify each type of emerging technology that respondents are willing to use. These data are independent variables (Section B and C) used to reveal relationships with dependent variables (Section D) collected in other chapters.

Table 3.1: Questionnaire Design

Section	**Item**
A	Respondents' Demographic Information
B	Adoption Benefits of Emerging Technologies for Safety and Health Management
C	Adoption Barriers of Emerging Technologies for Safety and Health Management
D	Willingness to Use Emerging Technologies for Safety and Health Management

In addition, sections B, C and D of the questionnaire select closed-ended questions to present the survey questions in the questionnaire. Therefore, respondents must choose from the options given in the questionnaire. It is also convenient for researchers to analyse data because the number of answers set for closed questions is limited, and it also allows respondents to complete the questionnaire in a short time. Besides that, all the closed questions are designed with the 5-point Likert scale, which is used to evaluate the respondents' agreement to various questions based on self-views and related knowledge (Likert, 1932). The ratings of the agreement are listed in Table 3.2. Section B and Section D of the questionnaire present the level of agreement according to Table 3.2, i.e., strongly disagree (=1) to strongly agree (=5). On the other hand, Section C of the questionnaire presents in the opposite direction, i.e., strongly disagree (=5) to strongly agree (=1). This ensures that all the data are moving in the same direction. For example, the adoption of benefits and willingness to use have a higher consistency than the adoption of barriers, which act as contrasting variables. It is helpful for this study to investigate their direction of correlation.

Table 3.2: Level of Agreement (5-Point Likert Scale)

Ratings	Definitions
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

(Source: Likert, 1932)

3.5.2 Pre-test

Pre-testing the questionnaire is essential before official data collection because failing to accomplish this could compromise the reliability of the collected data. Sheatsley (1983) suggested that the questionnaire pre-test should be conducted on at least 12 to 50 people. Thus, 12 questionnaires were distributed for the pre-test in this study, which was excluded from the formal data collection. A pre-test is a small-scale questionnaire test distributed before collecting official primary data from respondents. This tests the questionnaire's validity, feasibility, and appropriateness (Draisma and Dijkstra, 2014). In addition, the pre-test ensures that all respondents consistently understand the questionnaire questions to avoid inaccurate data. Beyond that, the pre-test eliminates unclear instructions and language errors in the questionnaire. Based on the feedback from the pre-test, the questionnaire was revised before it was formally distributed to the target respondents.

3.6 Sampling

Sampling is defined as the process of selecting samples from a large population of respondents. Since studying the entire population is very costly, an excellent sample selection can represent the entire population and achieve the reliability and accuracy of study results (Sarmah and Hazarika, 2012). In other words, sampling is selecting a group of individuals from the population who must have similar characteristics to the population. Then, the data is collected from these samples.

3.6.1 Sampling Method

The sampling method of this study adopted the simple random sampling method to select respondents. It is classified as a probability sampling technique, which is the technique of selecting a representative sample. Probability sampling techniques mean that selecting a sample from a large population is equal and random, thus, it is not affected by other external factors, such as the personal preferences of the researcher (Sarmah and Hazarika, 2012). The reason for using the simple random sampling method is that the sample represents the results of the population as a whole. This is because the sampling framework includes the entire target population, so every individual of the target population has an equal chance of being selected as a sample. Thus, simple random sampling removes all bias to produce reasonably reliable results, as each individual has the same probability of selection. Besides, simple random sampling is much simpler and requires less knowledge than other sampling methods (Sarmah and Hazarika, 2012). For example, the researcher does not need special knowledge or information to effectively complete the study from a larger population without dividing the population into subgroups or taking further steps. In conclusion, it is suitable for most quantitative studies, as it allows researchers to generate solid and valid statistical judgments and analyses of the entire population.

3.6.2 Sampling Frame

The sampling frame refers to the limitation of sample size in a large population group. The target population of this study is contractors in the Malaysian construction industry. Contractors have more opportunities to implement emerging technologies to improve site safety and health performance than developers and consultants. This is because the contractor is the principal responsible person and planner during the construction phase. In addition, according to the CIDB grade category, contractors can be classified as Grade 1 to Grade 7 (Malaya Corporate, 2022). The different grades limit the contractor's ability to tender, which results in the contractor not being entitled to undertake construction work beyond the specified value. Due to emerging technologies' high initial and maintenance costs, this study limited the target respondents to Grade 7 (G7) local contractors. The tender capacity does not limit the G7 contractor, so it can undertake any construction work value, unlike the G6 contractor, which can only undertake construction work value below RM10 million. Moreover, local contractors in Malaysia were selected as the target respondents. The target respondents held positions ranging from entry-level to managerial, regardless of experience, education, salary and the type of the project involved. Finally, based on the data provided by the Construction Industry Development Board (CIDB), there are 8,859 G7 contractors registered in Malaysia as of August 2022 (CIDB, 2022). Thus, the total population size for this study was 8,859. Beyond that, the target G7 contractors selected by simple random sampling were sent questionnaires via LinkedIn, WhatsApp and email based on information provided by the CIDB, including company name, phone number and email.

3.6.3 Sampling Size

Sampling size determines the validity, reliability and consistency of the sample to the data. If the sampling size is insufficient, this leads to incorrect study results. On the contrary, if the sampling size is excessive, it is a waste of funds and time to conduct the study. According to Sevilla (1992), the sample size (n) depends on two factors, including population size (N) and margin of error (e). In order to determine the sampling size of local Grade 7 contractors, this study employed Slovin's formula, as shown in Equation 3.1 (Sevilla, 1992).

$$\mathrm{n} = \frac{\mathrm{N}}{(1 + \mathrm{N}e^2)} \tag{3.1}$$

$$\mathrm{n} = \frac{8859}{(1 + 8859 * 0.05^2)} \approx 383$$

Where

n = Sample size

N = Population size

e = Margin of error

In this formula, the population size of Grade 7 contractors in Malaysia is 8,859. In addition, the margin of error allows errors with small samples, which may be between 1% and 10%, depending on the researcher's preference (Sevilla, 1992). However, this study requires a 95% confidence level of data. Hence margin of error is 0.05. After applying the population size and margin of error, the sampling size of this study was calculated according to the equation to be 383 respondents. Therefore, 800 questionnaires were distributed to local Grade 7 contractors in the Malaysian construction industry, and more than 383 valid questionnaires should be received. Table 3.3 showed that 800 questionnaires are distributed to each state and territory in Malaysia in proportion to the number of G7 contractors in each region.

Table 3.3: Number of Questionnaires Distributed in All States and Territory of Malaysia

Region	**No. of G7 Contractor**	**No. of Distribution**
Johor	696	63
Kedah	242	22
Kelantan	148	13
Malacca	178	16
Negeri Sembilan	206	19
Pahang	175	16
Penang	558	50
Perak	260	23
Perlis	34	3
Sabah	614	55
Sarawak	764	69
Selangor	3061	277
Terengganu	230	21
Kuala Lumpur	1653	149
Labuan	12	1
Putrajaya	28	3
Total	8859	800

3.7 Data Analysis

Data analysis is defined as collecting data from respondents to yield correct research results. Reliability analysis, descriptive analysis, normality test, correlation analysis and regression analysis were conducted on data obtained from questionnaire surveys to produce reliable findings and results. As mentioned earlier, the statistical package for the social sciences (SPSS) will be used with different tests so that researchers can perform various statistical analyses on the data collected.

3.7.1 Reliability Analysis

Reliability analysis refers to measuring the consistency of data and determining the dependability of results. Cronbach's alpha test is used to measure the closeness of the collected data (Tavakol and Dennick, 2011). This is used to test the validity of data collected from target respondents and measure the internal consistency of research data in questionnaires. Internal consistency can be described as whether all data are measured under the same structure or concept. According to the rule of thumb for the reliability test shown in Table 3.4, when the alpha value (α) is greater than 0.70, it illustrates that the variables are highly correlated in the research (Tavakol and Dennick, 2011).

Table 3.4: Rule of Thumb for Reliability Test

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

(Source: Tavakol and Dennick, 2011)

3.7.2 Descriptive analysis

The descriptive analysis allows for the decomposition of the collected data into smaller chunks of usable information which can be used to understand

and characterise the data obtained (Scheff, 2016). Descriptive statistics are divided into three main categories, position statistics (including mean, mode, median, and quartiles), dispersion statistics (including variance, standard deviation, range, interquartile range), and shape statistics (including skewness and kurtosis). In this study, the ranking of each questionnaire statement is calculated by mean ranking in descending or ascending order. The mean ranking shows how much respondents approve of the statement, which helps the researcher to analyse the differences between each statement (Scheff, 2016). For example, it can show the most significant and minor benefits or barriers to adopting emerging technologies.

3.7.3 Normality Test

The normality test determines whether the sample used, and the data obtained are normally or non-normally distributed (Gravetter and Wallnau, 2014). Normally distributed research data is vital in ensuring the validity of the findings. Besides, the normality of the obtained data needs to be tested before conducting parametric analysis as only normally distributed data can be used for parametric analysis (e.g., Pearson correlation analysis or multiple linear regression analysis). Furthermore, statistical normality tests is carried out in this study through Skewness and Kurtosis. Where skewness explains how uniform the data distribution is, and kurtosis determines how peaked or flat the data distribution is. Gravetter and Wallnau (2014) stated that skewness and kurtosis are in the range of -1.96 and +1.96 to be accepted as normal distributions.

3.7.4 Correlation Analysis

Correlation analysis is a statistical method used to measure the strength and direction of the correlation between two variables. There are four types of correlation analysis: Pearson correlation, Kendall rank correlation, Spearman correlation, and the Point-Biserial correlation in statistics. Pearson correlation analysis is the standard method to investigate the correlation between variables. According to Schober, Boer and Schwarte (2018), Pearson correlation analysis examines the correlation between two sets of continuous variables. The correlation coefficient (R) value is used to measure the strength and direction of the linear relationship between the independent and dependent variables, as described in Table 3.5. If the value of the correlation coefficient is higher, it indicates a stronger association between the two variables. In addition, the coefficient ranges from -1 to 1, with a correlation value of -1 representing a perfectly negative correlation and +1 representing a perfectly positive correlation. If the correlation coefficient is zero, the correlation between the variables is invalid. The positive and negative signs of correlation only indicate the direction of the relationship, which is independent of the strength of the correlation.

Table 3.5: Classification of Correlation Strength

Size of correlation (R)	Interpretation
0.9 to 1.0 (-1.9 to -1.0)	Very high positive (negative) correlation
0.7 to 0.9 (-0.7 to -0.9)	High positive (negative) correlation
0.5 to 0.7 (-0.5 to 0.7)	Moderate positive (negative) correlation
0.3 to 0.5 (-0.3 to 0.5)	Low positive (negative) correlation
0.0 to 0.4 (0.0 to-0.3)	Negligible correlation

(Source: Schober, Boer and Schwarte, 2018)

3.7.5 Regression Analysis

Regression analysis is used when analysing multiple variables, where the relationship consists of a dependent variable and one or more independent variables (Freund, Wilson and Sa, 2006). Simple linear regression analysis will be used when there is only one independent variable, while multiple linear regression analysis will be used when there are two or more independent variables involved. Dependent variables represent the main factors that are sought to be studied, while independent variables are the factors that impact the dependent variable. Simply put, regression analysis tests the causal relationship between a dependent variable and one or more independent variables. In the linear regression analysis, R-squared (R^2) value is measured to explain the consistency of the regression model to the collected data (Freund, Wilson and Sa, 2006). R^2 is always between 0 and 1. If the R^2 value of the regression model is immense, the regression model is more suitable for this study. Moreover, when the p-value of the regression model is less than 0.05, the study's independent variable significantly affects the dependent variable. In addition, the Beta value of the regression model allows for an analysis of the degree of influence of the independent variable on the dependent variable. For example, the higher the Beta value of the independent variable, the greater the influence on the dependent variable (Draper and Smith, 1998).

3.8 Summary of Chapter

This chapter defined the research method as the quantitative research method. In addition, the data needed for the study were mainly obtained through a questionnaire survey. Moreover, the sampling method used the simple random sampling method to select the target respondents. Finally, this section also determined techniques or tests for data analysis, including Cronbach's alpha test, mean ranking, skewness and kurtosis, Pearson correlation test and multiple linear regression analysis.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the data gathered from the questionnaire surveys were analysed using the statistical analysis techniques covered in the preceding chapter. These techniques included the reliability test, descriptive analysis, normality test, Pearson correlation coefficient analysis, and multiple regression analysis. In addition, the tool of SPSS Statistics 28 was used to collate, analyse and tabulate the data collected and compared these findings with the reviewed literature to clarify further the aim, objectives and hypotheses presented in Chapter 1.

4.2 Pre-test

The pre-test is required prior to the actual survey for the study. This ensures that the researcher's questions are well-articulated and that the target respondents correctly and consistently grasp the questions on the questionnaire (Draisma and Dijkstra, 2014). Thus, 12 pre-test questionnaires were distributed to professionals of the target Grade 7 contractors by random distribution and all 12 questionnaires were returned, resulting in a 100% response rate. The pre-test took place from 14th June 2022 to 17th June 2022. These 12 sets of questionnaires were excluded from the formal data analysis. In addition, feedbacks from the pre-test were improved, including obscure words, non-relevant options and linguistic errors, ensuring that the subsequent formal survey reduces confusion among the target respondents to the questionnaire while ensuring data quality and response rates.

4.3 Response Rate

In this study, the questionnaire was mainly collected from Malaysian Grade 7 contractors using an e-survey, distributed through LinkedIn, Facebook, WhatsApp and email. A total of 800 questionnaires were distributed, and 392 were received, resulting in a response rate of 49.00%. The questionnaire collection process took approximately four weeks, from 20th June to 10th

July 2022. Table 4.1 summarised the response rate of each region in this questionnaire survey. Moreover, Table 4.1 showed that most of the questionnaires collected were mainly from Grade 7 contractors in Selangor, Kuala Lumpur and Penang, with 152, 87 and 31 questionnaires, respectively.

Table 4.1: Response Rate

Region of Distribution	**Questionnaire**		**Response rate**
	Distributed	**Collected**	**(%)**
Johor	63	28	44.44
Kedah	22	7	31.82
Kelantan	13	4	30.77
Malacca	16	8	50.00
Negeri Sembilan	19	10	52.63
Pahang	16	5	31.25
Penang	50	31	62.00
Perak	23	9	39.13
Perlis	3	1	33.33
Sabah	55	16	29.09
Sarawak	69	26	37.68
Selangor	277	152	54.87
Terengganu	21	7	33.33
Kuala Lumpur	149	87	58.39
Labuan	1	0	0.00
Putrajaya	3	1	33.33
Total	800	392	49

4.4 Respondents’ Background

Table 4.2 summarised the frequencies and percentages of respondents in different parameters of demographic profile, focusing on the construction site's location, job title, working experience, academic qualification and characteristics of the project involved. The survey results showed that Selangor (33.7%), Kuala Lumpur (15.6%) and Penang were the major construction sites participated by the respondents, and the characteristics of these projects were mainly residential development (44.6%), mixed-use development (22.9%) and commercial development (11.5%). Therefore, the results contributed by this study were applied to residential, mixed-use and commercial developments in these three regions to promote the development of emerging technologies in safety and health management in the Malaysian construction industry. Furthermore, by analysing the nature of occupation and working experience, the positions held by the respondents in the Grade 7 contractor's organisations were mainly structural engineer (21.5%), quantity surveyor (17.6%) and architect (12.7%). In terms of working experience in the construction industry, 255 of the respondents (62.2%) had more than six years of experience, of which 151 (36.8%) had more than ten years of experience, so these respondents can be considered experts with sufficient experience in the construction industry to be trusted as a source for the data collected in this survey. In addition, more than half of the respondents (61.7%) had a bachelor's degree or higher academic level, which can provide a broader perspective for this study. These respondents were asked to assess the Malaysian construction industry's willingness to use emerging technologies and the associated benefits and barriers in this questionnaire based on their general experience and understanding of the industry.

Table 4.2: Demographic Profile of Respondents

Parameter	**Description**	**Frequency(n)**	**Percentage (%)**
Location of the current construction site	Johor	36	8.8
	Kedah	5	1.2
	Kelantan	3	0.7
	Malacca	17	4.1
	Negeri Sembilan	23	5.6
	Pahang	11	2.7
	Penang	37	9.0
	Perak	7	1.7
	Perlis	1	0.2
	Sabah	16	3.9
	Sarawak	26	6.3

Table 4.2 (Continued)

Parameter	Description	Frequency(n)	Percentage (%)
	Selangor	138	33.7
	Terengganu	5	1.2
	Kuala Lumpur	64	15.6
	Labuan	0	0.0
	Putrajaya	3	0.7
Job title	Company Director	3	0.7
	Project Manager	12	2.9
	Contract Manager	23	5.6
	Architect	52	12.7
	Structural Engineer	88	21.5
	M&E Engineer	48	11.7
	Quantity Surveyor	72	17.6
	Site Supervisor	32	7.8
	Safety Manager	15	3.7
	Safety Executive	24	5.9
	Clerk of Works	23	5.6
Working experience	5 years or less	137	33.4
	6–10 years	104	25.4
	11–15 years	76	18.5
	16–20 years	43	10.5
	More than 20 years	32	7.8
Highest academic Qualification	Primary School	7	1.7
	Secondary School	26	6.3
	Diploma	106	25.9
	Bachelor’s Degree	228	55.6
	Master’s Degree	25	6.1

Table 4.2 (Continued)

Parameter	Description	Frequency(n)	Percentage (%)
Characteristic of project involved	Residential	183	44.6
	Commercial	47	11.5
	Mixed-use	94	22.9
	Industrial	42	10.2
	Institutional	5	1.2
	Infrastructure	21	5.1

4.5 Reliability Test

In order to test the reliability of the data collected in this study, Cronbach's Alpha was used to measure the reliability of the data. According to Table 4.3, the Cronbach's Alpha values for adoption benefits of emerging technologies, adoption barriers of emerging technologies and willingness to use emerging technologies were 0.823, 0.875 and 0.860 respectively. The Cronbach's Alpha values for these four dimensions were all greater than 0.8, and data above 0.80 were considered good (Tavakol and Dennick, 2011). This indicated the high reliability and good internal consistency of the data collected in this study.

Table 4.3: Cronbach's Alpha Values of Reliability Test

Category	Cronbach's Alpha	Number of Items
Adoption benefits of emerging technologies	0.823	7
Adoption barriers of emerging technologies	0.873	12
Willingness to use emerging technologies	0.860	12

4.6 Descriptive Analysis

In this descriptive analysis, the adoption benefits, adoption barriers and willingness to use emerging technologies were ranked in terms of mean and standard deviation based on opinions of the Malaysian Grade 7 main contractor.

4.6.1 Adoption Benefits of Emerging Technologies for Safety and Health Management

The means of the adoption benefits of emerging technologies shown in Table 4.4 were ranked in descending order. According to Section 3.5.1, the 5-point Likert scale used for section B of the questionnaire (adoption benefits of emerging technologies for safety and health management) ranged from 1 (= strongly disagree) to 5 (=strongly agree). Therefore, if the means tend to be 5, the respondents agree more with the related adoption benefits of emerging technology.

Table 4.4: Mean Ranking of Adoption Benefits of Emerging Technologies for Safety and Health Management

Ref	Adoption Benefits	Mean	SD	Rank
T1	Enhance Hazard Identification	3.94	0.854	1
T2	Improve Safety Planning	3.87	0.862	2
T3	Intensify Safety Inspection	3.81	0.933	3
T7	Reinforce Accident Warning	3.73	0.861	4
T6	Boost Safety Awareness	3.70	0.838	5
T4	Strengthen Safety Monitoring	3.67	0.865	6
T5	Improve Safety Training	3.64	0.844	7

Enhance Hazard Identification was at the highest level, and therefore it could be considered the most potentially motivating factor for implementing emerging technologies in safety and health management. As hazard identification is the foundation of safety and health management, it is necessary for the design team to identify all potential hazards during the pre-design phase of a project and take preventive measures for each hazard (Newaz, et al., 2022). Adopting emerging technologies help the construction industry address the inefficiencies of traditional hazard identification methods, such as regular construction teams meeting regularly to prepare prevention strategies for potential hazards. However, this approach cannot grasp the situation on the site and does not reflect the potential danger of the construction site (Choe and Leite, 2017). In addition, the Malaysian construction industry still uses 2D drawings as the primary means of design and communication, which limits the ability of design and construction teams to effectively identify potential hazards on a project (Zhang, et al., 2015). If the construction industry in Malaysia were to adopt emerging technologies, this would significantly reduce the potential for accidents to occur to construction workers. Because the capabilities of emerging technologies allow construction teams to identify hazards on site in advance, construction teams can prepare preventive strategies to eliminate the presence of hazards. The best example of enhanced hazard identification is the use of BIM or sensing technologies on construction projects, which can collect data and analyse potential hazards on the construction project site so that they can provide immediate and automated feedback to the design team on undetected hazards (Guo, et al., 2021).

Improve Safety Planning rated second in the adoption benefits of emerging technologies. Since pre-project safety planning was implemented throughout the project life cycle, thus, effective safety planning is a crucial step (Chen, et al., 2021). The complexity of current projects and labour-intensive work patterns on construction sites (e.g., high-rise construction) make traditional safety planning approaches unable to consider potential hazards on construction sites in advance (Kim, Cho and Zhang, 2016). Furthermore, traditional safety planning relies heavily on the design team's ability to recognise safety hazards and the organisation's prescribed safety processes, which cannot meet the safety needs and changes of current projects (Zhang, et al., 2015). Emerging technologies present new opportunities for design teams to enhance safety planning, such as using BIM and sensing technology to predict the trajectory of workers and heavy equipment on-site, thereby avoiding collisions (Zhang, Cao and Zhao, 2017). Thus, adopting emerging technologies can help construction teams conduct accurate risk assessments for each construction task, which helps design teams develop effective safety measures to reduce the rate of injury and death of workers on site.

Intensify Safety Inspection was ranked third. Zailani, Abdullahi and Auwal (2021) stated that safety inspection is one of the core components of safety and health management, even though hazard identification and safety planning eliminate or reduce the occurrence of most safety issues. However, due to frequent changes on site, construction teams still need to promptly identify and correct safety hazards through regular safety inspections to prevent accidents on site. The use of new technologies can solve the problems of traditional safety inspection methods, such as the inability to ensure the safety of safety personnel themselves, especially in dangerous construction areas (Yap, Lee and Wang, 2021). Besides, emerging technologies can improve the efficiency and effectiveness of safety inspection assessments, for example, by using technology to inspect more quickly than humans, storing the information collected in the cloud, and cross analysing that information with databases to provide real-time feedback to safety enforcers to implement preventive measures. Ashour et al. (2016) believe that UAVs can simplify the traditional safety inspection process and replace the safety executive to enter dangerous areas for dangerous inspection. Therefore, emerging technologies provide an efficient way to observe construction sites.

Improve Safety Training ranked last among all the adoption benefits, although adopting emerging technologies to provide regular safety training for construction workers positively reduces accidents (Bavafa, Mahdiyar and Marsono, 2018). For example, by using virtual reality technology to generate virtual scenarios that resemble the construction environment and allowing construction workers to conduct safety training within the virtual world, this not only provides an immersive experience for the user but there are no physical hazards within the virtual world (Hou, et al., 2020). Safety training enables construction workers to be trained to react to and prevent hazards, thus reducing the risks involved in implementation. However, the benefits of emerging technologies for safety training are uncertain, primarily because of the unfriendly interactive experience of emerging technologies, such as unrealistic immersion or difficulty in manipulating the technology. Therefore, construction operators refused to use relevant emerging technologies to improve safety training (Zhang, et al., 2022).

4.6.2 Adoption Barriers of Emerging Technologies for Safety and Health Management

The means of the adoption barriers of emerging technologies shown in Table 4.5 were ranked in ascending order. The 5-point Likert Scale used in section C (adoption barriers of emerging technologies for safety and health management) of the questionnaire is from 5 (= Strongly Disagree) to 1 (= Strongly agree). If the mean value tends to be 1, it means that the respondents agree with the related barriers to adopting emerging technology.

Table 4.5: Mean Ranking of Adoption Barriers of Emerging Technologies for Safety and Health Management

Ref	Adoption Barriers	Mean	SD	Rank
R7	Extra Costs	2.12	0.918	1
R9	Additional Training	2.19	0.873	2
R8	Lack of Top Management Support	2.20	0.871	3
R2	Ineffectiveness of technology	2.21	0.872	4
R10	Lack of Occupational Safety and Health Regulations	2.24	0.850	5
R3	Inadaptability of Technology	2.29	0.902	6
R4	No assurance of Data Privacy	2.33	0.859	7
R11	Lack of Government Incentives and Promotion	2.34	1.015	8
R6	Closed Organizational Culture	2.34	0.944	9
R1	Time needed for learning and adoption	2.38	0.935	10
R12	Lack of Competitive Pressure	2.44	0.958	11
R5	Small Organizational Size	2.51	1.014	12

The most significant adoption barrier of emerging technologies was the Additional Cost, a finding consistent with much of the literature. According to Yap, et al. (2022), any emerging technology that improves safety performance requires a significant budget, but most clients and contractors do not have a dedicated budget for innovation. The cost not only involves the initial investment in software and hardware components necessary to purchase the new technology, but there are also actual costs associated with the day-to-day operation of the new technology, such as operational costs, maintenance costs and training costs to ensure that the functionality of the new technology is maximised (Khudzari, Rahman and Ayer, 2021). The Malaysian construction industry tempts to shun the adoption of new technologies once the high cost is involved. This limits the ability of contractors to introduce emerging technologies for construction projects because of the low-profit margins in the construction industry compared to other industries (Yap, et al., 2022).

Additional Training was the second most significant barrier to emerging technologies. If safety practitioners lack experience and familiarity with emerging technologies, this will affect the practical value of the technology (Yap, et al., 2022). Therefore, additional training is necessary to provide staff with the technology to fully grasp its features (Khudzari, Rahman and Ayer, 2021). Moreover, as the technology is upgraded with hardware and software, additional training may need to be provided, which requires ongoing money and time. In addition, older safety practitioners or construction workers require more training time to master the use of emerging technologies than younger workers (Zakari, et al., 2014). Therefore, this exacerbates the costs involved in training, and emerging technologies are likely limited in their use on construction sites.

Lack of Top Management Support was ranked third, as top management has the power to make various decisions such as funding allocation or safety training courses, so if the construction team does not have top management support, the promotion of emerging technologies in safety and health management will be hindered (Nnaji and Karakhan, 2020). In particular, top management in the Malaysian construction industry only cares about project profitability and completion time and is very unaware of safety (Yap, et al., 2022). Furthermore, most top management believes that using new technologies is not economically beneficial because the payoffs of using new technologies are not proportional to the rewards (Nnaji, 2020). Therefore, most of the management has an unintentional attitude towards adopting innovative solutions to improve safety hazards on the site.

Small Organisation Size was last placed in terms of emerging technology adoption barriers. Although in general, the larger the construction organisation, the more inclined it is to adopt new technologies as larger construction organisations have more resources, such as capital or workforce, to invest in emerging technologies to change traditional safety and health management practices (Rui, Khai and Alzoubi, 2022). However, with the emergence of certain new technologies with low investment costs, small and medium-sized construction companies have the opportunity and budget to introduce new technologies for improving safety and health management, such as UAV or digital signage (Zhang, et al., 2022).

4.6.3 Willingness to Use Emerging Technologies for Safety and Health Management

The means of the willingness to use emerging technologies shown in Table 4.6 were ranked in descending order. The 5-point Likert scale used in section D (willingness to use emerging technologies for safety and health management) of the questionnaire is from 1 (= strongly disagree) to 5 (=strongly agree). Therefore, if the mean is closer to 5, respondents are more willing to use the relevant emerging technology.

Table 4.6: Mean Ranking of Willingness to Use Emerging Technologies for Safety and Health Management

Ref	Type of Emerging Technologies	Mean	SD	Rank
W1	Building Information Model	4.04	0.806	1
W2	Wearable Safety Technology	4.01	0.863	2
W3	Unmanned Aerial Vehicle	3.91	0.809	3
W6	Sensing Technology	3.81	0.827	4
W7	Camera Network Systems	3.79	0.813	5
W10	3D Laser Scanning	3.78	0.835	6
W8	Robotics and Automation	3.72	0.866	7
W9	Digital Signage	3.71	0.851	8

Table 4.6 (Continued)

Ref	Type of Emerging Technologies	Mean	SD	Rank
W12	Artificial Intelligence	3.70	0.918	9
W5	Augmented Reality	3.68	0.956	10
W11	Exoskeleton	3.68	0.940	11
W4	Virtual Reality	3.64	0.851	12

Grade 7 contractors were most willing to use the emerging technology of Building Information Modelling (BIM). Afzal, Shafiq and Al Jassmi (2021) described the rapid rise in the use of BIM in safety and health management. This is due to BIM's visualisation, modularity and data integration capabilities that allow teams to enhance their hazard identification and safety planning capabilities, making BIM the most used emerging technology. Currently, BIM is mainly used in the planning and design stage, allowing projects to identify potential hazards on site through 3D models (Azmy and Zain, 2016). Besides, BIM is also integrated with numerous relevant safety databases, such as intelligent risk assessment systems and safety design knowledge bases, so that it can more accurately predict each risk on the site, which can finally assist the design team in preparing safety precautions in detail (Hossain, et al., 2018).

The second highest ranking in terms of willingness to use emerging technologies was Wearable Safety Technology. It embeds various small electronic sensors into personal protective equipment (PPE) such as bracelets, helmets, work boots or glasses, thus enabling real-time health monitoring and location tracking for construction workers in hazardous construction areas (Borhani, et al., 2018). In addition, wearable safety technology alerts workers to potential safety hazards in their surroundings to avoid accidents due to falls, entrapment and electrocution (Yap, Lee and Wang, 2021). Moreover, Yap, Lee and Wang (2021) found that wearable safety technology is less expensive to maintain, more durable and more portable than other emerging technologies, thus providing substantial safety benefits.

Unmanned Aerial Vehicle ranked third in terms of willingness to use emerging technologies. According to Borhani (2016), UAVs are mainly used for safety inspections and supervision of construction projects, which alleviates the time and workforce required to perform safety inspections and supervision. As the UAV can be operated remotely from the ground, it can replace safety enforcers to access dangerous construction areas in a short period, which eliminates the exposure of safety enforcers to safety hazards, such as performing dangerous structural inspections (De Melo, et al., 2017). In addition, UAVs can inspect and monitor safety conditions on construction sites from various perspectives so that safety enforcers can provide a more comprehensive treatment strategy based on the photographs and videos taken by the UAVs.

Virtual Reality was the most reluctant to use emerging technology, which allows safety enforcers to visualise the entire construction site through a virtual environment to look for potential safety threats (Chen, et al., 2021). Furthermore, VR allows construction workers to rehearse hazardous activities and explore the construction environment in a virtual world to identify potential collisions and hazards and prepare for unchangeable risks (Zhao and Lucas, 2015). Although VR has proven its capability for safety planning and safety training on construction projects, it is still immature in practice and remains mostly in ideal theory. Therefore, VR is not guaranteed to achieve the desired safety purpose (Zhang, et al., 2022). In addition, to experience virtual reality, users must be equipped with virtual reality headsets, so organisations must spend more money on hardware and software (Chen, et al., 2021). However, most organisations refuse to spend on emerging technologies with uncertain safety benefits to avoid wasting invested resources.

4.7 Normality Test

This section tested the statistical normality of the collected data using Skewness and Kurtosis, ensuring that the collected data's distribution is normal. Therefore, the data can be used to perform parametric tests, including Pearson correlation analysis and multiple regression analysis. Besides, Gravetter and Wallnau (2014) stated that skewness and kurtosis between -1.96 and +1.96 were acceptable values, indicating that the data were univariate normally distributed. The analysis in Table 4.7 below revealed that each variable's skewness and kurtosis values are within the acceptable range between -1.96 and +1.96. Thus, all data are normally distributed so that the data can be applied in the following parameter analysis. In addition, Figures Figure 4.1 to Figure 4.3 showed each variable's histograms, a visual method to observe the normal distribution of the data collected in this study.

Table 4.7: Skewness and Kurtosis Results of Normality Test

Variable		Skewness		Kurtosis	
		Statistic	**Std. Error**	**Statistic**	**Std. Error**
Independent Variables	Adoption benefits of emerging technologies	-0.572	0.123	0.989	0.246
	Adoption barriers of emerging technologies	0.452	0.123	0.240	0.246
Dependent Variables	Willingness to use emerging technologies	-0.683	0.123	1.543	0.246

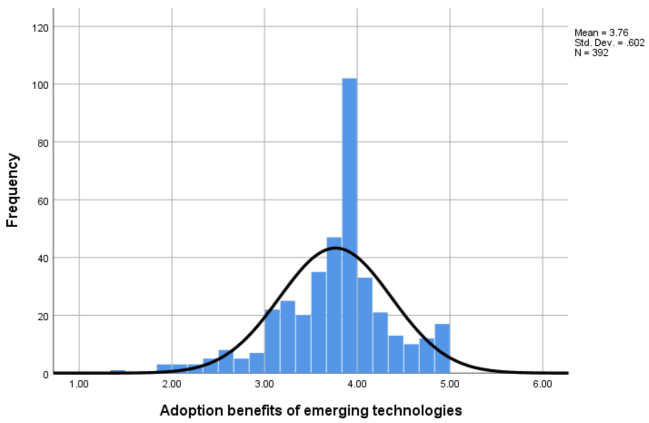

Figure 4.1: Histogram of Adoption Benefits of Emerging Technologies

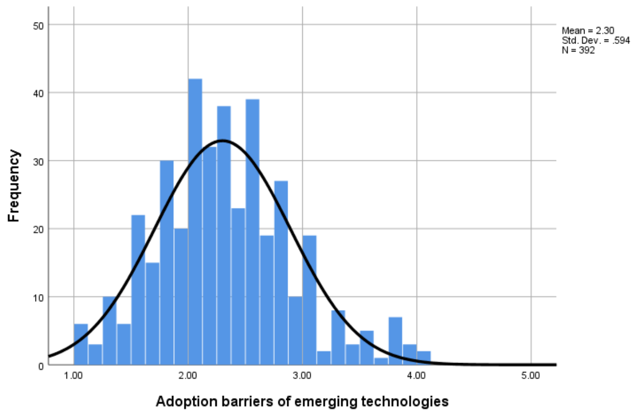

Figure 4.2: Histogram of Adoption Barriers of Emerging Technologies

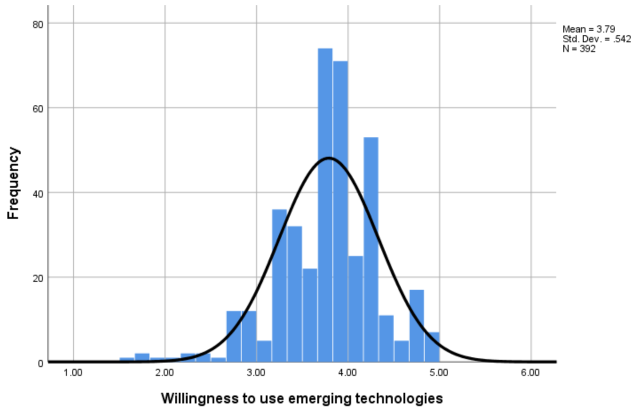

Figure 4.3: Histogram of Willingness to Use Emerging Technologies

4.8 Correlation Analysis

This study used Pearson correlation analysis to measure the relationship between the dependent and independent variables, including the adoption benefits and willingness to use emerging technologies, and the adoption barriers and willingness to use emerging technologies. The correlation between variables can be analysed by correlation strength and direction. The correlation coefficient determines the correlation's strength, which determines how close the variables are to each other, such as the higher the R-value of the Pearson correlation coefficient, the higher the strength of the association (Schober, Boer and Schwarte, 2018). Whereas the direction can be divided into positive (0 to 1) and negative (-1 to 0), the positive direction represents that the values of the two variables are increasing simultaneously. In contrast, the negative direction represents that when one variable's value increases, the other variable's value decreases (Schober, Boer and Schwarte, 2018).

Firstly, two-tailed (**) in the upper right-hand corner of all correlation coefficients were identified through Table 4.8, which represented a p-value of less than 0.01. If the p-value is 0.05 or less, the correlation coefficient is statistically significant; therefore, the likelihood of the results being wrong is extremely low (Schober, Boer and Schwarte, 2018). This further certified a significant relationship between the adoption benefits and willingness to use emerging technologies and between the adoption barriers and willingness to use emerging technologies.

Next, Pearson correlation analysis tested the strength and direction of the correlation between the dependent and independent variables. According to the Pearson correlation value (R) shown in Table 4.8, the correlation coefficient between adoption benefits and willingness to use emerging technologies was 0.729, while the correlation coefficient between adoption barriers and willingness to use emerging technologies was -0.502. Based on Schober, Boer and Schwarte (2018), the correlation coefficient between 0.7 and 0.9 is a highly positive correlation, while the correlation coefficient between -0.5 and -0.7 is a moderately negative correlation. Therefore, adoption benefits and willingness to use emerging technologies were a highly positive correlation, which implied that an increase in adoption benefits will increase the willingness of Grade 7 contractors to adopt emerging technologies, and the strength of the correlation was high. On the other hand, adoption barriers were in a moderately negative correlation with the willingness to use emerging technologies, meaning that an increase in adoption barriers decreases the willingness of G7 contractors to use emerging technologies. However, the strength of the correlation was moderate.

Finally, although there was a correlation between dependent and independent variables, this does not equate to the existence of causality between them, such as one variable affecting the other (Ksir and Hart, 2016). For example, a higher adoption benefit of emerging technologies is accompanied by an increase in the willingness of G7 contractors to use them, but this does not mean that the increase in the adoption benefit leads to an increase in the willingness to use emerging technologies, as this is also influenced by other factors, of which the adoption benefit is only one. Therefore, Section 4.9 used multiple linear regression analysis to verify the causal relationship between variables.

Table 4.8: Pearson Correlation Analysis on the Relationship between Adoption Benefits and Willingness to Use Emerging Technologies and Adoption Barriers and Willingness to Use Emerging Technologies

	Adoption Benefits of Emerging Technologies	**Adoption Barriers of Emerging Technologies**	**Willingness to Use Emerging Technologies**
Adoption Benefits of Emerging Technologies	1		
Adoption Barriers of Emerging Technologies	-0.528**	1	
Willingness to Use Emerging Technologies	0.729**	-0.502**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Additionally, Figure 4.4 and Figure 4.5 showed scatter plots of the linear relationships between the dependent and independent variables. Scatter plots can provide a quick check of correlation between variables. When the points are close to the line, this indicates a strong relationship between the variables. As the slope of the scatters plot in Figure 4.4 was positive, adoption benefits and willingness to use emerging technologies is a positive correlation. In contrast, the slope of the scatter plot in Figure 4.5 was negative, and adoption barriers and willingness to use emerging technologies is a negative correlation.

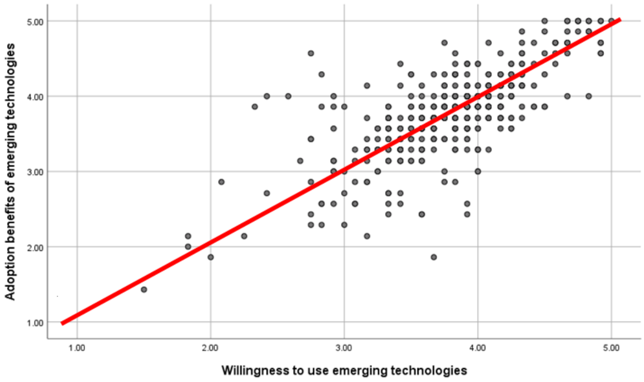

Figure 4.4: Scatter Plot Graph of Linear Relationship between Adoption Benefits and Willingness to Use Emerging Technologies

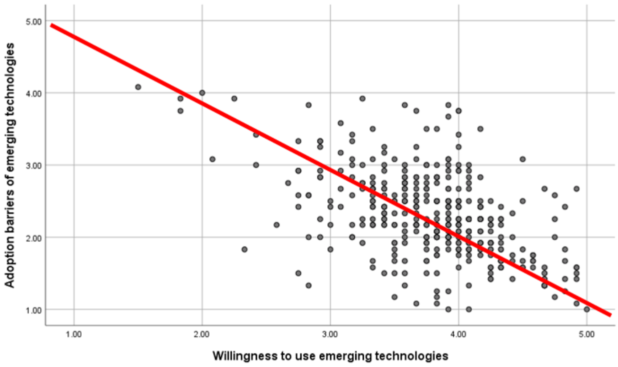

Figure 4.5: Scatter Plot Graph of Linear Relationship between Adoption Barriers and Willingness to Use Emerging Technologies

4.9 Regression Analysis

In this section, the influence of the two independent variables and a dependent variable were investigated through the application of multiple linear regression analysis, and their impact direction and strength. This enhanced the results of correlation analysis, as correlation analysis only presents the correlation between variables, whereas regression analysis predicts the causal relationship between variables.

Firstly, multiple linear regression analysis evaluated the goodness of fit of a regression model, which is usually measured using R^2 or adjusted R^2, with adjusted R^2 being more appropriate for regression models with multiple independent variables (Freund, Wilson and Sa, 2006). As only two independent variables exist in this study, R^2 was used to assess the regression model. The closer the R^2 is to 1, the better the model is, but there is no fixed criterion in the actual study (Freund, Wilson and Sa, 2006). Table 4.9 displayed that R^2 is 0.551, so the regression model fits reasonably well as R^2 is greater than 5, while this represented that the regression model is suitable for the investigation of this study. Furthermore, R^2 was used to show that 55% of the variance in the dependent variable (willingness to use emerging technologies) can be explained by the independent variables (adoption benefits and adoption barriers). Furthermore, the R-value reflected the degree of linear correlation between all the independent variables and the dependent variable, as shown in Table 4.9, with an R-value of 0.742, which indicated a high degree of correlation between all the independent variables and the dependent variable in the regression model.

Table 4.9: Model Summary of Regression Analysis

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.742a	0.551	0.549	0.36398

a. Predictors: (Constant), Adoption benefits of emerging technologies, Adoption barriers of emerging technologies

Secondly, Table 4.10 revealed the results of the Analysis of Variance (ANOVA) where the p-value was 0.000, less than 0.05. Therefore, this multiple linear regression model was statistically significant and of use. Furthermore, the individual variables included in the regression model are considered to have a significant effect (Freund, Wilson and Sa, 2006).

Table 4.10: Analysis of Variance (ANOVA)

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	63.263	2	31.632	238.763	.000b
	Residual	51.535	389	0.132		
	Total	114.799	391			

a. Dependent Variable: Willingness to use emerging technologies

b. Predictors: (Constant), Adoption benefits of emerging technologies, Adoption barriers of emerging technologies

Thirdly, Table 4.11 showed a p-value of 0.000 for the adoption benefits and barriers of emerging technologies. Since the p-value was less than 0.05, this indicated that the two independent variables in this study significantly affect the dependent variable (Freund, Wilson and Sa, 2006). Furthermore, since the Beta value for adoption benefits was greater than zero, this implied that adoption benefits positively affected the willingness to use emerging technologies. Whereas the Beta value of adoption barriers was less than zero, adoption barriers negatively affected the willingness to use emerging technologies. This satisfied and verified the hypotheses of this study.

Fourthly, the degree of influence of the independent variable on the dependent variable can be analysed in conjunction with the B-value of the regression analysis (Draper and Smith, 1998). Table 4.11 showed that the B-value for adoption benefits was 0.579, which indicated that for every 1 unit increase in adoption benefits, the willingness to use emerging technologies also increases by 0.579 units, holding other factors constant. Alternatively, the B-value for adoption barriers was -0.148, representing that for every unit increase in barriers to adoption, and the willingness to use emerging technologies would decrease by 0.148 units, holding all other factors constant.

Finally, suppose one wants to compare the influence of the independent variables (adoption benefits and adoption barriers) on the dependent variable (willingness to use emerging technologies). In that case, this can be done by comparing the magnitude of the Beta values (Freund, Wilson and Sa, 2006). According to the results in Table 4.11, the absolute value of Beta for adoption benefits was 0.644, which was greater than the absolute value of Beta for adoption barriers (0.162), indicating that the influence of adoption benefits on the willingness to use emerging technologies than adoption barriers. This further indicated that the Malaysian construction industry has the potential to implement emerging technologies in safety and health management, as G7 contractors perceive the benefits of emerging technologies to be more influential than the barriers to adoption. However, the barriers to adopting emerging technologies still cannot be ignored, especially the extra costs, additional training and lack of top management support as it affects the implementation of emerging technologies in safety and health management by some G7 contractors. Therefore, the private sector and government departments must provide more resources to remove most of the barriers to adoption and promote the benefits of using emerging technologies to increase the implementation of emerging technologies in safety and health management to reduce the casualty rate in the Malaysian construction industry.

Table 4.11: Results of Multiple Regression Analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.949	0.194		10.028	0.000
	Adoption benefits of emerging technologies	0.579	0.036	0.644	16.088	0.000
	Adoption barriers of emerging technologies	-0.148	0.037	-0.162	-4.055	0.000

a. Dependent Variable: Willingness to use emerging technologies

4.10 Summary of Chapter

These results were generated from data collected from 392 targeted respondents (professionals from G7 contractors). The overall response rate for the questionnaire was 49%. Firstly, Cronbach's alpha values obtained for this study were all above 0.80, indicating high data reliability and good internal consistency. Secondly, descriptive analysis successfully identified the top three emerging technologies for adoption benefits in safety and health management, including Enhance Hazard Identification, Improve Safety

Planning and Intensify Safety Inspection. In addition, Extra Costs, Additional Training and Lack of Top Management Support were identified as the most significant barriers to adopting emerging technologies. Moreover, the emerging technologies that Grade 7 contractors were willing to use for safety and health management were Building Information Model, Wearable Safety Technology and Unmanned Aerial Vehicle. Thirdly, Normality results showed that all Skewness and Kurtosis were within the accepted range, and therefore all data were normally distributed. Fourthly, the Pearson correlation analysis results demonstrated a significant correlation between the independent variables (adoption benefits and barriers of emerging technologies) and the dependent variable (willingness to use emerging technologies) for this study. Finally, multiple linear regression analysis further established a causal relationship between the two independent variables and the dependent variable.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This final chapter summarised the findings based on the aims, objectives and hypotheses established earlier in the study. In addition, the implications of the study for the construction industry and body of knowledge were discussed in this chapter. Moreover, this chapter analysed the limitations of the study and suggested related recommendations.

5.2 Accomplishment on Research Objectives

By comparing the results of the descriptive analysis with the previous literature review, this study accomplished three previously set objectives. Firstly, the study was completed to identify the adoption benefits of emerging technologies for safety and health management in the construction industry. 392 professionals from Grade 7 contractors perceived the significant benefits of using emerging technologies for safety and health management as enhancing hazard identification, improving safety planning and intensifying safety inspection. Eliminating hazards before they occur is the best way to deal with them, and using emerging technologies meets this need. It allows the construction industry to detect and eliminate accidents before they occur, which maximises the safety and health of workers on site. For example, BIM or wearable safety technology assist in identifying and monitoring individual workers from a distance, avoiding health risks caused by collisions with machinery or prolonged exposure to heat on-site. Furthermore, emerging technologies could also replace site workers in hazardous tasks, such as UAVs for inspection work at height. Besides, emerging technologies can assist safety officers in locating all employees more quickly in emergencies (e.g., fire or collapse) to reduce the risk to site workers.

Secondly, this study reached to identify adoption barriers of emerging technologies for safety and health management in the construction industry. Previous literature has classified adoption barriers of emerging technologies into three categories: technical, organisational and environmental factors. Based on the analysis results, the most significant barriers to using emerging technologies in safety and health management were extra costs, additional training and lack of top management support. Moreover, all three of these barriers were organisational factors, which meant that the most critical barriers to adopting emerging technologies come from the organisation itself. Generally speaking, using emerging technologies means more cost and time investment. In addition to the initial cost of the emerging technology and maintenance costs, it involves additional training, as inadequate training can be a burden and a significant risk for users. On top of this, most top managements are only concerned with the profitability of the projects, so top managements try to reduce expenditure costs as much as possible, and top managements have less commitment to improving safety and health on construction projects. However, top management should balance the profit with the cost of safety to achieve a win-win situation and create a sustainable and safe construction environment.

Finally, this study was achieved to identify the willingness to use emerging technologies for safety and health management in the construction industry. Based on the data collected, the emerging technologies that Grade 7 contractors were most willing to use to improve safety and health in the construction industry were building information modelling, wearable safety technology and drones. It is impossible to prevent workplace-related injuries completely. However, a wide range of emerging technologies is available for companies of all sizes to use to improve safety on construction sites. As a result, G7 contractors could use the emerging technologies that best suit their needs to improve the safe environment. For instance, BIM is the most widely used emerging technology as it offers incredible safety benefits. Hence, BIM is suitable for complex and large projects, which are often well funded and involve a large number of workers on site. Alternatively, if contractors face financial and time constraints, wearable safety technologies and UAVs are more appropriate as they have lower initial and maintenance costs and are less challenging to use, so it involves shorter periods of additional training.

5.3 Accomplishment on Research Hypotheses and Theoretical Framework

Pearson correlation analysis and multiple linear regression analysis were used to test the hypotheses and the theoretical framework of this study. The results of the Pearson correlation analysis showed a high positive correlation between the benefits of emerging technologies and willingness to use them (correlation coefficient of 0.729) and a moderate negative correlation between the adoption barriers of emerging technologies and willingness to use them(correlation coefficient of 0.502). Therefore, there was a correlation between this study's dependent and independent variables. Furthermore, the multiple linear regression analysis further completed the hypotheses. The regression model illustrated that the p-value of the dependent variable of this study (adoption benefits and adoption barriers of emerging technologies) was 0.000. Since the p-value was lower than 0.05, this could mean that the independent variable significantly influences the dependent variable. Furthermore, the regression model showed that the Beta value of the adoption benefits of emerging technologies is positive, so the adoption benefits positively affected the willingness to use emerging technologies, which satisfied hypothesis 1 in the theoretical framework. Conversely, as the Beta value for the adoption barriers of emerging technologies was negative, the adoption barriers negatively affected the use of emerging technologies, which was consistent with hypothesis 2 in the theoretical framework. As shown in Figure 5.1, since the research objectives and hypotheses have been achieved, the theoretical framework of this study has been established accordingly.

In the theoretical framework, the willingness of G7 contractors to use emerging technologies for safety and health management was driven when G7 contractors perceived more benefits to be gained by using them. For example, suppose BIM significantly enhances the ability to identify hazards on construction sites or assists safety managers in improving safety planning. In that case, this provides G7 contractors with a greater incentive to use BIM to reduce potential hazards on site. Moreover, if G7 contractors faced significantly organisational barriers, this would influence their willingness to use emerging safety and health management technologies. The reason was that the adoption barriers of emerging technologies would require G7 contractors to devote more resources and time to deal with the corresponding impediments. For instance, the extra cost or additional training associated with emerging technologies would reduce the willingness of G7 contractors to use BIM or other emerging technologies.

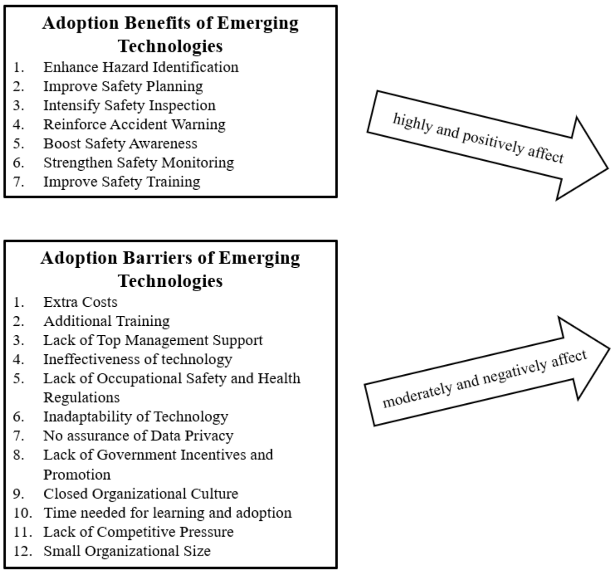

Figure 5.1: Key Findings of the Theoretical Framework

Note: The items in the box were arranged according to the data analysed.

5.4 Accomplishment on Research Aim

The multiple linear regression analysis achieved the aim of this study which is to deduce the potential and likelihood of implementing emerging technologies in the Malaysian construction industry for safety and health management purposes. The Beta values from the multiple linear regression analysis inferred that the influence of the adoption benefits of emerging technologies (Beta=0.644) was more significant than the influence of the barriers to adoption (Beta=-0.162) in terms of the willingness to use emerging technologies. Furthermore, the B-value of the regression model showed that for every 1 unit increase in the adoption benefits of emerging technologies, the willingness to use emerging technologies also increases by 0.579 units. Alternatively, for every unit increase in adoption barriers, the willingness to use emerging technologies would decrease by 0.148 units. If both dependent variables are increased by one unit simultaneously, the willingness to use emerging technologies remains positive. Therefore, it can be inferred that emerging technologies have the potential and possibility to improve safety and health management in the Malaysian construction industry.

5.5 Research Implications

The findings of this study expanded on the existing literature to raise awareness of the use of emerging technologies in safety and health management among construction practitioners. In addition, this study empirically analysed the potential for the implementation of emerging technologies in safety and health management in the construction industry. Although most construction practitioners are aware of the safety benefits that emerging technologies can bring to workers on site, adopting emerging technologies to decrease safety issues is still slow. Therefore, the findings of this study act as a catalyst to encourage government agencies and private organisations to take transformative action to remove barriers and provide resources to achieve the universalness of emerging technologies in safety and health management. Finally, this study provides other researchers with fundamental research as it provides information on the benefits, barriers and willingness to use emerging technologies for safety and health management in the construction industry, which will help researchers to get insight for future research on similar topics.

5.6 Research Limitations

This study was completed by one researcher in approximately six months, which limited the coverage of this study due to time and human resource constraints. For example, this study only covered two independent variables (benefits and barriers of using emerging technologies in safety and health management) and one dependent variable (the willingness to use emerging technologies in safety and health management). However, in terms of other theories, many other factors influence the willingness of G7 contractors to use emerging technologies. Therefore, this does not allow for a comprehensive perspective to achieve the aim of this study.

In addition, this study used a closed-ended questionnaire, which did not provide the opportunity for respondents to give their own opinions. Therefore, the data collected by the questionnaire could only explain the three variables mentioned above, which resulted in limited research findings. Besides, most of the questionnaires relied on online surveys to collect data, and the online distribution of questionnaires may have had low reliability of data results as the researcher was unable to monitor and check the survey process. Respondents may not be patient and honest in providing their opinions or may have a limited understanding of particular response options.

5.7 Research Recommendations

It is assumed that future research is constrained by time and human resources, so it is recommended that future researchers clarify and narrow the scope of the study. When the scope of the study is refined to a more specific range, this can improve the informative value of the findings—for example, narrowing down the overall scope of emerging technologies to a specific emerging technology (e.g., BIM or UAV), which also reduces the number of relevant dependent variables to be considered. Therefore, it allows researchers to complete a more comprehensive study in a shorter period and with fewer human resources.

Furthermore, as the online distribution of questionnaires may lead to inaccurate data from respondents, future researchers would be advised to try other methods to increase the reliability of the data, such as face-to-face distribution or postal questionnaires. Furthermore, closed-ended questionnaires limit the opportunity for respondents to provide their perspectives, so it is recommended that future researchers use telephone interviews or face-to-face interviews, which can gather more explanations and perspectives from respondents to provide more in-depth findings.

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APPENDICES

Appendix A: Survey Questionnaire

UNIVERSITI TUNKU ABDUL RAHMAN

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The Potential of Emerging Technologies for Safety and Health Management in the Malaysian Construction Industry

Dear Sir/Madam,

Sincere greetings and best regards to you.

I am a final year undergraduate student pursuing Bachelor of Science (Honours) Quantity Surveying in University Tunku Abdul Rahman (UTAR). I am currently conducting a study on "The Potential of Emerging Technologies for Safety and Health Management in the Malaysian Construction Industry". The target respondents for this study are Grade 7 main contractor from construction industry only.

Your participation would be deeply appreciated and contributed tremendously to this study. This questionnaire consists of four (4) sections, which will take approximately 10 minutes to complete. All the information collected through this survey will be used purely for academic purpose and will be strictly anonymous. If you have any queries about this survey, please do not hesitate to contact me at gordonlim111@1utar.my.

Thank you for your participation and time.

Yours faithfully,
Lim Kar Fai

Please tick "√" in the checkbox.

Important: This study only required Grade 7 main contractor respondents, others can leave the questionnaire. Thank you.

Section A: Respondents' Demographic Information

A1. Region of the company headquarters (*Please select one only*):

- ☐ Johor
- ☐ Kedah
- ☐ Kelantan
- ☐ Malacca
- ☐ Negeri Sembilan
- ☐ Pahang
- ☐ Penang
- ☐ Perak
- ☐ Perlis
- ☐ Sabah
- ☐ Sarawak
- ☐ Selangor
- ☐ Terengganu
- ☐ Kuala Lumpur
- ☐ Labuan
- ☐ Putrajaya

A2. Location of the current construction site (*Please select mostly involved project only*):

- ☐ Johor
- ☐ Kedah
- ☐ Kelantan
- ☐ Malacca
- ☐ Negeri Sembilan
- ☐ Pahang
- ☐ Penang
- ☐ Perak

- ☐ Perlis
- ☐ Sabah
- ☐ Sarawak
- ☐ Selangor
- ☐ Terengganu
- ☐ Kuala Lumpur
- ☐ Labuan
- ☐ Putrajaya

A3. Job title in the company (*Please select one only*):

- ☐ Company Director
- ☐ Project Manager
- ☐ Contract Manager
- ☐ Architect
- ☐ Structural Engineer
- ☐ M&E Engineer
- ☐ Quantity Surveyor
- ☐ Site Supervisor
- ☐ Safety Manager
- ☐ Safety Executive
- ☐ Clerk of Works
- ☐ Other: ____________________

A4. Working experience in the construction industry (*Please select one only*):

- ☐ 5 years or less
- ☐ 6–10 years
- ☐ 11–15 years
- ☐ 16–20 years
- ☐ More than 20 years

A5. Highest academic qualification (*Please select one only*):

- ☐ Primary School

- Secondary School
- Diploma
- Bachelor’s Degree
- Master’s Degree
- Doctorate/PhD

A6. Characteristic of the project involved *(Please select mostly involved project only*):

- Residential
- Commercial
- Mixed-use
- Industrial
- Institutional
- Infrastructure

Section B: Adoption Benefits of Emerging Technologies for Safety and Health Management

Definition of Emerging Technologies for Safety and Health Management: Emerging technologies will revolutionize safety practices in the construction industry. If emerging technologies such as wearable safety technology, unmanned aerial vehicle and virtual reality are applied to safety and health management, workplace hazards for workers will be reduced.

B1. Do you believe that using emerging technologies for safety and health will bring long-term benefits to the company?

- ☐ Extremely
- ☐ Vert
- ☐ Moderately
- ☐ Slightly
- ☐ Not at all

B2. Please indicate the level of agreement on the adoption benefits of emerging technologies for safety and health management in the construction projects below.

[1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree]

No.	Adoption Benefits of Emerging Technologies	1	2	3	4	5
T1	Enhance Hazard Identification	O	O	O	O	O
T2	Improve Safety Planning	O	O	O	O	O
T3	Intensify Safety Inspection	O	O	O	O	O
T4	Strengthen Safety Monitoring	O	O	O	O	O
T5	Improve Safety Training	O	O	O	O	O
T6	Boost Safety Awareness	O	O	O	O	O
T7	Reinforce Accident Warning	O	O	O	O	O

Section C: Adoption Barriers of Emerging Technologies for Safety and Health Management

C1. Have you faced any barriers that influence the decision to adopt emerging technologies for safety and health management?

- Extremely
- Vert
- Moderately
- Slightly
- Not at all

C2. Please indicate the level of agreement on the adoption barriers of emerging technologies for safety and health management in the construction projects below.

[5 = Strongly Disagree, 5 = Disagree, 3 = Neutral, 2 = Agree, 1 = Strongly Agree]

No.	**Adoption Barriers of Emerging Technologies**	**5**	**4**	**3**	**2**	**1**
Technological Factors						
R1	Time Needed for Learning and Adoption	O	O	O	O	O
R2	Ineffectiveness of Technology	O	O	O	O	O
R3	Inadaptability of Technology	O	O	O	O	O
R4	No Assurance of Data Privacy	O	O	O	O	O
Organizational Factors						
R5	Small Organizational Size	O	O	O	O	O
R6	Closed Organizational Culture	O	O	O	O	O
R7	Extra Costs	O	O	O	O	O
R8	Lack of Top Management Support	O	O	O	O	O
R9	Additional Training	O	O	O	O	O
Environmental Factors						
R10	Lack of Occupational Safety and Health Regulations	O	O	O	O	O
R11	Lack of Government Incentives and Promotion	O	O	O	O	O
R12	Lack of Competitive Pressure	O	O	O	O	O

Section D: Willingness to Use Emerging Technologies for Safety and Health Management

D1. How enthusiastic are you to adopt emerging technologies for safety and health use?

- ☐ Extremely
- ☐ Vert
- ☐ Moderately
- ☐ Slightly
- ☐ Not at all

D2. Please indicate the level of agreement on which you have used/intend to use the following emerging technologies for the safety and health management of construction projects.

[1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree/Have Used]

No.	Type of Emerging Technologies	1	2	3	4	5
W1	Building Information Model	O	O	O	O	O
W2	Wearable Safety Technology	O	O	O	O	O
W3	Unmanned Aerial Vehicle	O	O	O	O	O
W4	Virtual Reality	O	O	O	O	O
W5	Augmented Reality	O	O	O	O	O
W6	Sensing Technology	O	O	O	O	O
W7	Camera Network Systems	O	O	O	O	O
W8	Robotics and Automation	O	O	O	O	O
W9	Digital Signage	O	O	O	O	O
W10	3D Laser Scanning	O	O	O	O	O
W11	Exoskeleton	O	O	O	O	O
W12	Artificial Intelligence	O	O	O	O	O

----------------------------- The End of Survey -----------------------------

Thank you for taking the precious time to complete this survey.

Your response is of high importance for this study and is truly appreciated.