DRONE TECHNOLOGY AND ITS IMPLICATIONS TO THE MALAYSIAN CONSTRUCTION INDUSTRY

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

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DECLARATION

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

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APPROVAL FOR SUBMISSION

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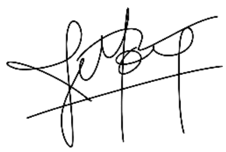

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ABSTRACT

The advancement in construction technology is changing the face of the construction industry. Construction technology is reshaping the construction industry by improving the safety, efficiency, productivity, and collaboration in construction projects. Drones, also known as Unmanned Aerial Vehicles (UAV), are one of the recent emerging construction technologies that have been actively adopted by construction industry worldwide. The state of drone adoption in the Malaysian construction industry remains an unknown issue. Does the Malaysian construction industry aware of drone technology? How are drones utilised in the Malaysian construction industry? What are the challenges faced by the Malaysian construction industry? This study aims to explore the application of drone technology in the Malaysian construction industry. Specifically, it investigates the awareness towards drone technology, its applications, and the challenges of drone adoption in the Malaysian construction industry. This study adopted the quantitative research approach where data is collected through questionnaire surveys using Google Form via email and the LinkedIn platform, from 123 contracting companies located within the Klang Valley area. Analysis techniques such as the Cronbach's alpha reliability test, descriptive analysis, Kruskal-Wallis test, and Mann-Whitney U test are conducted to interpret the collected data into inferential information. The findings revealed that Malaysian contracting community has a moderate level of awareness towards drone technology. Contractors aged between 25 to 34 years old recorded the highest awareness towards drone technology. Drone adoption level is at 17.89 %, with a total of 22 respondents from Grade 5, 6, and 7 contracting companies to have adopted the drone technology. The three most common applications of drone technology in the Malaysian construction industry are (1) progress monitoring; (2) safety inspection; and (3) security surveillance. The findings also revealed the three most significant challenges of drone adoption in the Malaysian construction industry. The challenges are (1) top management's support; (2) operational and maintenance costs; and (3) initial costs. As such, this study sought to provide an in-depth insight to increase the construction industry's awareness towards drone technology and its adoption in Malaysia.

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LIST OF SYMBOLS / ABBREVIATIONS

kg	kilogram
mph	miles per hour
km/hr	kilometre per hour
α	Cronbach's alpha coefficient
n	number of respondents
2D	two-dimensional
3D	three-dimensional
4D	four-dimensional
BIM	Building information modeling
CAAM	Civil Aviation Authority of Malaysia
CAD	Computer-aided design
CIDB	Construction Industry Development Board
FAA	Federal Aviation Administration
GNSS	Global navigational satellite system
GPS	Global positioning system
Inc.	incorporated
Ltd.	limited
OSHA	Occupational Safety and Health Act
PDF	Portable Document Format
RFID	Radio-frequency identification
SPSS	Statistical Package for the Social Science
UAV	unmanned aerial vehicle
UAV	United States
USD	United States Dollar

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CHAPTER 1

INTRODUCTION

1.1 Background Studies

In the wake of Industry 4.0, construction players have started to take their initiative to invest in new technologies such as cloud computing, three-dimensional (3D) printing, big data, and so on. Drones, also known as Unmanned Aerial Vehicle (UAV), are one of the major pillars of Industry 4.0 that would greatly benefit the construction industry. In recent years, drone adoption has been widespread within the construction industry. Construction industry players, especially the contractors are actively adopting it. For instance, Komatsu Ltd., the construction giant in Japan, had deployed 1,000 units of drones serving as a site topographic mapping tool to effectively provide site survey data in facilitating the earthwork execution (Grayson, 2018). Besides, drones have been used to perform mapping, inspection, and monitoring tasks in the euro motorway survey in Ireland (Deegan, 2018). Meanwhile, in Malaysia, drones have been used for land surveying and progress monitoring in infrastructure projects such as Tun Razak Exchange (TRX) and Mass Rapid Transit (MRT) (The Asean Post, 2019).

In the most recent research, the drone market is forecasted to continue to expand and reach a value of USD 47.76 billion by 2025 (ReportLinker, 2020). Construction drone adoption had reported a surge of 239 % in 2018 (DroneDeploy, 2018a) and the construction industry had subsequently dominated the drone market in 2019. The introduction of construction drones has revolutionized and streamlined the operations of the construction industry. In the operation of a consultant company, automated drones had rapidly replaced the traditional land survey procedure as it is capable of capturing vital information with high accuracy within a short time frame (Burger, 2019). Compared to the consultant companies, construction drones are of bigger interest to the contracting companies' operation. The real-time aerial data and images provided by drones are crucial in aiding the contractor to bridge the gap between time and cost overruns in a project. By utilizing drones in weekly progress tracking, the contractor could have early detection of the deviations and thus call for remedial action(s) to redirect it before it becomes costly and dragging the schedule further behind (DroneDeploy, 2018b). Besides, drones have been adopted by the contractors in operations such as material and equipment tracking, and safety inspection on the site personnel and building structure.

1.2 Problem Statement

As drones begin to emerge in the construction industry, various studies concerning drones have been conducted within the construction context. For instance, Tatum and Liu (2017) have researched the applications, risks, and futures of drones in the United States construction industry. Furthermore, Golizadeh, et al. (2019), researchers from Australia, contributed to the literature by uncovering the barriers to the adoption of drones on construction projects. Besides, in Italy, Ciampa, De Vito and Pecce (2019) had studied the practical issues on drone application for inspections in construction projects.

Although academicians and researchers have continuously contributed and extended the literatures on drones in the construction industry, yet there are no extensive studies conducted within the context of the Malaysian construction industry. Kammin, et al. (2017) have conducted a study on the applications of micro UAV in construction projects. Furthermore, Yunus, Hamzah and Azmi (2020) had studied the applications of drone technology as a tool in monitoring rural development. Although the studies conducted by the researchers have contributed valuable insights to the literature of drone technology in the context of Malaysian construction industry, the studies conducted are solely limited to the applications of drone technology in 3D modelling (Kaamin, et al., 2017a) and monitoring (Yunus, Hamzah and Azmi, 2020). The awareness towards drone technology and its applications and challenges in the Malaysian construction industry are yet to be known by industry players and scholars alike. Thus, this study looks into how Malaysian construction industry players, particularly the contractors in utilising drones for construction projects, apart from the impediments towards drone adoption in the industry.

1.3 Aim and Objectives

This study aims to explore the application of drone technology in the Malaysian construction industry. To achieve the aim, the following objectives have been identified-:

(i) To investigate the awareness of the Malaysian construction industry towards drone technology.

(ii) To determine the applications of drone technology in the Malaysian construction industry.

(iii) To investigate the challenges of drone adoption in the Malaysian construction industry.

1.4 Scope and Limitation of the Study

This study focuses on the applications of drone technology towards the contracting companies. Moreover, the scope of the study is limited to contracting companies located within the Klang Valley area, where the vast majority of the established contracting companies are located.

1.5 Contribution of the Study

This study could provide the new players from the construction industry who are interested in investing in drone technology with the knowledge of drone technology. The disclosure of the applications and benefits of drone technology in this study could attract and encourage potential investors, for instance, contractors to embrace drone technology. At the same time, this study could serve as a tool to increase awareness of the industry towards this emerging technology.

Moreover, this study could enlighten the future researcher with a better insight into drone technology and the factors influencing its adoption in the Malaysian construction industry and served as a reference for future study in a similar field. The researchers could utilize the discussions, methods, and results in this study as a support in their future research.

Ultimately, the results and insights obtained from this study could be utilized by local and international drone manufacturers to drive future research and development (R&D). Knowing how the industry players utilise drones and the barriers to drone adoption in the Malaysian construction industry, drone companies could perform evaluation and research to improve their drones' hardware or technical performance to cater to the needs and expectations of the industry, so as to promote their drones to the industry.

1.6 Outline of the Report

This study is structured into five chapters. Chapter 1 serves as an introductory chapter for the studies. It outlines the general introduction of drone technology. The problem statement, aim, and objectives that drive this study are revealed in this chapter. Besides, this chapter also outlined the scope, limitation, and contribution of the study.

Chapter 2 deals with the critical review of previous studies on drone technology pertaining to the type and features of construction drones, the technologies adopted by drone, drone platform and data processing software, the applications of drone, the benefits of drone, and lastly the factors influencing the adoption of drones. A theoretical framework for drone is proposed after the review of the literatures.

Chapter 3 introduced the research design and instrument implemented in this study to achieve the research aim and objective. This chapter also revealed the questionnaire design framework, sample design, and the data analysis method adopted in this study.

Chapter 4 presents an analysis and discussion of the data. The collected survey data are systematically tabulated and presented. Subsequently, statistical tests for data generalisation were performed, followed by the analysis.

Chapter 5 is the concluding chapter, which presents the ultimate findings of the study. The conclusion was drawn to affirm the accomplishment of the aim and objectives. Lastly, the study winded up with recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 presents a succinct description of the drones. The development of drones is presented in subchapter 2.2. The description of types of drones is presented in subchapter 2.3, while the discussion of drone components is presented in subchapter 2.4. Subchapter 2.5 presents the discussion on drone technology followed by the discussion on drone platform and drone data processing and visualisation software in subchapter 2.6 and subchapter 2.7, respectively. The applications, benefits, and challenges of drone technology in the construction industry are discussed in subchapter 2.8, subchapter 2.9, and subchapter 2.10, respectively. This chapter is wrapped up in Chapter 2.11 with the proposed theoretical framework.

2.2 Development of Drones

A drone, also known as an unmanned aerial vehicle (UAV), is an uncrewed aircraft with no onboard passenger that operates via the remote control by a human operator or, at the other end of the spectrum, fly autonomously through a software pre-programmed flight plan. Tracing back to the history of drones, the primitive usage of drones was solely for military purposes. According to Rouse (2019), UAVs were first recorded serving as a balloon carrier in the fight between Venice and Austria in 1849, when the Austrian soldiers used hot air balloons equipped with bombs to attack the foe. The UAV's innovations have continued to develop since the first pilotless aerial torpedo was invented by the US Army and continually be of interest to the military. For instance, military drones have been deployed as decoy and reconnaissance tools in the Vietnam War and the Israel-Syria War (Vyas, 2020).

Though drones were primarily intended for military purposes, the application of drones for non-military purposes has taken place during the past decades. Commercial drones made their first appearance in 2006, serving as a monitoring tool to monitor the United States and Mexico border. Although non-military drones were introduced in 2006, the usage expansion of commercial drones was not significant and have continued to be used in hobbyist activities for the later years. Commercial drones were not mainstream until late 2013 when Amazon announced to adopt commercial drones for delivery activities (Alkobi, 2019). Since then, commercial drones have prospered and widely adopted by entities such as government, personal, industrial, and commercial, for multiple purposes including search and rescue, cargo delivery, advertising, weather forecasting, urban planning, agriculture monitoring, and disaster response (CB Insights, 2020).

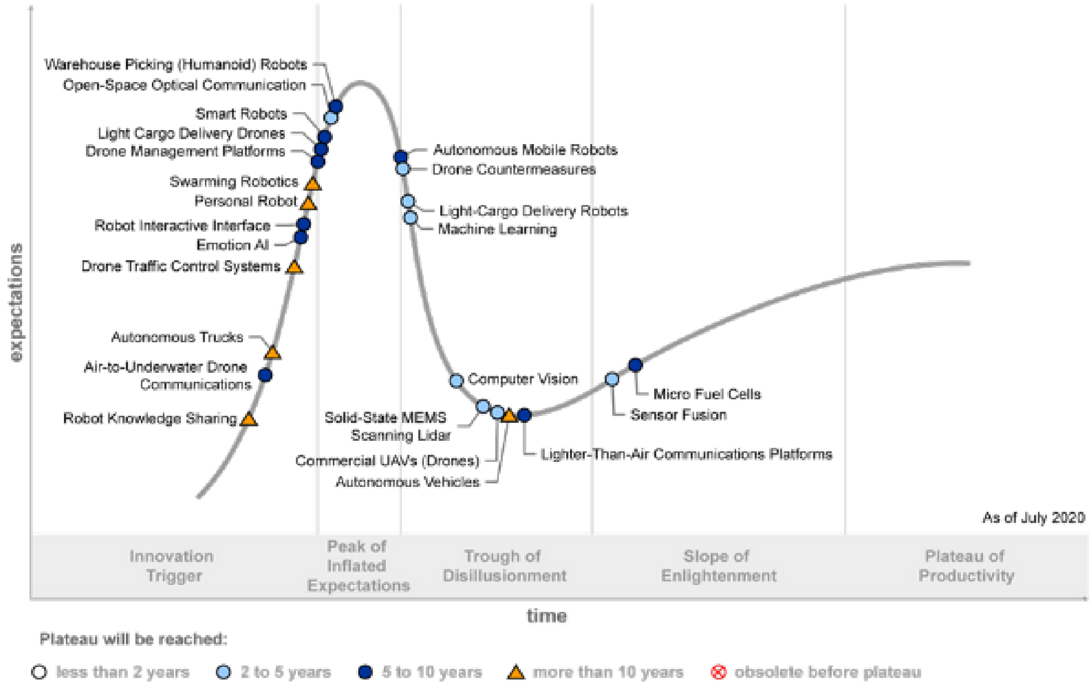

Figure 2.1: Gartner Hype Cycle for Drones and Mobile Robots, 2020.

(Source: Muynck, 2020)

The development of commercial drones is demonstrated in the Gartner Hype Cycle. Gartner Hype Cycle demonstrated the life cycle of technology in five phases, from its innovation triggering phase to the phase of the plateau of productivity where mainstream adoption begins to take off. Refer to the Gartner Hype Cycle for Drones and Mobile Robots 2020 in Figure 2.1, as of July 2020, commercial drones are in the trough of disillusionment where the interest in commercial drones waned owing to the failure in delivering experiments and implementations. The investment in commercial drones would be continued only if the giant drone providers in the market succeed to improve commercial drones as a more viable business technology to the early adopter’s satisfaction (Gartner, 2020). Once the trough is breakthrough, commercial drones would reach the plateau of productivity and adoption in the next two to five years.

2.3 Types of Drones

There are a few options available for drones, each having its strength and weakness. Generally, drones are classified into four major categories, which are multi rotor drones, single rotor helicopter, fixed wing drones, and fixed wing hybrid vertical take-off and landing (VTOL).

2.3.1 Multi Rotor Drones

Multi rotor drones are by far the most commonly used drones among hobbyists and professionals for aerial photography and surveillance due to their affordability. This type of drone has multiple power-driven engines (rotor) that allow them to take off vertically and equipped them with better stability to hover in the sky for perfect aerial photography capture. Multi rotor drones can be further categorised based on the rotor counts on the aerial platform, for instance, tricopters (three rotors), quadcopters (four rotors), hexacopters (six rotors), and octocopters (eight rotors). However, multi rotor drones are not an ideal UAV for long-distance and large-scale aerial mapping due to their limited 25 to 30 minutes flying time (Giordon, et al., 2020).

2.3.2 Single Rotor Helicopter

As the name suggests, a single rotor helicopter has only one large rotor on its aerial platform, and both the design and structure of this drone resemble an actual helicopter. Single rotor drones prevail over the multi rotor drones by higher flying times and greater ability to carry a heavier payload as these units are generally built with higher strength and durability (Chapman, 2016). However, these units exert a greater operational risk as the large blade could pose a threat to the individual in the event of mishandling.

2.3.3 Fixed Wing Drones

Fixed wing drones are equipped with airplane-liked fixed wings to generate lift. As all airplanes do, fixed wing drones could not hover in the air. As such, fixed wing drones are not suitable for aerial mapping, but they are ideal for long-distance operations such as oil pipeline surveying due to their superior energy efficiency (Hayley, 2018).

2.3.4 Fixed Wing Hybrid VTOL

According to Chapman (2016), a fixed wing hybrid is an integrated model of drone that merges the merit of fixed wing drones, like high flying time, and rotor-based drones, such as hovering. These drones have both fixed wings and rotors on their aerial platform and can perform vertical take-off and landing like rotorcrafts.

2.4 Drone Components

All drone components are essential to a seamless and safe drone operation flight. Components made up a drone are illustrated in Figure 2.2, which includes standard and pusher propellers, brushless motors, GPS module, landing gear, electrical speed controller (ESC), battery, camera, flight controller, the receiver, and the transmitter. The function provided by each of the drone components are tabulated in Table 2.1.

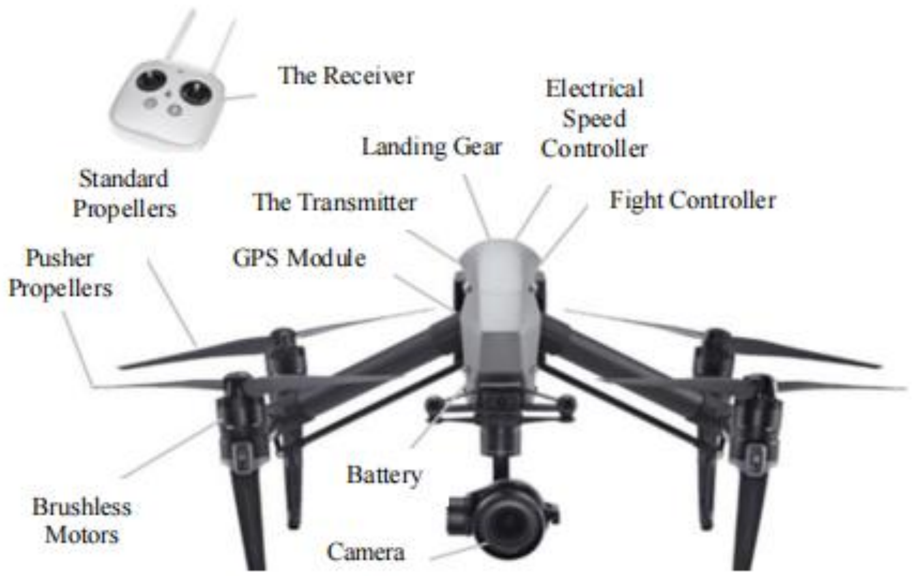

Figure 2.2: Drone Components.

(Source: Grind Drone, 2017)

Table 2.1: Drone Components and their Functions.

Drone Components	Functions
Standard Propellers	The standard propellers are accountable for the drone’s orientation and motion (Corrigan, 2020a).
Pusher Propellers	The pusher propellers are located at the back of the drone. They control the forward and backward thrust of a drone (Corrigan, 2020a).
Brushless Motors	The brushless motors thrust the propellers by converting the electrical energy from the power source to mechanical energy (Smith, 2018).
GPS Module	The GPS Modules receive GPS satellites signal and processes to identify the current position, speed, and elevation (Dronefly, 2019).
Landing Gear	The landing gear absorbs and dispels the kinetic impact during landing to allow a safe landing (Grind Drone, 2017).
Electrical Speed Controller (ESC)	The electrical speed controller receives commands from the flight controller and regulates the motor’s speed (Smith, 2018).
Flight Controller	The flight controller is the motherboard of a drone that interprets and converts signals from sensors and receivers into actions of drone operations (Grind Drone, 2017).
Battery	The battery is the power source providing electrical power to the drone (Dronefly, 2019).
Camera	The camera provides a drone with photography and filming functionality (Corrigan, 2020a).
The Transmitter	The transmitter transmits and communicates radio signals from controller to drone to issue flight commands (Grind Drone, 2017).
The Receiver	The receiver collects signals from the radio transmitters (Smith, 2018).

2.5 Drone Technology

Drones are generally equipped with state-of-the-art technology to improve their functionality. The technologies where a drone is usually acquired are the Global Navigational Satellite Systems (GNSS), collision avoidance technology, propulsion system, high performance and zoom camera, inertial measurement unit (IMU), and first person view (FPV) technology.

2.5.1 Global Navigational Satellite System (GNSS)

The Global Navigational Satellite System (GNSS) is the umbrella of all the regional satellite navigation systems which comprises the Global Positioning System (GPS), BeiDou Navigation Satellite System, and other satellite navigation systems (European Global Navigation Satellite Systems Agency, 2020). GPS is the most commonly adopted navigation system in commercial drones to provide reliable navigation during a drone flight. GPS plays an important role in both autonomous and remote modes of operation of a drone. In autonomous flight mode, a drone flies in a pre-programmed path guided by GPS. Whereas, in the drone flight where the drone is remotely controlled by a drone operator through a ground station remote controller, a GPS is used to help the drone operator track the exact location of the flying drone (The Geospatial, 2019). The precise pinpoint of the drone location via GPS would improve the reliability of data captured during the drone’s mission.

2.5.2 Collision Avoidance Technology

The lightweight characteristics make the drone fragile appliances that are prone to damage when it collides with obstacles. Therefore, collision avoidance technology is essential to secure the drone from the collision. According to Corrigan (2020b), several sensors can integrate to constitute the collision avoidance system in drones, for instance, the infrared (IR) sensor, light detection and ranging (LIDAR) sensor, vision sensor, monocular vision, ultrasonic, and Time of Flight (ToF). The general operating principle of these sensors in collision avoidance is emitting light sources and observing the reflected light sources to determine the distance from the obstacles. Among the available sensors, LIDAR is the ideal sensor to provide outstanding performance in obstacle detection and collision avoidance of drones (Sabatini, Gardi and Richardson, 2014).

2.5.3 Propulsion System

The drone propulsion system is the most significant technology which a drone must be equipped for to fly in the sky. The fundamental drone propulsion system comprises motors, propellers, and electronic speed controllers (ESC) (Corrigan, 2020c). The two motors commonly adopted by drones are brushed motors and brushless motors (Reid, 2019). A drone motor is functioned to thrust the propellers by converting the electrical energy from the power source to mechanical energy, while the ESC, as the name suggests, is functioned to regulate the speed of the motors (Lovati, 2019). In short, generates upward and forward thrust to lift and fly the drones is generated by the synergy of the motor, propeller together with the ESC,

2.5.4 High Performance and Zoom Camera

The camera is an important feature to provide the drone with photography and filming functionality. A high-performance camera allows the high capturing frame rates in high resolution. Simply put, it can produce a high-quality aerial image and video (Juniper, 2020). The production of high-quality aerial imagery and video would eventually improve the reliability and accuracy of the outcome of the drone's mission.

A zoom camera allows the drone operator to visualise a distant object and bring it into the frame. There are two means of camera zoom: digital zoom and optical zoom. Digital zoom is the post-flight zooming, where the drone operator performs manual zooming on the captured image displayed in the device, while an optical zoom is the zooming carried out during the drone flight with adjusting the focal length of the optical camera lens (Flynt, 2019).

2.5.5 Inertial Measurement Unit (IMU)

An Inertial Measurement Unit (IMU) is mounted on a drone to measure the rotation and velocity using the incorporated inertial sensors in the unit, such as the gyroscopes and accelerometers. The gyroscope sensor in the IMU detects the angular rotation of the drone while the accelerometer sensor measures the change in the flying speed of a drone (Rees, 2018). The purpose of detecting the velocity and orientation of the flying drone is to ensure that the drone is flying or hovering in a stable and smooth flight condition (Perez-D'Arpino, et al., 2011).

2.5.6 First Person View (FPV) Technology

First Person View (FPV) Technology allows the on-ground drone operator to have a real-time view as if they were physically onboard on the drone (NIAS, 2018). To have the first-person view, an FPV camera connects with the FPV video transmitter must be mounted on the drone. The FPV video transmitter transmits the data captured by the FPV camera as an input radio signal to the FPV video receiver. The FPV video receiver later converted the input radio signal back to the data and displayed it on the FPV goggles (GetFPV, 2018).

2.6 Drone Platform

A platform is critical to support the operation of drones. The leading drone platform in the industry is the DroneDeploy and FlytBase. The following subchapter 2.6.1 and subchapter 2.6.2 presented a brief introduction to the DroneDeploy and FlytBase platform.

2.6.1 DroneDeploy

DroneDeploy is an exclusive cloud-based software platform for commercial drone mapping that creates insight-rich aerial maps and 3D models easier than ever before with just a single click. The platform supports complete reality capture at any altitude and angle in a single mobile app platform that is accessible on any device. Simultaneous upload and process of massive data-rich drone imagery in the cloud are realisable with the DroneDeploy platform as it supports cloud access with no specialised software and hardware required (DroneDeploy, 2021). This platform offers solutions for agriculture, construction, insurance agencies, oil and gas, and surveying and mining. It offers a suite of analytical capabilities for the users to accurately inspect, measure, annotate and report the value of stockpiles and earthwork. Integrating DroneDeploy with various document and project management applications such as Procore, Azure, and Bluebeam Revu brings the drone insights and data to the project team (Chowdhry, 2017).

2.6.2 FlytBase

FlytBase is a drone platform that offers drone agnostic software solutions for the at-scale deployment of commercial drones that are fully autonomous and cloud-connected. As the world’s first Internal of Drone (IoD) platform, FlytBase connected drone fleets with cloud-based business applications for smart drone-cloud connectivity to leverage drone technology for automated business applications and workflows (McNabb, 2017). This IoD platform offers autonomous drone solutions for security and surveillance, inspection, emergency response, and warehouse management. All major drones such as DJI, PX4, Yuneec, and hardware platforms such as Qualcomm, Samsung, and Intel are compliant with FlytBase. With enterprise-grade reliability and security, multiple deployment solutions, and data analytics and progress tracking capabilities, FlytBase has become a platform choice for commercial drone applications (FlytBase, Inc., 2021).

2.7 Drone Data Processing and Visualisation Software

The information by solely drone imagery or video footage is deficient for the contracting companies to realise the objective of data collection through the utilisation of drones. To extract more detailed and informative output data, drone data shall be integrated into advanced construction and drone data processing and visualisation software. The software that can be utilised to process and visualise drone data are discussed in the following subchapter 2.7.1 to subchapter 2.7.3.

2.7.1 Autodesk

The Autodesk software has been rapidly utilised for drone data processing and visualisation. Among the available software offered by Autodesk Inc, the software used for drone data integration are the ReCap Pro, AutoCAD, Civil 3D, and BIM 360.

Autodesk ReCap Pro is a 3D scanning software that generates point clouds and meshes enriching 2D and 3D models from the imported aerial imagery or laser scans (Autodesk, Inc., 2021a). In general, the integration between Autodesk ReCap Pro with drone data is merely to process and convert the captured drone imagery into 3D models. The 3D models generated through Autodesk ReCap Pro are imported into other Autodesk software such as Autodesk AutoCAD and Autodesk Civil 3D for further drawing overlaying and measurements (Phan, 2017).

Autodesk AutoCAD is a computer-aided design (CAD) software that allows the generation of digital 2D and 3D drawings. Autodesk AutoCAD is featured with industry-specific toolsets for intelligent drafting and production of architecture, mechanical and electrical design (Autodesk, Inc., 2021b). Drone data is integrated into Autodesk AutoCAD for deviation detection by overlaying 2D original construction plans onto the drone captured site imagery (DroneDeploy, 2018c). Also, the contracting companies may use Autodesk AutoCAD to measure the distance, radius, angle, area, and volume on the ReCap Pro post-processed 2D model.

Autodesk Civil 3D is a BIM-supporting software for civil infrastructures design and documentation (Autodesk, Inc., 2021c). The drone data captured during the topography and earthwork survey, after processed with Autodesk ReCap Pro, are imported into Autodesk Civil 3D for data and surface generation. The contracting companies may later perform various analyses such as volumetric analysis and cut and fill analysis on the generated contour surfaces to extract desired measurement value and to enrich the existing construction data (Bergen, 2017).

Autodesk BIM 360 is an Autodesk construction clouds platform that allows effortless collaboration on construction projects using the building information modeling (BIM) process. BIM 360 solutions provide enhanced collaboration in construction management, information sharing, project lifecycle management, and innovation in a construction project (Autodesk, Inc., 2019). The integration of Autodesk BIM 360 with drone platforms such as Drone Deploy allows seamless drone data sharing and retrieval on and off the job site between the project stakeholders. Moreover, the effortless integration of reality and drone aerial photography into construction worksite management is realisable with the utilisation of Autodesk BIM 360 integrating with the drone platform. The contracting companies may overlay the CAD and PDF drawing files from Autodesk BIM 360 onto orthomosaics to detect deviations between the as-planned and the as-built (March, 2017).

2.7.2 Procore

Procore is an all-in-one cloud-based construction project management software. The software streamlined the resource, financial and project management of the construction projects from the project bidding to the project closeout. It maintains the real-time request for information (RFI), submittals, daily log, photos, drawings, documents of construction projects in a centralised cloud-based platform to allow seamless project management and collaborations among the project stakeholders (Procore Technologies, Inc., 2021). The drone imageries are imported into the Procore software for a real-time progress update and constant progress monitoring of the construction projects for seamless inner and outer communications and project workflow management. The aerial insights keep the project teams well informed of the up-to-date progress and catch the construction deviations before it adds weeks to the project (DroneDeploy, 2018d).

2.7.3 Bluebeam Revu

Bluebeam Revu is a cloud-based document management and collaboration software adopted by the industry players to review, markup, edit, takeoff, and organise PDF drawings. Bluebeam Revu solutions transform unorganised scanned images into easily searchable and organised documents stored in a centralised cloud platform. The utilisation of Bluebeam Revu enhanced the collaboration over plans as the invited users in a construction project may access the platform to create, annotate, share and collaborate the documents in real-time (Bluebeam, Inc., 2021). Using Bluebeam Revu to perform annotation on drone imagery is an added value to the drone imagery, making it actionable imagery with accurate information (Lander, 2019). The export of annotated drone imagery PDF into the Bluebeam project would keep the team information aligned during the construction project.

2.8 Applications of Drone in the Construction Industry

In the aspect of the construction industry, drones have been deployed for various applications in the pre-construction, construction, and post-construction phase of a construction project. The works of literature studied for the applications of drones in the construction industry are presented in Table 2.2.

Table 2.2: Applications of Drone Technology in the Construction Industry.

Previous Research	Pre-construction Topographic Survey	Pre-construction Planning and Design	Earthwork Survey and Analysis	Progress Monitoring	Safety Inspection	Security Surveillance	Structure Inspection	Inventory Tracking	Post-construction Maintenance Inspection
Tatum and Liu (2017)	√					√			
Yeh, et al. (2018)	√								
Wingtra (2020a)		√							
DeCamara and McMillan (2019)		√							
Siebert and Teizer (2014)			√						
Hugenholtz, et al. (2015)			√						
Akgul, et al. (2017)			√						
Mosly (2017)			√						
Zollmann, et al. (2014)				√					
Lin, Han and Golparvar-Fard (2015)				√					
Kielhauser, et al. (2020)				√					
Irizarry, Gheisari and Walker (2012)					√				
Mole, et al. (2017)					√				
Dukowitz (2020)						√			
Koutsogiannis (2018)						√			
Morgenthal and Hallermann (2014)							√		

Table 2.2 (Continued)

Previous Research	Pre-construction Topographic Survey	Pre-construction Planning and Design	Earthwork Survey and Analysis	Progress Monitoring	Safety Inspection	Security Surveillance	Structure Inspection	Inventory Tracking	Post-construction Maintenance Inspection
Eschmann, et al. (2013)							√		√
Bown and Miller (2018)							√		
Srewil (2015)								√	
Hubbard, et al. (2015)								√	
Grosso, et al. (2020)									√
Yeum and Dyke (2015)									√
Wang, et al. (2009)									√
Kaamin, et al. (2017b)									√

2.8.1 Pre-construction Topographic Survey

A conventional topographic survey is performed using robotic total station (RTS), terrestrial laser scanning (TLS), a global positioning system (GPS), or light detection or ranging (LIDAR). A topographic survey is essential to facilitate the planning of site development as topographic visualisation provides the project team an early realisation of the land situation. Drones have been rapidly integrated into the land surveying task to perform topography mapping as drones could economically and speedily capture topographic data and imagery compared to the traditional surveying method. Integrating topographic data with the high-resolution footage and image of the land captured by drone into the drone software system allows the production of high accuracy 2D and 3D contour maps (Tatum and Liu, 2017). Yeh, et al. (2018) have compared the performance of drone systems and total stations in the modelling of slope topography. The authors concluded that a total station-based survey could obtain more accurate information, but however required a greater time, cost, and manpower contribution. However, although a drone-based topographic survey data may exert some error, the centimetre error variance is acceptable. Most importantly, drone-based topographic surveys can capture more information as detailed as possible within a short time frame at a low operating cost.

2.8.2 Pre-construction Planning and Design

Drone imagery could provide invaluable assistance in project planning and design. Superimposing the 3D models of the new project over the drone aerial map captured on the actual site allows the project team to visualise the project better. With the projected holistic view, the project team could analyse the impact of the new project on the area of development from both practical and aesthetic viewpoints. The realisation of 3D models allows the visualisation and analysis of outlooks and cast shadows (Wingtra, 2020a). The visualisation of the project outcome allows the project team to assess the compatibility of the project design with the surrounding environment and make necessary modifications to iterate the design in response to the site condition. Besides, the drone data collected may also assist in the pre-construction planning. The project team could through the superimposed imagery, identify the challenges and risks to the project such as traffic constraints and landslide risk in the sloping area, and thereafter develop plans to accommodate the challenges. The data collected may also assist planning in locating utilities and materials, where the project team can evaluate the site imagery to select the best locations for the placing and storing of materials and utilities (DeCamara and McMillan, 2019).

2.8.3 Earthwork Survey and Analysis

Lately, as technical advancements have led to a decline in the expense of drone devices, civilian use of drones has become popular for earthwork reconnaissance and data collection. Performance analysis of the drone system for the excavation work on a highway construction was conducted by Siebert and Teizer (2014). The volumetric data measured by the automated UAV direct geo-referenced mapping approach on the earth piles are compared with the data obtained through the RTS survey method. The authors found an average 11 % of data difference between the UAV and RTS method, and yet the authors deduced that drone-based earth volume estimate is more accurate as the measurement resolution generated by the drone-based survey is denser. Hugenholtz, et al. (2015) through their study, found out that a drone-based volumetric survey can yield a result that is comparable to the conventional techniques. The authors however suggested to optimise the surveying cost, the drone-based volumetric survey niche would be earthwork project sized between 0.05 and 30 km^2, with the upper limit vary depending on the project's configuration. Akgul, et al. (2017) presented an evaluation on UAV-based and GNSS-based earthwork surveys. The study showed that a UAV-based survey could provide more credible and precise results in a cost-effective and timely manner.

2.8.4 Progress Monitoring

Drones have been adopted actively to achieve a lower cost and risk, broader field-of-view, and speedy progress monitoring of the construction site. According to Mosly (2017), the application of drone technology that draws the most interest from researchers and the construction industry players is construction activities monitoring. Zollmann, et al. (2014) have developed a system that allows the spatial visualisation of the construction site's progress information by leveraging drone with augmented reality (AR), where the progress information captured by a drone is rendered and overlaid into the mobile AR system for direct visualisation on the physical construction site. Furthermore, Lin, Han and Golparvar-Fard (2015) have developed a framework for automated construction progress monitoring using drones, where 4D BIM models are superimposed onto the aerial construction site images captured by drones to achieve a better analysis and evaluation of the construction work in progress. Kielhauser, et al. (2020) have studied the practicability of drones to collect progress information on a commercial building for progress and quality monitoring. The study revealed that the deviations in the construction progress and the constructed built volume could be identified and monitored by volumetric comparison between drone-derived digital building volume with the digital building volume of BIM.

2.8.5 Safety Inspection

The Occupational Safety and Health Act (OSHA) required an employer to provide the workers with a safe working environment. At the construction site, the safety manager is responsible for performing regular walkthroughs and inspections on the material, equipment, and workers to ensure that the safety hazards are mitigated. However, due to time and staff limitations, the safety manager would not have been to perform safety inspection at all the time, thus causing a late response to the safety risks (Irizarry, Gheisari and Walker, 2012). Drones can be deployed in performing safety inspections on the construction site. The study carried out by Mole, et al. (2017) in the construction sites in Brazil presented the applicability of drones in performing construction site inspection. Throughout the safety inspection using a drone, Mole, et al. (2017) have managed to visualise 57 % and 38 % of the safety checklist item on the two construction sites, respectively. Noncompliance on the safety requirements such as the defective guardrails and safety nets, workers without personal protective equipment (PPE), overload in safety platforms have been detected through the drone footage. Irizarry, Gheisari and Walker (2012) have conducted a similar assessment on the usability of drones in construction safety inspection, but the safety check was limited to examine if the construction workers have worn a hard hat in the construction site. The authors have in their opinion, proposed that an ideal safety inspection assistant drone shall possess the following feature: autonomous navigation, voice interaction, and improved battery life.

2.8.6 Security Surveillance

A drone can provide an extra security layer to the construction sites especially at night when the construction sites are vulnerable to civilian entry after the construction works stopped. Using a drone for security surveillance to identify perimeter and security breaches of the construction site could prevent the entry of civilians, which could be detrimental to the valuable assets in the construction site and the safety of the site personnel (Dukowitz, 2020). The flyover of drones for security patrol could in real-time provide the security team the information on any suspicious movement. It would significantly enhance the security in the construction site, especially areas located in CCTV blind spots with a low level of security (Koutsogiannis, 2018). A drone can be integrated into the security alarm system by docking a drone on a rooftop station at the construction site. When a security alarm is triggered, the drone will fly out from the station and fly around the construction site to record the incident (Tatum and Liu, 2017).

2.8.7 Structure Inspection

Conventional inspection tasks required bulky scaffolding, manpower, and machinery in the execution. It is often constrained by limited access to hard-to-reach areas and safety concerns arose when attempting inspections on high altitude places. The introduction of drones in performing non-contact inspections on a building's structure brings the construction inspection to a new level of economy, quality, and safety. Morgenthal and Hallermann (2014) conducted a study on drone applications for visual inspection on civil structures. The authors claimed the applications of drones in structure inspection are enormous and the image data can be generated efficiently at a reduced cost, but the quality of the image is yet influenced by environmental factors. Eschmann, et al. (2013) used a drone to perform an inspection on infrastructures and found out that detailed and large-scale inspections could be performed speedily and easily on infrastructures by using drones. Drones are also an economical, safe, and efficient tool for a roof inspection. Bown and Miller (2018) found that a drone-based structure inspection on a 30,000 square feet sloped roof can be done well within two hours without risking the inspector's life and damaging the roof structure.

2.8.8 Inventory Tracking

Traditional inventory tracking could be a tedious process, especially when there was suspected missing inventory on a large construction site. The contractor would have to spend considerable time checking the inventory record in the Excel spreadsheets and physically present on the site to look for the inventory. However, with a drone, the sophisticated inventory tracking procedure would be relieved as the contractor could fly the drone over the site for quick access to the geo-location of the inventory through GPS, thus saving both time and cost. The asset detection and tracking procedure can be further improved by using radio-frequency identification (RFID) tag (Srewil, 2015). Hubbard, et al. (2015) has presented the capability of the RFID sensor mounted drone to detect the radio signal of the RFID-tagged material. The installation of RFID tags on the asset would not affect the construction of the structures and it can remain on the structures even after the structures are built. Thus, if there is a detected defect on a particular batch of the material, for instance, the installed pipe, the contractor could deploy an RFID sensor mounted drone to help in the location detection of the pipe.

2.8.9 Post-construction Maintenance Inspection

Scheduled visual inspection to assess the conditions of the constructed buildings and infrastructures is essential for defects and damages identifications, assessments, and subsequent restoration or maintenance planning based on the outcome of inspections. Grosso, et al. (2020) suggested drones as feasible and yet economical maintenance visual inspection instruments in the field of the built environment. Yeum and Dyke (2015) have adopted drones for visual inspection to detect crack damage in a bridge and have determined the need for maintenance measures based on the inspection results. Wang, et al. (2009) have employed drones mounted with visible light and infrared cameras to detect faults on power line corridors. The authors accredited the applicability of drones to higher efficiency, lower cost, and safe power line inspection. Drones have also been adopted for non-destructive damage detection and assessment tasks on monuments (Eschmann, et al., 2013) and historical buildings (Kaamin, et al., 2017b).

2.9 Benefits of Drone Adoption in the Construction Industry

There are various benefits that a drone is bringing to construction projects and contracting companies. The literatures studied for the benefits of drone adoption in the construction industry are summarised in Table 2.3.

Table 2.3: Benefits of Drone Adoption in the Construction Industry.

Previous Research	Cost Saving	Time Saving	Worker Safety	Site Security	High Accuracy	Improved Communication	Better Documentation	Dispute Reconciliation	Business Competitiveness
Agarwal, Chandrasekaran, and Sridhar (2016)	√								
Wingtra (2020b)	√								
Bagatsing (2017)	√		√		√				
Beesley (2020)		√							
Goodman (2020)		√							
Howard, Murashov and Branche (2017)			√						
Gheisari and Behzad (2016)			√						
Oliveri (2018)				√					
Heliguy (2020)				√					
Wingtra (2020c)					√				
DroneDeploy (2017)						√			
Tackels (2018)						√			
DroneDeploy (2018e)							√		
Wingtra (2020a)							√		
Zeidel (2020)								√	
Walker and Bourchier (2018)								√	
Lorman (2018)									√
Hagen (2018)									√

2.9.1 Cost Saving

Cost overrun has become a norm in a construction project, where large-scale construction projects are typically 80 percent over budget (Agarwal, Chandrasekaran, and Sridhar, 2016). Misaligned construction due to poor pre-construction planning is one of the causes of cost overrun. With the use of drones in the planning phase, challenges and deviations in a construction project can be pinpoint before they lead to great cost implications in the future, thus saving a great amount of money in the long run. In the case study of the solar farm project of Bacon Farmer Workman Engineering and Testing Inc. (BFW) in 2019, with the utilisation of drones in pre-construction site mapping, BFW has noticed elevation drop off in the site with potential flood hazard. With such alarm, BFW has rearranged their construction planning and succeeded in saving themselves from substantial construction errors and financial losses. Furthermore, drone adoption offers cost-saving in surveying tasks with a reduction of surveying expenses by half as compared to the traditional survey method (Wingtra, 2020b).

Moreover, cost-saving is achieved by early construction deviation through the overlay of the drone-captured site progress image with the as-design drawings. As drones can be set up anytime for a flight, it is easy for the project manager to keep track of the progress and evaluate if the construction is in line with the schedule and the drawing. If discrepancies are discovered, they can be addressed without delay before it causes a huge cost impact on the construction (Bagatsing, 2017).

2.9.2 Time Saving

In the traditional approach of data collection and site monitoring in a construction project, quantity surveyors and project managers generally contribute a great field time to physically present in the construction site for manual data collection and site inspection. Drones can significantly reduce field time consumption and contemporaneously increase the efficiencies of data collection and reporting. Drone survey is proven results to ten times faster topographic survey compared to the traditional method. In a test survey run by Arcadis to examine the surveying time between a drone survey and a traditional survey, the findings showed that a traditional survey took three hours while a drone survey took only 20 minutes (Beesley, 2020). As drones become the go-to instrument that allows constructing companies to more efficiently survey, map, track and manage construction sites, it drives faster decision-making in construction. The speedier data collection and reporting drive faster decision-making and enables the project team to move fast to the next task as the project team can obtain the drone data within a few hours (Goodman, 2020).

2.9.3 Worker Safety

The use of drones for visual inspection for hard-to-reach and risky areas such as roofs is a clear benefit of the construction site personnel, as it would mitigate the risk associated with the inspection task. Having a drone to replace the role of a construction worker in performing a non-contact visual inspection would safeguard the construction worker from the risk of falling from a great height (Bagatsing, 2017). A drone could proactively improve worker safety, preventing the workers from injuries or deaths results from accidents such as falling, equipment collision, and electric shock (Howard, Murashov, and Branche, 2017). Furthermore, with the real-time high-quality drone imagery and footage delivered by a drone during the safety inspection, it allows the safety manager to fully evaluate the site conditions and have an early identification on the potential safety hazard or noncompliance in site safety measures (Gheisari and Behzad, 2016).

2.9.4 Site Security

Vandalism, unauthorised trespassing, theft, worker attack, and fire have been threats to the life of the site personnel and the damage of valuable assets in the construction site. The adoption of drones as real-time closed-circuit television (CCTV) to regularly patrol along a pre-programmed flight path over the construction site would enhance the overall security posture of the construction site. In the detection of an event of a security breach such as a burglar, a drone would alarm the site security personnel on the event while keeping surveillance on the burglar movement until the security personnel arrives at the scene (Oliveri, 2018). Moreover, a drone integrated with a thermal camera could help in early fire hazard detection before a large-scale fire outbreak. The usage of electrical systems and the storing of flammable construction materials in the construction site cause the site vulnerable to fire hazards. Having a thermal imaging camera mounted on the drone during drone surveillance flight could help to early identify hot spots with abnormal temperature change and receive an early warning response before the full-on conflagration that would compromise the site safety (Heliguy, 2020).

2.9.5 High Accuracy

Drone surveys reduced human error in data collection and contributed to high accuracy data. The accuracy of drone data is influenced by the performance and quality of the drone and its features. A high-end drone flying under an optimal condition would yield down to 1 cm absolute accuracy data. The capability of drones in generating high accuracy data is confirmed in the case study of the Indiana port survey conducted by SPACECO, a Chicago-based survey firm in the USA. SPACECO has conducted drone surveys on three ports in Indiana with a total area of 3,000 acres using a high-end WingtraOne drone and the results of the survey have provided an absolute accuracy of 1.5 cm (Wingtra, 2020c). Bagatsing (2017) highlighted that high accuracy results within 2 cm accuracy can be achieved through the usage of drones, and this would help in improving the decision-making in a construction project. Ultimately, having drones to generate highly accurate data would reduce the need for re-work and re-measurement in the future.

2.9.6 Improved Communication

Drone makes the information exchange and collaboration in a construction project smoother, boosting the overall communication. Unlike the fragmented photo captured in every corner of the construction site, drones can produce bird’s eye view aerial imagery. The project stakeholders can capture the big picture of the current construction progress on-demand through the bird's eye view aerial imagery captured by drone. The integration of drone data with cloud-based platforms such as DroneDeploy and FlytBase allows efficient information sharing and communication between the project stakeholders as the stakeholders can have real-time access to the live video stream of drone and the annotated maps (DroneDeploy, 2017).

Besides improving communications between stakeholders, drones improve communication on job sites by real-time job site monitoring and site inspection. The ability of a drone to collect real-time data contributed to a sharp increase in the efficiency of communication. Having drones to perform weekly or even daily regular mapping flights allows the project manager or site engineer to catch conflicts sooner and effectively communicate with the project team to resolve and redirect the conflict at a minimal cost (Tackels, 2018).

2.9.7 Better Documentation

Documentation is essential in every construction project as it is the contemporaneous record of the events in a construction project. For a general contractor, construction job site photo documentation is essential to provide site updates to the head office for decision making and to assist in monthly progress reporting and construction payment claims. The busy schedule of construction activities makes it challenging to ensure regular job site progress photo capturing and the centralised yet comprehensive documentation of construction job site photos. However, with automated weekly or even daily drone photo flights, it provides effortless and efficient capture of job site progress photos and helps to generate consistent and informative progress photo reports (DroneDeploy, 2018e). The captured job site photos are stored in a single centralised cloud-based platform and it is accessible via any device at any time, thus ultimately simplifying and promoting better construction job site photo documentation.

Furthermore, drones promote better post-project documentation for future construction quality improvement benchmarking purposes. The documented changes and visual imagery captured by the drone allow the project team to assess the project results and devise corrective, preventive, and improvement measures to optimise the project performance in the future job (Wingtra, 2020a).

2.9.8 Dispute Reconciliation

Although dispute inevitably happens in construction projects due to the multidisciplinary nature of the project team and the complex nature of the construction projects, drones offer invaluable benefits as dispute avoidance and dispute resolution tools in the construction industry. Dispute avoidance was realised by deploying a drone to conduct a thorough pre-construction site topographic survey for an early detection of information discrepancies between the site information provided by the project owner with the actual site environment (Zeidel, 2020). Having an early discrepancy detection, the contracting companies could nip the source of dispute in the first place before it develops into severe disputes in the future.

If the dispute is unavoidable, drone data could act as a dispute resolution tool. The data and records gathered by drone could provide invaluable and clear evidence against the dispute and be the key to unlock the dispute, thus facilitating speedy reconciliation between the disputing parties before the dispute becomes more involved (Walker and Bourchier, 2018).

2.9.9 Business Competitiveness

A drone has become a competitive advantage for a contracting company. The most significant business competitiveness drone providing the contracting company is enabling the company to make a much more ambitious bid. Preliminary thorough construction site drone mapping before the bid submission enables the contracting company to uncover mistakes and obstacles to future construction. With the information captured, appropriate price adjustments are made for an optimised and ambitious bidding price submission and therefore reinforced the chances of obtaining a considerable profit margin from the project (Lorman, 2018).

Moreover, drones improve the business competitiveness of a contracting company by streamlining the construction workflow management. The ability of a drone to collect and report informative data within a short frame enabled faster decision making in the construction workflow management and therefore allows a speedy completion of construction works such as safety inspection, site surveying, and progress monitoring at a significantly low cost without compromising the quality (Hagen, 2018). With this competitive advantage, the contracting company could differentiate themselves from ordinary competitors. They would be able to retain long-term clients and attract new clients who appreciate the endurance and intelligence drones are providing the construction project.

2.10 Challenges of Drone Adoption in the Construction Industry

As drones continue to develop and be of the interest of the construction industry, challenges of drone adoption are slowly coming to light. There are various barriers that could hamper the adoption of drones in the construction industry, as summarised in Table 2.4.

Table 2.4: Challenges of Drone Adoption in the Construction Industry.

Previous Research	Safety Concerns	Weather Constraints	Limited Flight Time	Costs	Ethical and Privacy Issues	Legal Restrictions	Professional Skills	Ease of Use	User’s Attitude	Practicability	Top Management
Li and Liu (2018)	√	√	√			√	√				
Rao, Gopi and Maione (2016)	√				√	√					
Kaćunić, Librić and Car (2016)	√	√		√		√					
Opfer and Shields (2014)	√	√	√	√							
Jordan, et al. (2018)	√					√	√				
Siebert and Teizer (2014)	√										
Clarke and Moses (2014)	√				√						
Jordan (2015)		√									
Li, et al. (2016)		√									
Morgenthal and Hallermann (2014)		√	√				√				
Leahy, et al. (2015)			√								
Pecoraro, Harper and Wang (2017)				√		√					
Luppicini and So (2016)					√						
Wilson (2014)					√						

Table 2.4 (Continued)

Previous Research	Safety Concerns	Weather Constraints	Limited Flight Time	Costs	Ethical and Privacy Issues	Legal Restrictions	Professional Skills	Ease of Use	User’s Attitude	Practicability	Top Management
Panahi (2014)					√						
Finn and Wright (2016)					√						
Attorney General’s Chambers of Malaysia (2016)						√					
Federal Aviation Administration (2020)							√				
Pettey (2015)								√			
Hertzman (2017)								√		√	
Wingtra (2020a)								√			
Franklin and Aguenza (2016)									√		
Egan and Fjermestad (2005)									√		
Elgohary and Abdelazyz (2020)									√		
Delaney and D’Agostino (2015)									√		
Thompson Tractor (2019)										√	

Table 2.4 (Continued)

Previous Research	Safety Concerns	Weather Constraints	Limited Flight Time	Costs	Ethical and Privacy Issues	Legal Restrictions	Professional Skills	Ease of Use	User’s Attitude	Practicability	Top Management
Mulholland (2020)										√	
Chouki, et al. (2019)											√
Borhani (2016)											√
Hunt (2014)											√

2.10.1 Safety Concerns

A drone could trigger safety concerns to the construction site personnel and the pedestrian passes by the construction site. Flying drones in the construction site may cause distractions to the construction workers, thus triggering safety issues (Li and Liu, 2018). Direct contact with the flying drone’s blades could cause injuries to an individual as the blade is turning at thousands of revolutions per minute. The crashes of drones are life-threatening to the public, construction personnel, and the property (Rao, Gopi and Maione, 2016). Drones could lose control and fall due to the error in the operation (Kaćunić, Librić and Car, 2016), mechanical failure, power outage (Opfer and Shields, 2014), and communication failure between the drone operators and the UAV (Jordan, et al., 2018). The hovering or flying of drones over the densely populated area in the construction site where the construction workers crowded to carry out the work should be avoided (Siebert and Teizer, 2014) as the direct falling impact of the drone or its payload on the personnel could be fatal (Clarke and Moses, 2014).

2.10.2 Weather Constraints

The flight reliability and applicability of drones are limited in critical wind and rain situations (Li and Liu, 2018). A drone's operation is limited to a maximum wind speed of 30 km/hr (Opfer and Shields, 2014), and it is not functional in adverse weather conditions such as heavy rain (Kaćunić, Librić and Car, 2016). The flight control of a drone in a strong wind condition exceeding 30 km/hr would be challenging as the adverse weather condition would cause the UAV operator to lose fine control of the drone as it is toilful to maintain the lightweight drone in its position. Morgenthal and Hallermann (2014) highlighted that drone flights are very sensitive to environmental changes, especially in critical wind situations. The strong wind could cause the drone to off track from the predetermined flight path and triggers unintentional collision with individuals or obstacles (Jordan, 2015). According to Li, et al. (2016), the operation of a drone in unfavourable weather would give rise to inaccurate aerial mapping.

2.10.3 Limited Flight Time

There is a variety of power sources for a UAV between the battery power, gas engines, or turbines. Gas engines or turbines power sources are unlikely to be used in the construction industry due to the associated high maintenance cost and the noise distraction generated during the operation. Nevertheless, the lithium-polymer battery power is a popular choice of the industrial player due to the higher amperage charge densities of the battery, which yielded a higher flight time (Opfer and Shields, 2014). Although battery power is offering a higher drone flight time, most of the consumer-based drones have a limited flight time of 20 to 30 minutes (Li and Liu, 2018) due to the payload associated with drones. The payload equipped by a drone would determine the size of the battery pack to be carried with the drone. A drone with a limited payload would have a limited flight time as it allows only the carry of a small battery pack (Morgenthal and Hallermann, 2014). The limitation in UAV flight time tends to limit the applicability and efficiency of drones in its monitoring and surveillance mission, especially in the mission requiring a long-distance flying to cover a broad construction area (Leahy, et al., 2015).

2.10.4 Costs

Like other equipment, the acquisition of a drone requires expenditures on the acquisition, operational, and maintenance of the drone. The initial cost of the drone acquisition appeared to be higher than ordinary equipment (Pecoraro, Harper and Wang, 2017) as a great amount of monetary contribution is required to increase the capability of drone with features such as high-quality camera, stabilisation gimbal, ultrasonic sensors, and others. A drone equipped with basic features can be purchased for less than 1,000 USD, but a more capable unit can be priced up to 5,000 USD (Opfer and Shields, 2014).

The operational and maintenance costs associated with drones are high as drones need periodic maintenance and inspection to mitigate the operational risk and ensure optimal operational performance. Most of the expenditure in the high maintenance cost of the drone comes from the costs to replace drone components due to worn out or damaged in the event of falling (Kaćunić, Librić and Car, 2016).

2.10.5 Ethical and Privacy Issues

The use of drones could trigger ethical and privacy issues. Despite the positive impact that drone has brought to the industry, the abuse of drone use could lead to violence, contributing to an ethical and privacy issue (Luppicini and So, 2016). Ethical concerns arise when drone operators operate drones for unethical purposes, leading to a negative impact on the individual who experiences such impact due to the use of drones by the operators (Wilson, 2014). The use of drones for surveillance or image capturing may amount to privacy invasion. There was once a picture of a woman sunbathing topless in her backyard was accidentally captured by a real estate drone and later being shown in the property advertising campaign, leading to privacy infringement and an ethical debate on the use of drones (Panahi, 2014). This incident raises the concern on the ethical and privacy challenges when deploying drones. Whether intentionally or not, drones during their operation would capture the aerial imagery of any individual or any activity within their capture range. It could contravene the privacy of the individual as their conduct is captured and even revealed to the public in the case if the image was leaked to a third party (Finn and Wright, 2016). The drone operator or the organisation is liable to the charges in contravention of privacy if they are negligent in ethical intelligence practice during drone operation.

Besides, data privacy is a concern for drone operation. A drone can be hijacked, controlled, and compromised by strangers (Clarke and Moses, 2014), leading to the leak of information and even the loss of ownership. Even if the owner suspected a leak of information, it is untraceable. Drones could not ensure foolproofness on their data security, as proven in the investigation when the Iraq military intercepted military information from the US military drone (Rao, Gopi and Maione, 2016).

2.10.6 Legal Restrictions

There are local regulations governing drone usage. In the US, drone usage is governed by the Federal Aviation Administration (FAA), while in Malaysia it is the Civil Aviation Authority of Malaysia (CAAM). Though the drone regulations intended to protect the user's interest by centralising and providing a clear guideline on drone usage (Kaćunić, Librić and Car, 2016), Li and Liu (2018) claimed that the regulation is imposing limitations on drone usage at the same time. In the US, FAA regulations had imposed limitations on drone usage such as mandating the drone operator to acquire a pilot license (Pecoraro, Harper and Wang, 2017), limiting the weight of commercial drone to 55 pounds with a maximum air speed of 100 mph (Rao, Gopi and Maione, 2016), and limiting the height of flying drone at a maximum altitude of 400 feet above the ground (Jordan, et al., 2018).

In Malaysia, the laws regulating the unmanned aircraft system are contained in Regulations 140 to 144 of the Civil Aviation 2016. Similar to the FAA regulations, the CCAM regulations restricted the maximum flying altitude of drones at a maximum altitude of 400 feet above the ground and prohibited the flying of drones with maximum mass not more than 20 kg, unless with authorisation from the authority (Attorney General's Chambers of Malaysia, 2016).

2.10.7 Professional Skills

The professional skills held by a drone operator are indispensable to navigate the drone safely (Li and Liu, 2018). A professional operator should be capable of managing the critical situation that arises during the drone operation such as the loss of a drone due to GPS failure (Morgenthal and Hallermann, 2014) before it leads to damages to the personnel or the property. The operators must go through an extensive training course to equip themselves with the professional skills that would meet the requirement of the CAAM (Jordan, et al., 2018). As a professional drone operator, the operator must be knowledgeable in areas such as radio communication control, preflight and postflight inspection procedures, emergency courses, and so on. Most importantly, the operators shall be able to demonstrate aeronautical professionality in their decision-making (Federal Aviation Administration, 2020).

2.10.8 Ease of Use

The ease of use of a product is a driving factor to the users' decision to adoption, and the same goes for drones (Pettey, 2015). Whether a drone can be ready-to-fly once it is out of the box or would require complex assemblies and set up to start its flight determines the ease of use of a drone (Hertzman, 2017). A barrier-free installation and easy setup is a bonus that would drive consumers' interest in drone adoption, especially for the drone novice.

The ease of operation of drone software exerted an influence on drone adoption. Sole drone imagery could provide only limited information to the users. Therefore, drone data must incorporate into specialised construction and drone data visualisation software to process and extract informative output data. The drone adoption eventually hampered if the data process workflow on drone software is complex and requires specialists such as geospatial experts to process and extract information (Wingtra, 2020a).

2.10.9 User's Attitude

The user's attitude towards the adoption of new technology is a significant determinant of the success of a new technology implementation in an organisation, and yet it is challenging to have the user's openness and willingness to adopt new technology. Resistance to change is the innate behaviour that most people possessed when it comes to the introduction of new technology into the organisation. Most of the resistance to a technological change in an organisation comes from the staff level. The employees are resistant and reluctant to change as they are more attached to the traditional way of operation and preferred to maintain the current status quo (Franklin and Aguenza, 2016). The introduction of new technology into the organisation implied that the employees must learn new things and adapt to the routine change, forcing employees to leave their comfort zone where most employees resist (Egan and Fjermestad, 2005).

Fear of the future state is a factor that drove user's resistance to change and hampered the successful implementation of new technology in an organisation. The insufficient information and understanding of the changes raised a sense of job insecurity among the employees where the employees are fearful of losing their control and power on the job (Elgohary and Abdelazyz, 2020). The employees who ascertain professional skills may see the new technology implementation as a threat which would undermine their competencies and cause the loss of job if they failed to adapt to the changes (Delaney and D'Agostino, 2015).

2.10.10 Practicability

The practicability of drones to be used in the construction site and if it could fit into the existing operation is a significant concern for the consumer before deciding to adopt drones. A construction site is known to be full of dust and dirt and for sure, the contact of the drone with the dust and dirt during the flight would result in inevitable wear and tear on the drone. If a drone is not durable to withstand the typical rough construction site environments, an organisation may see the drone as a non-practical investment for the organisation (Thompson Tractor, 2019). Furthermore, the portability of a drone is crucial when it needs to be frequently cycled between different construction sites (Hertzman, 2017). If a drone is too heavy and huge to carry around, it could limit the practicability of the organisation to fully utilise the drone for task executions in different sites.

The benefits of drones may be outweighed if drone adoption causes disruptions and breaks the existing operational workflows. An organisation may have thousands of tasks to handle. If drones could not fit into the existing operation but required the organisation to create a new workflow just to cater to the adoption, it would cause pain more than worth. Furthermore, the redefining of existing workflow to leverage drone technology into the organisational operation could cause job insecurity among the employees. If a drone is integrated well into the existing workflow without disrupting the current efficient way of operations, the drone's value can be optimised and maximised (Mulholland, 2020).

2.10.11 Top Management

The decision to technology adoption in an organisation is often made top-down and not bottom-up. Although the initiative may come from the staff level, the decision to invest in technology is on the top managements. The top management's knowledge and support would influence the new technology adoption, either as a barrier or a driver to adoption. The lack of knowledge and awareness of the top managements on the emerging technology would cause the organisation to miss the opportunities to obtain technological benefits that would enhance the current business models. The technology adoption in an organisation may be restricted owing to the top management's non-confidence in the new technology due to the limited knowledge and understanding of the technology (Chouki, et al., 2019).

Top management's support in resource allocation and strategy formulation is crucial to successful technology adoption in an organisation. New technology is curbed without the support of resources. The top management shall allocate sufficient resources such as time, money, training, and human resources to facilitate technology adoption (Borhani, 2016). Furthermore, the top management shall develop a long-term strategy and a clear road map to facilitate new technology adoption (Hunt, 2014). A well-developed road map providing an overall visualisation of the technology adoption would promote greater adoption engagement on the staff level and effectively directs the organisation to successful technology adoption.

2.11 Proposed Theoretical Framework for Drone

A theoretical framework for drone that summarised the literature reviewed was proposed, as shown in Figure 2.3. The awareness towards drone technology is the main determinant which influenced the adoption of drone technology, yet it is influenced by the challenges of drone adoption. Besides, the challenges of drone adoption could have a contingent effect on the awareness towards drone technology.

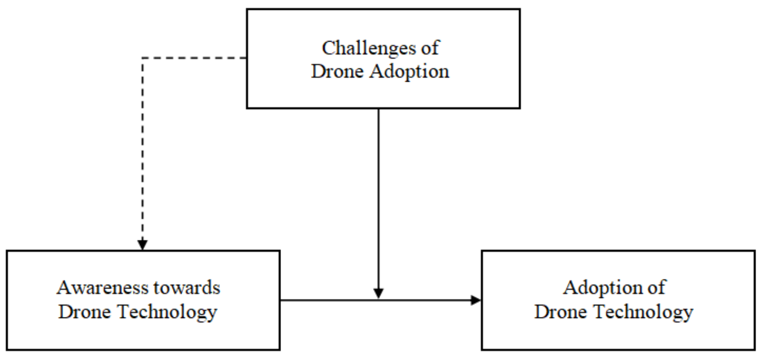

Figure 2.3: Theoretical Framework for Drone Adoption.

There are nine applications and 11 challenges of drone technology outlined in the literature of this study. However, the 11 challenges of drone technology presented in subchapter 2.10 have been further expanded into 18 factors, as demonstrated in Table 2.5.

Table 2.5: 18 Challenges of Drone Technology after Expansion.

11 Main Challenges	18 Challenges after Expansion (based on the 11 Main Challenges)
Safety concern	Safety concern
Weather constraints	Weather constraints
Limited flight time	Limited flight time
Costs	Costs – initial costs
	Costs – operational and maintenance costs
Ethical and privacy issues	Ethical and privacy issues – individual privacy
	Ethical and privacy issues – data privacy
Legal restrictions	Legal restrictions
Professional skills	Professional skills
Ease of use	Ease of use – ease of operation of drone software
	Ease of use – ease of use of drone
User's attitude	User's attitude – user's reluctance to change
	User's attitude – user's fear and resistance to new technology
Practicability	Practicability – durability of drone
	Practicability – portability of drone
	Practicability – adaptability of drone
Top management	Top management – top management's knowledge
	Top management – top management's support

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter reveals the research methodology adopted in this study. The research methodology adopted in this study is discussed in subchapter 3.2, while the research design is outlined in subchapter 3.3. The research instrument and the sample design are described in subchapter 3.4 and subchapter 3.5, respectively. The methods of data analysis are discussed in subchapter 3.6. A summary is provided in subchapter 3.7 to wrap up the chapter.

3.2 Research Methodology

Research is a systematic process of searching for pertinent information and detailed study on a specific topic using the scientific method (Kothari, 2004). A research methodology is a path through which the research was conducted by the researcher. The research methodology established the procedures and techniques applied to the field of study to identify, pick, process, and analyse the information (Sileyew, 2019).

There are three methods that a researcher can adopt in a study as a contextual framework to guide the flow of the research, which are the quantitative method, the qualitative method, and the mixed methods. Quantitative research involved the collection and analysis of the quantitative data obtained from a large sample group to test theories and hypothesis to ultimately establish generalisable facts on the research topic, while qualitative research involved the gathering and interpretation of the in-depth insight obtained from a small sample group to explore and formulate new theory and hypothesis on the research topic. A mixed method is the combination of the quantitative and the qualitative method (Creswell and Creswell, 2018).

3.2.1 Quantitative Research

Quantitative research is a process of collecting numerical data using systematic techniques and then evaluating it using statistical methods to derive pertinent insight from the data. Creswell and Creswell (2018) highlighted that in quantitative research, the data are collected through strategies such as experiments and surveys to yield statistical data. The quantitative research methodology is adopted for the study that deals with a large group population. The purpose of conducting quantitative research is to examine the statistical relationship between the variables and generalise findings to represent the population (Apuke, 2017).

A quantitative research methodology is adopted in this study to collect statistical data on the awareness, applications, and the challenges of drone technology from the large group of contracting companies located in the Klang Valley area. The statistical data is collected using questionnaires via email and the LinkedIn platform. Collected data are analysed using Statistical Package for the Social Sciences (SPSS) to derive the findings.

The rationale for choosing the quantitative research approach in this study is because the collection of a large quantity of data is realisable in this approach. Therefore, with the large quantity of data collected, it could present the population more concretely (Giancola and Viteritti, 2014). The validity of the data to represent the population as a whole is crucial to achieve the objectives in this study to determine the awareness, applications, and the challenges of drone technology in the Malaysian construction industry.

3.3 Research Design

A research design is a framework established for a study to ensure the research problem is addressed effectively. Research design can be broadly classified into four main categories: descriptive, explanatory, correlational, or exploratory study. This study is a descriptive study. A descriptive design is a theory-based design method that intended to systematically describe and interpret the problem and situation under the research study. In a descriptive study, there are no attempts made to control or manipulate the variables, but only observes and analyses them (Mertler, 2015). In this study, the data are collected, analysed, and presented to explain the awareness, applications, and the challenges of drone technology in the Malaysian construction industry.

3.4 Research Instrument

The research instrument adopted in this study is a quantitative survey. Questionnaires are distributed to the targeted respondents via Google form through email and the LinkedIn platform. The questionnaire collects quantitative data on the awareness, applications, and challenges towards drone technology adoption in the Malaysian construction industry.

3.4.1 Questionnaire Design

The questionnaire design of this study is developed from the proposed framework in Figure 2.12. The theoretical framework proposed in subchapter 2.11 is adopted to assist the illustration of the questionnaire design, as presented in Figure 3.1.

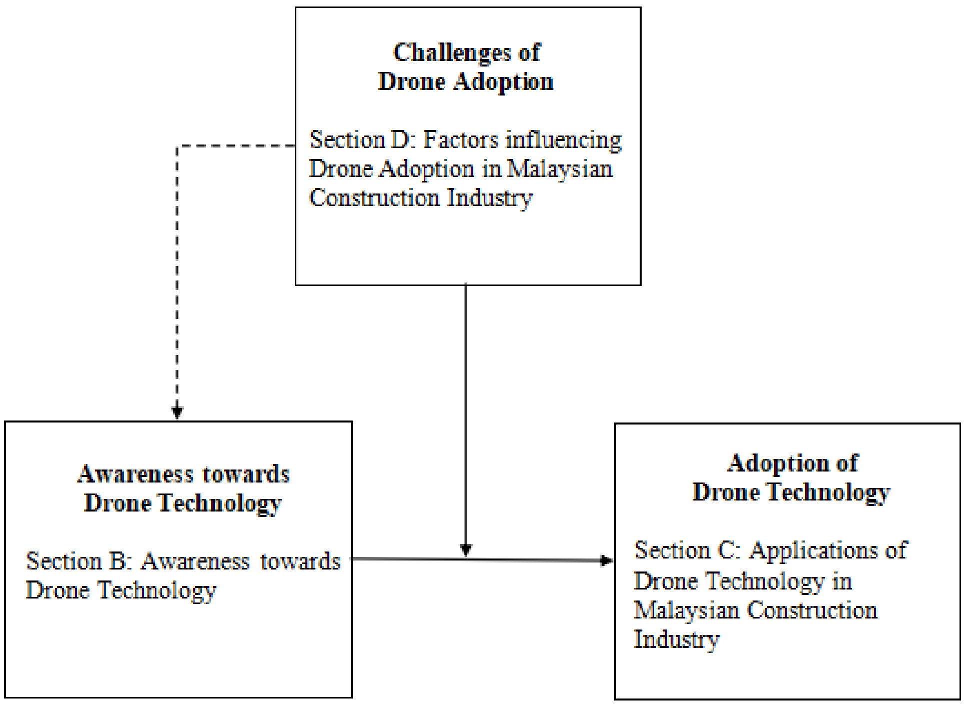

Figure 3.1: Theoretical Framework for Questionnaire Design.

The questionnaire is structured into five sections. Section A collects the demographic profile of the respondents. The demographic profile collected includes respondent's age, working experience, organisation's CIDB contractor-registration, and the nature of the project undertaken. Table 3.1 summarises the demographic data assessed in Section A.

Table 3.1: Respondent’s Demographic Profile Assessed in Section A.

Question	Demographic Profile
1	Age
2	Working experience
3	Organisation’s CIDB contractor-registration
4	Nature of project undertaken

Section B examines the respondent’s awareness towards drone technology. The respondents are required to answer questions related to the frequency and the channel of hearing about drone technology in questions five and six in the questionnaire. Questions seven and eight examine the respondent’s agreement on the nine statements on the applications of drone technology and the 20 statements on the benefits of drone technology.

Table 3.2: Area of Assessment in Section B.

Question	Area of assessment
5	Frequency of hearing about drone technology
6	Channel of hearing about drone technology
7	9 statements on applications of drone technology
8	20 statements on benefits of drone technology

Section C examines the applications of drone technology in the construction industry. This section examines the adoption level of drone technology, years of adoption of drone technology, and the likeliness to advocate drone technology. Moreover, the respondents are required to answer the multiple-choice questions and matrix questions regarding the drone-operating personnel, drone platform and data visualisation software, project utilising drone technology, circumstances driving the adoption of drone technology, and the applications of drone technology.

Section D reveals the challenges of drone adoption in the Malaysian construction industry. The review on the challenges of drone technology in subchapter 2.10 showed 11 challenges that would influence the adoption of drone technology. In the formulation of the questionnaire, the 11 factors are expanded into 18 statements for examinations. This section consists of a matrix question. The respondents are required to rate from no influence to very high influence for these 18 statements pertaining to the factors that would affect drone adoption in the Malaysian construction industry. The data is collected and analysed to identify the factors that would impede drone adoption in the industry.

Lastly, section E consists of an optional open question for the respondents to provide additional comments or suggestions to encourage the adoption of drone technology, increasing the level of awareness, as well as overcoming the challenges of drone adoption in the Malaysian construction industry. The suggestions from the respondents are welcomed and would further value add to the study findings.

3.5 Sample Design

Sample design is the planning of techniques and processes in which a researcher carried out to obtain samples from a large population (Kothari, 2004). Sample design shall be carried out before the data collection to determine the sampling method and sampling size of the study. A well-designated sampling method and sampling size are crucial in determining the power of the study as incompetent sample design would cause the data collected to be less reliable and making it inappropriate in addressing the research problem.

3.5.1 Sampling Method

The sampling method adopted in this study is convenience sampling. A convenience sampling is a non-probability sampling technique in which the member of the population is being chosen randomly from the sample frame based on their availability and accessibility. Convenience sampling is the least time-intensive and the easiest approach for the researcher to collect samples (Bornstein, Jager and Putnick, 2013). In this study, the members of the sample are randomly selected from the list of the contracting companies in the Klang Valley area obtained from the CIDB database. Questionnaires are distributed to the contracting companies that are available and approachable via email and the LinkedIn platform.

3.5.2 Sampling Frame

A sampling frame is the list of individuals in the population from which the sample would be drawn (Greener, 2008). According to Neuman (2014), a sampling frame can be tax records, telephone directories, and driver's license records. A good and accurate sampling frame is the key to accurate sampling as the validity of a sample would be weakened by any mismatch between the population and the sampling frame.

The sampling frame for this study is the list of contracting companies obtained through the Centralized Information Management System (CIMS) of the CIDB. It is the database recording all the contracting companies that have registered with the CIDB.

3.5.3 Sampling Size

The Cochran formula was used to determine the sample size in this study. The confidence level in this study is assumed to be of 95 % (Z = 1.96), while the marginal error is of 5 % (e = 0.05). The maximum variability is assumed to be 50 % (ρ = 0.5). The sampling size of this study is demonstrated in Equation 3.1.

$$n = \frac{Z^2 \rho q}{e^2} \tag{3.1}$$

$$n = \frac{1.96^2(0.5)(1-0.5)}{(0.05)^2} = 384$$

where

n = sampling size

Z = confidence level

ρ = estimated proportion of an attribute in the population

q = 1 - ρ

e = margin of error

3.5.4 Central Limit Theorem (CLT)

The central limit theorem (CLT) states that the distribution of the sample means would approach a normal distribution as the sample size increases. This indicates the mean and standard deviation of the sample is closer in value to the population mean and standard deviation as the sample size increases. This theorem holds for sample sizes over 30, regardless of whether the original variables are skewed or normally distributed. The CLT helps in the accurate prediction of a phenomenon in a population as the average of the sample means would be the population mean (Kozak, 2021).

3.6 Data Analysis

The collected data are integrated into Statistical Package for the Social Sciences (SPSS) to perform further statistical data analysis. In this study, there are four methods of data analysis performed on the collected data, which are Cronbach's alpha reliability test, descriptive analysis, Kruskal-Wallis test, and the Mann-Whitney U test.

3.6.1 Cronbach's Alpha Reliability Test

Cronbach's alpha reliability test is a measure of internal consistency and reliability. It determines how closely these data are related to one another. In this research, Cronbach's alpha reliability tests are carried out to examine the overall reliability of the collected data of the multiple-question Likert scale. The Cronbach's alpha coefficient α reflects the reliability of the data, and it normally ranges between 0.0 and 1.0. The closer the Cronbach's alpha coefficient to 1.0, the greater the reliability of the data. The alpha coefficient value of 0.70 is the benchmark value for the acceptable internal consistency (Gliem and Gliem, 2003). The rule of thumb for Cronbach's Alpha Reliability Test is shown in Table 3.3.

Table 3.3: Rule of Thumb for Cronbach's Alpha Reliability Test.

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

3.6.2 Descriptive Analysis

Descriptive analysis is applied to summarise and give the general overview of the studied samples. A descriptive analysis is conducted to obtain descriptive statistics such as the mean, mode, median, standard deviation, ranking, frequency, and percentage of the collected data (Creswell and Creswell, 2018). Descriptive analysis allows the collected data to be presented in manageable form and eases the visualisation and interpretation of data. In this study, the mean, frequency, and percentage are used to rank the variables.

Means are the measures to determine the level of awareness towards drone technology, the ranking of the applications of drone technology, and the ranking of the challenges of drone adoption in this study. A high mean score indicated high agreement from the respondents. The variables with the highest mean score are ranked as the most significant applications and challenges of drone technology.

The scale used to measure the overall level of awareness towards drone technology is the mean score, as presented in Table 3.4. The scale to measure level of awareness in this study adopted similar settings to the scale in the study of Din, Haron and Ahmad (2013). The authors segregate the level of awareness according to the mean score based on a 6-point likert scale leading to the mean score of 0 to 1.67 which indicates poor level of awareness, mean score of 1.68 to 3.33 representing average level of awareness, and the mean score of 3.34 to 5 for high level of awareness. However, with a 5-point scale adopted in the multiple-choice and matrix questions that examines the awareness towards drone technology in this study, the range of the mean score obtained is between 1 to 5. Dividing the range of mean score into three levels of awareness, a mean score of 1 to 2.33 represents a low level of awareness, while a mean score of 2.34 to 3.67 indicates a moderate level of awareness. A mean score of 3.68 to 5 represents a high level of awareness.

Table 3.4: Scale to Measure Level of Awareness.

Level of Awareness	Mean
Low	1 - 2.33
Moderate	2.34 - 3.67
High	3.68 – 5

3.6.3 Kruskal-Wallis Test

The Kruskal-Wallis test is a test to examine if there is a significant difference among three and more sampling group's parameters, such as median and mean, on a dependent variable. The Kruskal-Wallis test is used to examine non-parametric data which does not follow a normal distribution (Weaver, et al., 2017).

In this study, the Kruskal-Wallis test is conducted to examine if there is any statistically significant difference among the tested respondent groups pertaining to their awareness towards the applications and the benefits of the drone technology. The alpha value adopted for the Kruskal-Wallis test is 0.05. The null hypothesis assumed there is no difference in the awareness across the respondent groups while the alternative hypothesis assumed there is a difference in the awareness across the respondents group.

The decision rule applicable in the Kruskal-Wallis test is the null hypothesis is rejected when the level of significance or known as the asymptotic significance is less than or equal to the alpha value 0.05. This signified there is a significant difference among the respondent groups and there is sufficient evidence in the sample in favour of the alternative hypothesis. However, the null hypothesis is failed to reject if the asymptotic significance level is greater than 0.05. The failure to reject the null hypothesis indicates insufficient evidence to support that alternative hypothesis (Ott and Longnecker, 2001).

3.6.4 Mann-Whitney U Test

The Mann-Whitney U test is a non-parametric test alternative to the parametric two-sample t-test (McDonald, 2014). Identical to the Kruskal-Wallis test, the Mann-Whitney U test is used to examine the existence of significant differences in the mean or median of a non-normally distributed data. However, this test is only applicable to examine the difference between two independent sample groups on a dependent variable (Fagerland and Sandvik, 2009).

The Mann-Whitney U test is conducted in this study to examine the difference in the concerns towards the challenges of drone adoption between the two respondent groups. Mann-Whitney U test applied the same decision rule as the Kruskal-Wallis test, where the null hypothesis is rejected when the asymptotic significance value is less than or equal to 0.05 while the null hypothesis is failed to reject when the asymptotic significance value is greater than 0.05.

3.7 Summary

The research methodology implemented in this study is defined in this chapter. This study is a descriptive study that implemented a quantitative approach to collect quantitative data on the awareness, applications, and challenges of drone technology in the Malaysian construction industry. A questionnaire consisting of five sections is carefully designed to ensure the inclusion of relevant questions towards achieving the objectives of the study. Convenience sampling is adopted for the sample's selection, based on the contracting companies located within the Klang Valley area. Lastly, several analysis techniques such as the Cronbach's alpha reliability test, descriptive analysis, Kruskal-Wallis test, and Mann-Whitney U test are conducted in interpreting the collected data into useful information.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The findings of the surveys were analysed and reported in this chapter. The data collected from the surveys are systematically rearranged and processed using the Statistical Package for the Social Science (SPSS) to obtain meaningful information for discussion. The survey response analysis is presented in subchapter 4.2, followed by the reporting on the respondent's profile in subchapter 4.3. The awareness towards drone technology, the applications of drone technology, and the challenges on drone adoption are discussed in subchapter 4.4, subchapter 4.5, and subchapter 4.6, respectively. Subchapter 4.7 presents the additional comments and suggestions by the respondents on drone technology, and subsequently, followed by a conclusion in subchapter 4.8.

4.2 Survey Response Analysis

In this study, a total of 450 questionnaires were disseminated to the contracting companies in the Klang Valley area through email and the LinkedIn platform. The response rate of the survey is tabulated in Table 4.1. The survey was conducted for approximately five weeks, starting from 26 January 2021 until 1 March 2021. Among the 450 questionnaires distributed, only 123 returned responses, where 58 responses were from the emails and 65 responses were from the LinkedIn platform. The overall response rate for the survey was 27.33 %. Although the response size of 123 responses does not achieve the predetermined sample size of 384 responses, it is still valid to represent the population. It is because the sample size has achieved the requirement of equal to or greater than 30 samples for the central limit theorem to hold.

Table 4.1: Response Rate of the Survey.

Distribution Method	Distributed	Collected	Response Rate (%)
Email	200	58	29.00
LinkedIn	250	65	26.00
Total	450	123	27.33

4.3 Respondents' Profile

The demographic profile of the respondents is summarised in Table 4.2. The demographic data collected are the age, working experience, CIDB contractor-registration, and the types of the project undertaken.

Table 4.2: Demographic Profile of the Respondents.

General Information	Categories	Frequency (*n*)	Percentage (%)
Age	Below 25 years old	34	27.60
	25 - 34 years old	51	41.50
	35 - 44 years old	30	24.40
	45 - 54 years old	6	4.90
	55 - 64 years old	2	1.60
Working Experience	Less than 3 years	40	32.50
	3 -5 years	22	17.90
	6 - 8 years	28	22.80
	9 years and above	33	26.80
CIDB Contractor-Registration	Grade 1	9	7.31
	Grade 2	4	3.25
	Grade 3	6	4.88
	Grade 4	7	5.69
	Grade 5	26	21.14
	Grade 6	29	23.58
	Grade 7	42	34.15
Types of Project	Residential Development	88	71.54
	Commercial Development	75	60.98
	Mix-used Development	65	52.85

Table 4.2 (Continued)

	Industrial Development	59	49.97
	Infrastructure Development	36	29.97

The majority of the respondents are aged between 25 to 34 years old (51 respondents, 41.50 %). There are 34 respondents (27.60 %) who are aged below 25 years old and 30 respondents (24.40 %) aged between 35 to 44 years old. The responses from the respondents aged above 45 years old are relatively less in this survey, where there are only six responses (4.90 %) collected from individuals aged between 45 to 54 years old, and two responses (1.60 %) from the individuals aged between 55 to 64 years old.

When it comes to working experience in the construction industry, the majority of the respondents (40 respondents, 32.50 %) are having fewer than three years of working experience. There are 33 respondents (26.80 %) who have nine years and above working experience in the industry, followed by 28 respondents (22.80 %) with six to eight years of working experience, and 22 respondents (17.90 %) with three to five years of working experience.

Among the contracting companies in the Klang Valley area, most of the returned responses came from Grade 7 contracting companies, with 42 responses (34.15 %). Grade 5 and Grade 6 contracting companies also demonstrated an active participation in the survey, where 29 responses (23.58 %) were obtained from Grade 6 and 26 responses (21.24 %) were obtained from Grade 5 contracting companies. The response rate was relatively low among the Grade 1 to Grade 4 contracting companies.

The most common types of projects undertaken by the companies are residential development (88 respondents, 71.54 %), followed by the commercial development (75 respondents, 60.98 %), and the mix-used development (65 respondents, 52.85 %). Among the 123 responses collected, 59 respondents (49.97 %) were involved in industrial development, and 36 respondents (29.97 %) who were involved in infrastructure development.

4.4 Awareness towards Drone Technology

This subchapter outlined the analysis performed to examine the awareness towards drone technology in the construction industry. The awareness towards drone technology in the construction industry was examined from three aspects, which is if the respondents have heard of drone technology and if the respondents are aware of the applications and benefits of drone technology in the construction industry.

4.4.1 Frequency of Hearing about Drone Technology in the Construction Industry

Table 4.3 summarised the frequency of hearing about drone technology among the respondents. Out of 123 respondents, 45 respondents (36.59 %) have occasionally heard about the usage of drone technology in the construction industry. There are 32 respondents (26.02 %) who responded that they have often heard about drone technology and only 7 respondents (5.69 %) have always heard about drone technology. As compared to the respondents who have sometimes, often, and always heard about drone technology, there is a comparatively low percentage of respondents who have rarely (35 respondents, 28.45 %) and never (4 respondents, 3.25 %) heard about drone technology. The mean of 3.02 indicated the respondents have a moderate level of awareness towards drone technology as the majority of the respondents have just sometimes heard about drone technology.

Table 4.3: Frequency of Hearing about Drone Technology.

Frequency of hearing about drone technology	Frequency (*n*)	Percentage (%)	Mean
Never	4	3.25	3.02
Rarely	35	28.45	
Sometimes	45	36.59	
Often	32	26.02	
Always	7	5.69	

Table 4.4 summarised the channel of hearing about drone technology by the respondents. The internet is the most common channel where the respondents heard about drone technology, where 109 respondents (88.62 %) have reported that they get to know drone technology through the internet such

as search engines and social media. Most of the people nowadays own electronic devices such as a smartphone, laptop computer, desktop computer, or a tablet computer. Since people are now always connected to social media, the internet is the primary channel conveying drone-related information to the public. One respondent (0.81 %) responded that she gets to know drone technology during the project progress reporting. Drones have been actively adopted by the construction industry for construction monitoring and reporting (Anwar, Izhar, and Najam, 2018).

Table 4.4: Channel of Hearing about Drone Technology.

Channel of hearing	Frequency (*n*)	Percentage (%)
Internet (Search Engines, Social Media, etc.)	109	88.62
Word of Mouth	62	50.41
Advertisement (Promotional Videos, Television, etc.)	52	42.28
Event (Webinar, Seminar, etc.)	32	26.83
Project Progress Reporting	1	0.81

4.4.2 Awareness towards the Applications of Drone Technology

The respondents' agreements towards the nine applications of drone technology were analysed to examine their awareness towards the applications of drone technology. Table 4.5 presented the mean of the agreements towards the applications of drone technology in the construction industry. The Cronbach's Alpha reliability test conducted on the nine statements of drone applications showed a Cronbach Alpha value of 0.902, indicating an excellent internal consistency and reliability of the data. The average mean of 3.75 indicated that the respondents are highly aware of the applications of drone technology. Refer to Table 4.5, the top three applications of drone technology with the most agreement from the respondents are:

(i) Progress Monitoring (Mean = 4.22).
(ii) Safety Inspection (Mean = 3.96).
(iii) Security Surveillance (Mean = 3.85).

Table 4.5: Mean of the Agreements towards the Applications of Drone Technology in the Malaysian Construction Industry.

Applications of Drone Technology	Rank	Mean	Average Mean
Progress Monitoring	1	4.22	3.75
Safety Inspection	2	3.96	
Security Surveillance	3	3.85	
Pre-construction Topographic Survey	4	3.80	
Earthwork Survey and Analysis	5	3.75	
Structure Inspection	6	3.70	
Inventory Tracking	7	3.57	
Post-construction Maintenance Inspection	8	3.56	
Pre-construction Planning and Design	9	3.36	

Kruskal-Wallis test was conducted to examine if there is a statistically significant difference in the awareness towards the applications of drone technology between the three age groups “below 25 years old”, “25 to 34 years old”, and “35 to 44 years old”. The age groups “45 to 54 years old” and “55 to 64 years old” was not examined because the collected response size of six and two respondents, respectively, does not meet the sufficient requirement of 30 sample size for the central limit theorem to hold. The hypotheses generated are:

(i) Null Hypothesis (H_0): There is no difference between age groups in the awareness towards the applications of drone technology in the construction industry.

(ii) Alternative Hypothesis (H_1): There is a difference between age groups in the awareness towards the applications of drone technology in the construction industry.

The alpha value adopted is 0.05 with two degrees of freedom. The null hypothesis is rejected when an asymptotic significance value less than or equal to 0.05 is obtained. It indicated a statistically significant difference in the result. Table 4.6 summarised the outcome of the Kruskal-Wallis test on the awareness towards applications of drone technology across the age groups.

Table 4.6: Kruskal-Wallis Test on the Awareness towards Applications of Drone Technology.

Applications	Below 25 years old (*n* = 34)		25 - 34 years old (*n* = 51)		35 - 44 years old (*n* = 30)		Asymp. Sig.
	Mean Rank	Rank	Mean Rank	Rank	Mean Rank	Rank	
Pre-construction Topographic Survey	45.90	9	66.00	4	58.12	2	0.015*
Pre-construction Planning and Design	58.16	1	64.67	6	46.48	9	0.045*
Earthwork Survey and Analysis	46.68	8	64.65	7	59.53	1	0.037*
Progress Monitoring	49.12	6	64.20	8	57.53	3	0.086
Safety Inspection	54.87	2	61.25	9	56.03	5	0.604
Security Surveillance	48.68	7	65.18	5	56.37	4	0.058
Structure Inspection	49.43	5	66.94	1	52.52	6	0.026*
Inventory Tracking	54.54	3	66.13	3	48.10	8	0.038*
Post-construction Maintenance Inspection	53.57	4	66.28	2	49.17	7	0.037*
Average Mean Rank	51.22	-	65.03	-	53.76	-	-

Note: * indicates the mean rank difference is significant at 0.05 significance level.

The results showed that there is a statistically significant difference in the awareness across the age groups towards the applications of drone technology in:

(i) Pre-construction topographic survey (Asymp. Sig. = 0.015).

(ii) Pre-construction planning and design (Asymp. Sig. = 0.045).

(iii) Earthwork survey and analysis (Asymp. Sig. = 0.037).

(iv) Structure inspection (Asymp. Sig. = 0.026).

(v) Inventory tracking (Asymp. Sig. = 0.038).

(vi) Post-construction maintenance inspection (Asymp. Sig. = 0.037).

The null hypothesis is rejected since the asymptotic significance values are less than the alpha value of 0.05. It provides sufficient strong evidence to conclude that there is a statistically significant difference in the awareness across the age groups towards the mentioned six applications of drone technology.

The null hypothesis on the respondents' awareness towards applications of drone technology in progress monitoring, safety inspection, and security surveillance is failed to reject and showed no significant difference because the asymptotic significance value of the results is greater than 0.05. It is deduced that there is no significant difference in the respondents’ awareness towards the three mentioned applications of drone technology because the respondents experienced about the same exposure to the information on the applications. According to the review done by Mosly (2017), between 2014 and 2017, there are at least 29 articles concerning the applications of drone technology in progress monitoring, safety inspection, and security surveillance were published. Although the other applications of drone technology such as pre-construction topographic survey, earthwork analysis and survey, and many others, have also been widely discussed in the literature, it is perceived the exposure to the related literature varies between different age groups of respondents as different individuals between different age groups are having a different level of engagement to the internet. Therefore, the awareness of the respondents towards the applications showed a significant difference across the age groups.

The Kruskal-Wallis test revealed that the respondents aged between "25 to 34 years old" demonstrated a significant high awareness towards the applications of drone technology. According to the statistics from the Department of Statistics Malaysia, individuals aged between "25 to 34 years old" formed the largest working population group in Malaysia (DOSM, 2020). These respondents are the millennials who actively work in the construction industry. They are intensely committed to personal growth and desire to keep learning for rapid career growth (PwC, 2011). Therefore, these respondents always keep themselves updated with the new technology that emerged in the construction industry.

The results also revealed that the respondents aged "below 25 years old" demonstrated a significantly lower awareness than the respondents aged between "35 to 44 years old" towards the applications of drone technology in pre-construction topographic survey, earthwork survey and analysis, and structure inspection. It may be due to the incapability of the respondents to visualise the applications of drone technology. The respondents aged "below 25 years old" are recent graduates who have recently entered the construction industry. They are yet to familiarise themselves with the industry's practice. Therefore, it is hard for these respondents to visualise the applications of drone technology.

The respondents aged between "35 to 44 years old" demonstrated a significantly lower awareness than the respondents aged "below 25 years old" towards the three applications of drone technology, which are pre-construction planning and design, inventory tracking, and post-construction maintenance inspection. Most of the respondents under this age group have been long working in the construction industry. They normally have formed their own work habit. They might prefer the traditional way to carry out pre-construction planning and design, inventory tracking, and post-construction maintenance inspection. Thus, the respondents aged "35 to 34 years old" see drone technology less significant in the applications of pre-construction planning and design, inventory tracking, and post-construction maintenance inspection.

Based on the average mean rank, the age group possessed the highest awareness on the applications of drone technology is the respondents aged "25 to 34 years old" (average mean rank = 65.03), followed by respondents aged

"35 to 44 years old" (average mean rank =53.76) while the respondents aged "below 25 years old" (average mean rank = 51.22) possessed the lowest awareness on the applications of drone technology. The reason that gives rise to the result is due to the variance in the frequency of hearing about drone technology among the respondents in each age group. The frequency of hearing about drone technology in the different age groups is tabulated in Table 4.7.

Table 4.7: Frequency of Hearing about Drone Technology in the Construction Industry across Different Age Groups.

Age Group	Frequency of Hearing	Number of Respondents (*n*)
Below 25 years old	Never	3
	Rarely	13
	Sometimes	14
	Often	4
	Always	0
	Total	34
25 - 34 years old	Never	0
	Rarely	10
	Sometimes	17
	Often	21
	Always	3
	Total	51
35 - 44 years old	Never	0
	Rarely	10
	Sometimes	11
	Often	6
	Always	3
	Total	30

It is observed that the respondents aged "below 25 years old" have rarely heard about drone technology as compared to the other two age groups, where only four respondents have often heard about drone technology. There are also three respondents in this age group who have never heard about drone technology before. Whereas, among the respondents aged "35 to 44 years old", it is reported that nine of the respondents have often and always heard about drone technology. The frequency of hearing of drone technology is reported the highest in respondents aged "25 to 34 years old" where 24 respondents have often and always heard about drone technology.

Since most of the respondents aged "below 25 years old" have rarely heard about drone technology as compared to the other age groups, the respondent's awareness towards the application of drone technology is, therefore, the lowest among the three tested age groups. Moreover, since the respondents aged "25 to 34 years old" have more often heard about drones than the respondents aged "35 to 44 years old", it therefore perceived a higher awareness towards the applications of drone technology.

4.4.3 Awareness towards the Benefits of Drone Technology

Table 4.8 summarised the mean towards the agreements reached by the respondents towards the 20 statements of the benefits of drone technology. The data is excellently internally consistent with a Cronbach Alpha value of 0.912. The average mean of 3.87 indicated a high level of awareness among the respondents towards the benefits of drone technology. Based on Table 4.8, the top three benefits of drone technology which received the highest agreement from the respondents are:

(i) Improved jobsite communication - real-time jobsite monitoring and site inspection (Mean = 4.15).

(ii) Better jobsite photo documentation - consistent jobsite progress photo capture (Mean = 4.15).

(iii) Worker safety - reduction of inspection risk on hard-to-reach area (Mean = 4.13).

Table 4.8: Mean of the Agreements on the Benefits of Drone Technology in the Construction Industry.

Benefits of Drone Technology	Rank	Mean	Average Mean
Improved jobsite communication - real-time jobsite monitoring and site inspection	1	4.15	3.87
Better jobsite photo documentation - consistent jobsite progress photo capture	1	4.15	
Worker safety - reduction of inspection risk on hard-to-reach area	3	4.13	
Improved stakeholder communication - on-demand visual imagery through cloud-based platform	4	4.07	
Site security - regular drone security patrol over the site	5	4.05	
Time saving - efficient data collection and reporting	6	3.95	
Time saving - reduce field time	7	3.94	
Dispute reconciliation - drone data and imagery provide clear evidence against the mistake	7	3.94	
Cost saving - prevent costly misaligned construction	9	3.86	
Worker safety - early safety hazard identification	10	3.80	
Better post-project documentation - assessment on the documented changes and visual imagery captured by drone for future construction quality improvement benchmarking	10	3.80	
Site security - early fire hazard identification through thermal camera mounted drone	12	3.79	
Cost saving - early construction deviation detection	13	3.77	

Table 4.8 (Continued)

Benefits of Drone Technology	Rank	Mean	Average Mean
Cost saving - reduction of surveying expenses	14	3.76	
Time saving - enable faster decision making	15	3.75	
High accuracy - reduce the need for re-work and re-measurement	16	3.73	
Dispute avoidance - early information discrepancy detection through pre-construction topographic survey	16	3.73	
Business competitiveness - enable better workflow management	18	3.71	
Business competitiveness - enable contractor to make ambitious bids	19	3.63	
High accuracy - reduction of human error in data collection	20	3.61	

Kruskal-Wallis test was conducted to examine if there is a statistically significant difference in the awareness towards the benefits of drone technology in the construction industry between the three age groups “below 25 years old”, “25 to 34 years old”, and “35 to 44 years old”. The null hypotheses generated for the Kruskal-Wallis test are:

(i) Null Hypothesis (H_0): There is no difference between age groups in the awareness towards the benefits of drone technology in the construction industry.

(ii) Alternative Hypothesis (H_1): There is a difference between age groups in the awareness towards the benefits of drone technology in the construction industry.

The alpha value adopted is 0.05 with two degrees of freedom. The null hypothesis is rejected when an asymptotic significance value less than or equal to 0.05 is obtained. It indicated a statistically significant difference in the result.

The outcome of the Kruskal-Wallis test on the awareness towards benefits of drone technology across the age groups is summarised in Table 4.9.

Table 4.9: Kruskal-Wallis Test on the Awareness towards Benefits of Drone Technology.

No	Benefits	Below 25 years old (n = 34)		25 - 34 years old (n = 51)		35 - 44 years old (n = 30)		Asymp. Sig.
		Mean Rank	Rank	Mean Rank	Rank	Mean Rank	Rank	
1	Cost saving - prevent costly misaligned construction	46.56	18	65.71	8	57.87	4	0.021*
2	Cost saving - reduction of surveying expenses	51.84	9	63.34	18	55.90	9	0.224
3	Cost saving - early construction deviation detection	43.93	20	66.65	3	59.25	1	0.004*
4	Time saving - reduce field time	50.10	13	65.37	12	54.42	10	0.063
5	Time saving - efficient data collection and reporting	51.29	10	64.80	15	54.03	11	0.099
6	Time saving - enable faster decision making	53.18	6	67.51	2	47.30	20	0.010*
7	Worker safety - reduction of inspection risk on hard-to-reach area	52.44	8	64.21	16	53.75	12	0.131
8	Worker safety - early safety hazard identification	47.49	16	65.38	11	57.37	6	0.027*

Note: * indicates the mean rank difference is significant at 0.05 significance level.

Table 4.9 (Continued)

No	Benefits	Below 25 years old (*n* = 34)		25 - 34 years old (*n* = 51)		35 - 44 years old (*n* = 30)		Asymp. Sig.
		Mean Rank	Rank	Mean Rank	Rank	Mean Rank	Rank	
9	Site security - regular drone security patrol over the site	45.71	19	66.59	4	57.33	7	0.007*
10	Site security - early fire hazard identification through thermal camera mounted drone	51.15	11	65.86	7	52.40	13	0.049*
11	High accuracy - reduction of human error in data collection	49.94	14	68.25	1	51.97	14	0.007*
12	High accuracy - reduce the need for re-work and re-measurement	55.65	3	65.43	10	48.03	18	0.048*
13	Improved stakeholder communication - on-demand visual imagery through cloud-based platform	51.07	12	62.56	9	58.10	3	0.248
14	Improved jobsite communication - real-time jobsite monitoring and site inspection	56.22	1	63.33	19	50.95	15	0.177

Note: * indicates the mean rank difference is significant at 0.05 significance level.

Table 4.9 (Continued)

No	Benefits	Below 25 years old (*n* = 34)		25 – 34 years old (*n* = 51)		35 – 44 years old (*n* = 30)		Asymp. Sig.
		Mean Rank	Rank	Mean Rank	Rank	Mean Rank	Rank	
15	Better jobsite photo documentation – consistent jobsite progress photo capture	55.84	2	63.64	17	50.87	16	0.157
16	Better post-project documentation – assessment on the documented changes and visual imagery captured by drone for future construction quality improvement benchmarking	47.19	17	64.96	14	58.43	2	0.038*
17	Dispute avoidance – early information discrepancy detection through pre-construction topographic survey	53.72	5	66.17	6	48.97	17	0.031*
18	Dispute reconciliation – drone data and imagery provide clear evidence against the mistake	53.09	7	62.32	20	56.22	8	0.350
19	Business competitiveness – enable contractor to make ambitious bids	54.31	4	66.40	5	47.90	19	0.026*

Note: * indicates the mean rank difference is significant at 0.05 significance level.

Table 4.9 (Continued)

No	Benefits	Below 25 years old (*n* = 34)		25 - 34 years old (*n* = 51)		35 - 44 years old (*n* = 30)		Asymp. Sig.
		Mean Rank	Rank	Mean Rank	Rank	Mean Rank	Rank	
20	Business competitiveness - enable better workflow management	47.66	15	65.05	13	57.73	5	0.036*
	Average Mean Rank	50.92	-	65.18	-	53.94	-	-

Note: * indicates the mean rank difference is significant at 0.05 significance level.

The results showed that there is a statistically significant difference in the awareness across the age groups towards the benefits of drone technology, except for the benefits of drone technology in:

(i) Cost saving - reduction of surveying expense (Asymp. Sig. = 0.224).

(ii) Time saving - reduce field time (Asymp. Sig. = 0.063).

(iii) Time saving - efficient data collection and reporting (Asymp. Sig. = 0.099).

(iv) Worker safety - reduction of inspection risk on hard-to-reach area (Asymp. Sig. = 0.131).

(v) Improved stakeholder communication - on-demand visual imagery through cloud-based platform (Asymp. Sig. = 0.248).

(vi) Improved jobsite communication - real-time jobsite monitoring and site inspection (Asymp. Sig. = 0.177).

(vii) Better jobsite photo documentation - consistent jobsite progress photo capture (Asymp. Sig. = 0.157).

(viii) Dispute reconciliation - drone data and imagery provide clear evidence against the mistake (Asymp. Sig. = 0.350).

The null hypothesis of these eight statements of benefits is failed to reject as the asymptotic significance value is more than the alpha value of 0.05, thus there is no sufficient strong evidence to reject the null hypothesis and to conclude that the awareness across the age groups towards the eight statements of benefits of drone technology is different. However, the null hypothesis for the remaining 12 statements pertaining to the benefits of drone technology is rejected as the asymptotic significance value obtained is lesser than 0.05.

There is no significant difference in the awareness across the age groups towards the eight benefits of drone technology because the respondents perceived about the same agreement towards the eight benefits of drone technology. This may because they have heard or get to know that the eight benefits have been reap by the drone adopters in the construction industry. Therefore, they are more aware of the benefits. Moreover, it can be deduced that the respondents are holding similar expectations to reap the eight benefits when they adopt drone technology. The discussions on the respective eight benefits of drone technology can be referred at subchapter 2.9.

The outcome of the Kruskal-Wallis test also revealed that the respondents aged “25 to 34 years old” perceived the highest awareness towards the benefits of drone technology (average mean rank = 65.18), followed by respondents aged “35 to 44 years old” (average mean rank = 53.94). The respondents aged “below 25 years old” possessed the lowest awareness (average mean rank = 50.92) towards the benefits of drone technology. As previously discussed in subchapter 4.4.2, drone technology is less heard of by the respondents aged “below 25 years old” as compared to the respondents aged between “25 to 34 years old” and “35 to 44 years old”. Therefore, they perceived the lowest awareness towards the benefits of drone technology. The details on the frequency of hearing about drone technology across the age groups can be referred to Table 4.7.

4.4.4 Overall Awareness towards Drone Technology

Table 4.10 summarised the respondent’s awareness on the frequency of hearing, the applications, and the benefits of drone technology, examined in subchapter 4.4.1 to 4.4.3. The respondent’s level of awareness is high towards the applications and benefits of drone technology but moderate on the frequency of hearing about drone technology. However, based on the overall average mean of 3.55, the overall awareness of the respondents towards drone technology is of moderate level.

Table 4.10: Summary on Level of Awareness towards Drone Technology.

Area of Assessment	Mean	Level of Awareness
Frequency of Hearing about Drone Technology	3.02	Moderate
Awareness towards Applications of Drone Technology	3.75	High
Awareness towards Benefits of Drone Technology	3.87	High
Overall Level of Awareness	3.55	Moderate

4.5 Applications of Drone Technology

Subchapter 4.5 outlined the applications of drone technology in the Malaysian construction industry. The respondent's response on drone adoption level, likeliness to advocate drone technology, drone-operating personnel, drone platform and data visualisation software, projects utilising drone, circumstances driving the adoption of drone, and the applications of drone technology in the Malaysian construction industry are discussed in the following subchapters.

4.5.1 Drone Adoption Level

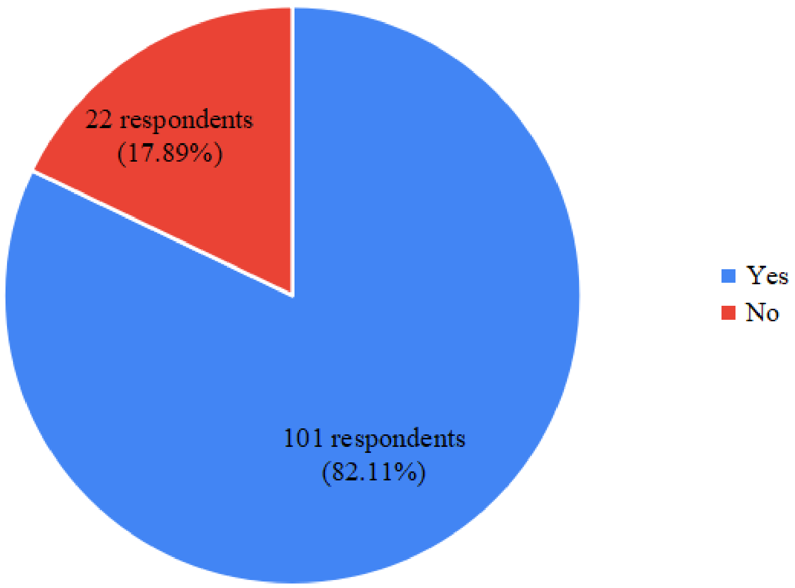

Figure 4.1: Drone Adoption Level in the Malaysian Construction Industry.

Based on Figure 4.1, 101 respondents (82.11 %) have not adopted drone technology while 22 respondents (17.89 %) have adopted drone technology. Further analysis was conducted on the 22 respondents who have adopted drone technology. The general information of the respondents who have adopted drone technology is tabulated in Table 4.11.

Table 4.11: General Information of the Respondents who have Adopted Drone Technology.

General Information	Categories	Frequency (*n*)	Percentage (%)
CIDB Contractor-Registration	Grade 5	2	9.09
	Grade 6	6	27.27
	Grade 7	14	63.64
Years of Drone Adoption	Less than 1 year	6	27.27
	Less than 2 years	4	18.18
	2 years and above	12	54.55

Based on Table 4.11, Grade 7 contracting companies have formed the most significant group who have adopted drone technology, where 17 out of the 22 respondents (63.64 %) who have adopted drone technology were from Grade 7 contracting companies. The remaining respondents who have adopted drone technology were from Grade 6 contracting companies (6 respondents, 27.27 %) and Grade 5 contracting companies (2 respondents, 9.09 %). A total of 12 companies (54.55 %) have adopted drones for two years and above, while six companies (27.27 %) and four companies (18.18 %) have adopted drone technology for less than one year and less than two years, respectively.

It is observed that the early adopters of drone technology tend to come from large-sized contracting companies (Grade 7 and 6). The early adopters of technology are commonly the leading contracting companies who have high social status and fair access to finances. Large-sized companies are always looking for differentiation strategies by technology adoption and the company leaders are visionaries to invest in new technology (Ayob, 2017).

4.5.2 Likeliness to Advocate Drone Technology

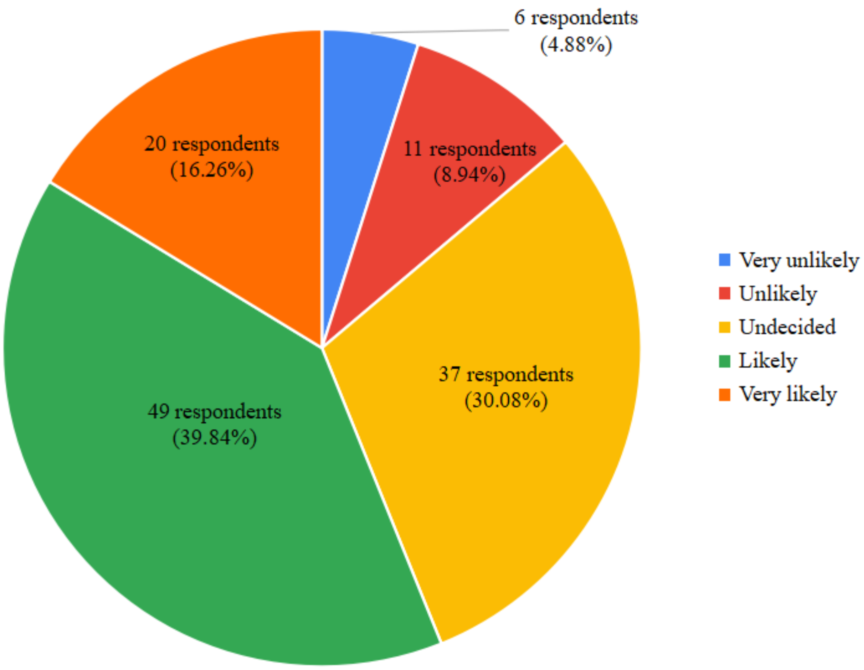

Figure 4.2: Likeliness to Advocate Drone Technology.

Figure 4.2 presents the respondents' likeliness to advocate drone technology. Based on the collected responses, the respondents can be further categorised into the respective segment of adopters in the technology adoption life cycle proposed by Rogers (1962). According to the social system proposed by Rogers (1962), the technology adopters can be categorised into five categories, which are the innovators, early adopters, early majority, late majority, and laggards. Every segment of innovation adopter showed different personality traits that influenced the degree to which an individual would adopt a new technology comparatively early than other members of the social system.

Based on Figure 4.2, the majority of the respondents hold a positive attitude towards drone adoption, where 49 respondents (39.84 %) are likely to advocate drone technology and 20 respondents (16.26 %) are very likely to advocate drone technology. These respondents are not the innovators. They showed a trait as the early adopters, where they are visionaries, more social forward, and adventurous to take high risk to try on new technology (Interaction Design Foundation, 2020).

Moreover, 37 respondents (30.08 %) are still undecided to advocate drone technology. These respondents may be the early majority drone adopters in the future mainstream market. Although these mainstream adopters may share some ability to relate to the technology, they are usually pragmatic and would not be willing to take the risk as the early technology adopters are (Weitzel, 2019). The organisation in the mainstream market would generally adopt a wait-and-see approach to technology adoption until the benefits of the technology are demonstrated and confirmed by the early adopters.

Several respondents showed their unlikeliness to adopt drone technology, where 11 respondents (8.94 %) are unlikely, and six respondents (4.88 %) are very unlikely to advocate drone technology. These respondents are the late majority and the laggards in technology adoption. The late majority adopter and the laggards are generally individuals with a low social and economic status who are sceptical of change and more bound to traditional ways of doing work (LaMorte, 2019).

Further analysis was conducted on the 22 respondents who have adopted drone technology to examine their likeliness to advocate drone technology. The observations are tabulated in Table 4.12.

Table 4.12: Likeliness to Advocate Drone Technology of the Respondents who have adopted Drone Technology.

Likeliness	Frequency (*n*)	Percentage (%)
Likely	12	54.55
Very likely	10	45.45

All of the 22 respondents who have adopted drone technology showed the likeliness to advocate drone technology, where 12 respondents (54.55%) are likely, and ten respondents are very likely (45.45 %) to advocate drone technology. The respondents are having a positive attitude towards drone technology because they have a good experience with the usage of drone technology. This statement is supported by the findings by Deng, et al. (2010), satisfaction would drive continuance intention on the usage of IT.

4.5.3 Drone-Operating Personnel

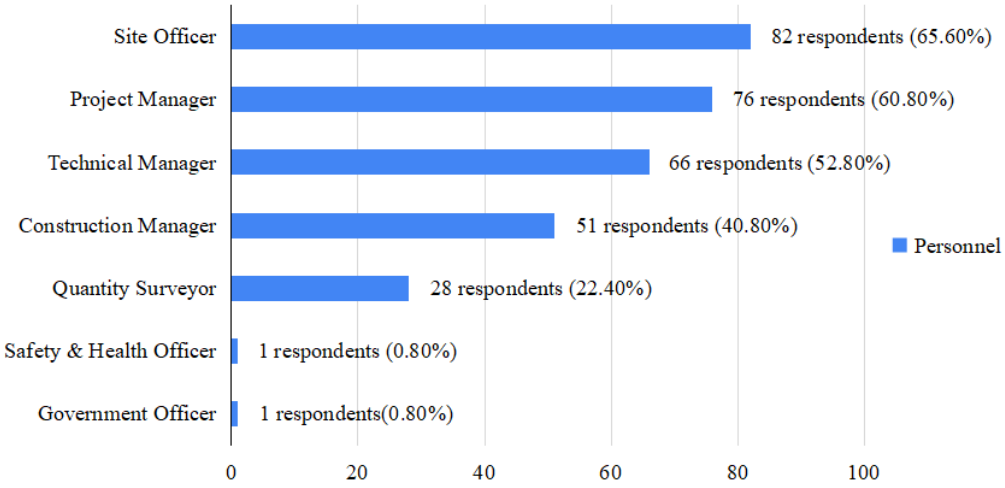

Figure 4.3: Rating on Drone-Operating Personnel.

Figure 4.3 illustrated the respondent's ratings on the drone-operating personnel in a construction project. There are 82 respondents (65.60 %) who believe that the site officer is the person who usually operates drones in a construction project. The rating on the drone-operating personnel is followed by project manager (76 respondents, 60.80 %), technical manager (66 respondents, 52.80 %), construction manager (52 respondents, 40.80 %), and quantity surveyor (28 respondents, 22.40 %). One respondent (0.80 %) believed that the health and safety officer would be operating drones in a construction project. Moreover, one respondent (0.80 %) believed that drones are operated by government officers. Further analysis was performed on the 22 contracting companies that have adopted drone technology to identify the person who operates drones in the companies. The results are tabulated in Table 4.13.

Table 4.13: Drone Operating Personnel in the Drone-Adopting Contracting Companies.

Personnel	Frequency (*n*)	Percentage (%)
Project Manager	17	77.27
Site Officer	15	68.18
Technical Manager	13	59.09
Construction Manager	10	45.45
Quantity Surveyor	8	36.36
Safety & Health Officer	1	4.55

As tabulated in Table 4.13, in the current applications of drone technology, a drone is normally operated by the project manager, as reported by 17 respondents (77.27 %) who have adopted drone technology. DroneDeploy (2018a) has reported that project managers are the primary person who led the operation of drones in the construction work site. A project manager is responsible for the day-to-day project operations and management. A project manager could through the usage of drones, efficiently and effectively track and monitor the project progress and make informed decisions to keep the project on track (Invonto, 2019).

4.5.4 Drone Platform and Data Visualisation Software

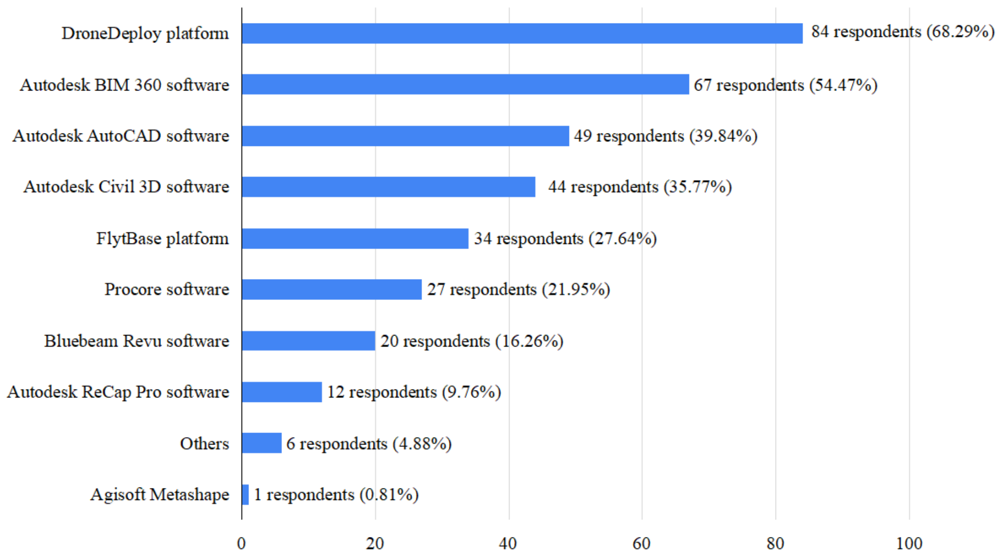

Figure 4.4: Rating on Drone Platform and Data Visualisation Software.

Figure 4.4 illustrated the respondent's opinions on the platform and data visualisation software that are usually integrated with the drone technology. The DroneDeploy platform received the highest agreement from the respondents, where a total of 84 respondents (68.29 %) perceived that the DroneDeploy platform was the most commonly used platform integrated with the usage of drone. The drone data visualisation software which received the highest agreement from the respondents is the Autodesk BIM 360 software. Moreover, among the 123 respondents, six respondents (4.88 %) said that they are clueless about the types of platform and software integrated with drone technology. These six respondents are the respondents who are "never" and "rarely" heard of drone technology before, and they therefore lack knowledge on the drone platform and data visualisation software.

Further analysis was performed on the 22 respondents who have adopted drone technology to examine the drone platform and data visualisation software that have been currently utilised by the industry with the operation of drones. The results are tabulated in Table 4.14.

Table 4.14: Drone Platform and Data Visualisation Software Currently Adopted by the Drone-Adopting Contracting Companies.

Drone Platform and Data Visualisation Software	Frequency (*n*)	Percentage (%)
DroneDeploy platform	18	81.82
Autodesk AutoCAD software	17	77.27
Autodesk BIM 360 software	16	72.73
Autodesk Civil 3D software	15	68.18
Procore software	8	36.36
Autodesk ReCap Pro software	7	31.82
FlytBase platform	5	22.73
Bluebeam Revu software	5	22.73
Agisoft Metashape	1	4.55

The DroneDeploy platform was rated the most commonly used drone platform among the respondents (18 respondents, 81.82 %) who have adopted drone technology. Moreover, one respondent reported that their organisation has utilised Agisoft Metashape software in the operation of drones to generate 3D spatial data. Among the data visualisation software, Autodesk AutoCAD is the most commonly used software among the respondents who have used drones, where 17 respondents (77.27 %) have used Autodesk AutoCAD software for drone data visualisation. As reported by DroneDeploy (2018a), the most commonly used leading software by the DroneDeploy users for drone maps and models was the Autodesk AutoCAD software. The outcome of this survey reflected that Autodesk AutoCAD is the most commonly used drone data visualisation software, and this outcome is in line with the finding by DroneDeploy (2018a).

4.5.5 Project Utilising Drone Technology

Table 4.15 tabulated the mean on the types of projects where drone is utilised. Meanwhile, the mean on the types of projects where drone is utilised by drone-adopting contracting companies are tabulated in Table 4.16.

Table 4.15: Mean on the Types of Project Utilising Drone Technology.

Types of Project	Rank	Mean
Infrastructure Development	1	3.95
Industrial Development	2	3.77
Mix-used Development	3	3.56
Commercial Development	4	3.33
Residential Development	5	3.13

Table 4.16: Mean on Types of Projects Utilising Drone Technology by Drone-Adopting Contracting Companies.

Types of Project	Frequency (*n*)	Rank	Mean
Residential Development	16	1	4.36
Mix-used Development	11	2	4.09
Commercial Development	14	3	4.05
Industrial Development	12	4	3.91
Infrastructure Development	12	5	3.77

Refer on Table 4.15, most of the respondents perceived drone technology is utilised in infrastructure development, where the characteristics of the constructions are comparatively complex as compared to other types of development. However, in the current applications of drone technology by the drone-adopting contracting companies, as shown in Table 4.16, drone technology is more often adopted in residential development. This is because residential development is the most common type of projects undertaken by most of the contracting companies that have adopted drones. Thus, drone technologies are more rapidly being adopted in residential development as compared to other types of project developments.

4.5.6 Circumstances Driving the Adoption of Drone Technology

Table 4.17 tabulated the circumstances driving the adoption of drones among the respondents. The most significant circumstance that would drive the adoption of drones among the respondents is when the utilisation of drones was requested by the client. According to Nguyen (2009), the technological change in an organisation is often driven by the pressure from the customers, where the organisation has to adopt technology to satisfy the requirements of the customers and to meet the industry standards.

Table 4.17: Circumstances Driving the Adoption of Drone Technology among the Respondents.

Circumstances	Rank	Mean
Under the request of the client	1	3.64
To enhance the overall delivery of the construction project	2	3.04
Special grants and incentives are given on drone adoption in the construction project	3	2.85
To enhance the competitiveness of the organisation in the construction industry	4	2.76
To resolve certain problem arouse in the construction project	5	2.72

Further analysis was performed to examine the circumstances that drove the adoption of drones among the organisations that have adopted drone technology. The results are tabulated in Table 4.18.

Table 4.18: Circumstances Driving the Adoption of Drone Technology among the Drone-Adopting Contracting Companies.

Circumstances	Rank	Mean
To enhance the competitiveness of the organisation in the construction industry	1	3.82
Under the request of the client	2	3.27
To enhance the overall delivery of the construction project	3	3.14
To resolve certain problem arouse in the construction project	4	2.91
Special grants and incentives are given on drone adoption in the construction project	5	1.86

Refer to Table 4.18, the most significant circumstances that would drive the adoption of drone technology among the contracting companies which have adopted drone technology is when the contracting companies wish to enhance their organisation competitiveness in the construction industry (mean = 3.82). As afore discussed in subchapter 4.4.1, the large-sized contracting companies are desired to differentiate themselves from their competitors by investing in new technology. The interest in drone technology to enhance their business competitiveness would therefore be the most significant factor driving their investments and adoptions.

4.5.7 Applications of Drone Technology

Table 4.19 tabulated the mean ranking of the applications of drone technology appreciated by the respondents. The Cronbach's Alpha reliability test conducted on the nine statements of drone applications showed a Cronbach Alpha value of 0.951, indicating an excellent internal consistency and reliability of the data. The top three applications of drone technology appreciated by the respondents are progress monitoring, safety inspection, and security surveillance. The most recognised application of drone technology by the respondents is progress monitoring, and it is unanimous with the finding of Mosly (2017) where the application of drone technology that draws the most interest of the researchers and the construction industry players are construction activities monitoring.

Table 4.19: Mean on the Applications of Drone Technology.

Applications	Rank	Mean
Progress monitoring	1	2.59
Safety inspection	2	2.56
Security surveillance	3	2.43
Pre-construction topographic survey	4	2.37
Earthwork survey and analysis	5	2.31
Structure inspection	6	2.30
Pre-construction planning and design	7	2.14
Inventory tracking	8	1.97
Post-construction maintenance inspection	9	1.95

Further analysis was conducted to examine the current applications of drone technology exercised by the drone-adopting contracting companies. The results are tabulated in Table 4.20.

Table 4.20: Current Applications of Drone Technology by the Drone-Adopting Contracting Companies.

Applications	Frequency (*n*)	Percentage (%)
Progress monitoring	22	100
Safety inspection	18	81.82
Security surveillance	14	63.64
Pre-construction topographic survey	14	63.64
Earthwork survey and analysis	13	59.09
Structure inspection	10	45.45
Pre-construction planning and design	10	45.45
Inventory tracking	6	27.27
Post-construction maintenance inspection	3	13.64

The current applications of drone technology exercised by the drone-adopting organisations showed a consistent outcome with the applications appreciated by the respondents in Table 4.19, where the most common application is progress monitoring (22 respondents, 100 %), and the least common application is post-construction maintenance inspection (3 respondents, 13.64 %).

4.6 Challenges of Drone Adoption

Table 4.21 summarised the mean on the challenges of drone adoption in the Malaysian construction industry. The respondent's concerns towards the 18 statements of the challenges of drone adoption were examined to determine the most significant factor that would influence drone adoption in the Malaysian construction industry. The data showed a good internally consistent with a Cronbach Alpha value of 0.832. Based on Table 4.21, the top three challenges of drone adoption are:

(i) Top Management - Top management's support (Mean = 4.05).
(ii) Costs - Operational and maintenance costs (Mean = 4.04).
(iii) Costs - Initial costs (Mean = 4.02).

Table 4.21: Mean of the Challenges of Drone Adoption in the Malaysian Construction Industry.

Challenges of Drone Technology	Rank	Mean
Top management - top management's support	1	4.05
Costs - operational and maintenance costs	2	4.04
Costs - initial costs	3	4.02
Legal restrictions	4	3.93
User's attitude - user's fear and resistance towards new technology	5	3.88
Ease of use - ease of operation of drone software	6	3.85
User's attitude - user's reluctance to change	6	3.85
Professional skills	8	3.83
Top management - top management's knowledge	8	3.83
Practicability - adaptability of drone	10	3.80
Practicability - durability of drone	11	3.69
Ethical and privacy issues - individual privacy	12	3.66
Ease of use - ease of use of drone	12	3.66
Ethical and privacy issues - data privacy	14	3.62

Table 4.21 (Continued)

Practicability - portability of drone	15	3.60
Limited flight time	16	3.46
Weather constraints	17	3.42
Safety concerns	18	3.33

Mann-Whitney U test was conducted to examine if there is a statistically significant difference in the concerns towards challenges of drone adoption in the construction industry between the two respondent groups that are “undecided” and “likely” to advocate drone technology. The respondent groups that are “very unlikely”, “unlikely”, and “very likely” to advocate drone technology was not examined because the collected response size of six respondents, 11 respondents, and 20 respondents, respectively, does not meet the sufficient requirement of 30 sample size for the central limit theorem to hold. The hypotheses generated for the Mann Whitney U test are:

(i) Null Hypothesis (H_0): There is no difference in the concerns towards challenges of drone adoption in the construction industry between the respondent groups that are “undecided” and “likely” to advocate drone technology.

(ii) Alternative Hypothesis (H_1): There is a difference in the concerns towards challenges of drone adoption in the construction industry between the respondent groups that are “undecided” and “likely” to advocate drone technology.

The alpha value adopted is 0.05 with one degree of freedom. The null hypothesis is rejected when an asymptotic significance value less than or equal to 0.05 is obtained. It indicated a statistically significant difference in the result. Table 4.22 presented the outcome of the Mann Whitney U test on the concerns towards challenges of drone adoption.

Table 4.22: Mann Whitney U Test on the Concerns towards Challenges of Drone Adoption.

No	Challenges	Undecided (n = 37)		Likely (n = 49)		Asymp. Sig.
		Mean Rank	Rank	Mean Rank	Rank	
1	Safety concerns	46.12	5	41.52	13	0.379
2	Weather constraints	34.66	18	50.17	1	0.003*
3	Limited flight time	35.53	17	49.52	2	0.007*
4	Costs - initial cost	46.12	5	41.52	13	0.370
5	Costs - operational and maintenance costs	45.73	7	41.82	12	0.444
6	Ethical and privacy issues - individual privacy	44.54	13	42.71	6	0.725
7	Ethical and privacy issues - data privacy	44.78	10	42.53	9	0.662
8	Legal restrictions	39.36	16	46.62	3	0.154
9	Professional skills	44.61	12	42.66	7	0.703

Note: * indicates the mean rank difference is significant at 0.05 significance level.

Table 4.22 (Continued)

No	Challenges	Undecided (n = 37)		Likely (n = 49)		Asymp. Sig.
		Mean Rank	Rank	Mean Rank	Rank	
10	Ease of use - ease of operation of drone software	45.01	8	42.36	11	0.600
11	Ease of use - ease of use of drone	40.74	15	45.58	4	0.350
12	User's attitude - user's reluctance to change	46.19	4	41.47	15	0.365
13	User's attitude - user's fear and resistance towards new technology	48.59	1	39.65	18	0.080
14	Practicability - durability of drone	44.95	9	42.44	10	0.632
15	Practicability - portability of drone	46.74	3	41.05	16	0.267
16	Practicability - adaptability of drone	42.82	14	44.01	5	0.817
17	Top management - top management's knowledge	44.74	11	42.56	8	0.666
18	Top management - top management's support	47.39	2	40.56	17	0.180
	Average Mean Rank	43.81	-	43.26	-	-

Note: * indicates the mean rank difference is significant at 0.05 significance level.

The results showed that there is a statistically significant difference in the concern on weather constraints (Asymp. Sig. = 0.003) and limited flight time (Asymp. Sig. = 0.007) as the asymptotic significance value is less than the alpha value of 0.05. There is sufficiently strong evidence to reject the null hypothesis and to conclude that there is a significant difference in the concerns between the respondent groups that are “undecided” and “likely” towards the challenges of “weather constraints” and “limited flight time”.

The significant difference existed on the concern towards the challenges of “weather constraints” and “limited flight time” is due to the variance in the mean rank between the two respondent groups on the factors. Refer to Table 4.22, in the respondent group that are “likely” to advocate drone technology, the factor “weather constraints” was ranked the first with a mean rank of 50.17, and the factor “limited flight time” was ranked the second with a mean rank of 49.52. As observed, 12 respondents out of 49 respondents who are “likely” to advocate drone technology have adopted drone technology. They exert high concerns towards the challenges as they see “weather constraints” and “limited flight time” a more practical constraints and challenges of drone adoption because these challenges are the possible real challenges that they have encountered during their drone operation. This concurred with the findings by Morgenthal and Hallermann (2014) and Leahy, et al. (2015). Morgenthal and Hallermann (2014) found that environmental factors such as wind speed would influence the drone’s operation while Leahy, et al. (2015) have found out that the short flight time of the drone is limiting the operation of the drone.

However, in the respondent group that are “undecided” to advocate drone technology, the factor “limited flight time” was ranked 17 (the second last) with a mean rank of 35.53, and the factor “weather constraints” was ranked 18 (the last one) with a mean rank of 34.66. The respondents exert low concerns towards the two challenges as the respondents who are "undecided" to advocate drone technology are not able to see "weather constraints" and "limited flight time" a significant practical issue in drone adoption because none of them have adopted drone technology. As such, a significant difference existed in the concerns towards the challenges of “weather constraints” and “limited flight time” between the two respondent groups.

Based on the average mean rank in Table 4.22, the respondents who are “undecided” to advocate drone technology have in overall, have higher concerns (average mean rank = 43.81) towards the challenges on drone adoption. However, the respondents who are “likely” to advocate drone technology showed greater concerns towards the challenges of drone on:

(i) Weather constraints (Mean rank = 50.17).
(ii) Limited flight time (Mean rank = 49.52).
(iii) Legal restrictions (Mean rank = 46.62).
(iv) Ease of use - ease of use of drone (Mean rank = 45.58).
(v) Practicability - adaptability of drone (Mean rank = 44.01).

The respondents that are “undecided” to advocate drone technology tend to have higher concerns towards the challenges because they have not adopted drone technology, as some of the respondents that are “likely” to advocate do. Based on Table 4.23, there are 12 respondents who are “likely” to advocate drone technology have adopted drones. However, there is no drone adoption among the respondents who are “undecided” to advocate drone technology. Therefore, higher concerns towards the challenges are triggered among the respondents who are “undecided” to advocate drone technology because they have no experience with the technology.

Table 4.23: Adoption of Drone Technology in the Respondents who are “Undecided” and “Likely” to advocate Drone Technology.

Likeliness to Advocate Drone Technology	Adoption of Drone Technology	Number of Respondents (*n*)
Undecided	Adopted	0
	Not adopted	37
	Total	37
Likely	Adopted	12
	Not adopted	37
	Total	49

4.7 Other Comments and Suggestions from Respondents

Comments and suggestions have been received from the respondents on the possible means to increase the awareness towards drone technology and to encourage the adoption of drone technology in the Malaysian construction industry. In the respondents' opinion, the government played a vital role in promoting and encouraging the adoption of drone technology in the construction industry. The respondents suggested that the Construction Industry Development Board (CIDB) of Malaysia shall conduct an information-sharing campaign and training program to spread awareness and to familiarise the industry with drone technology. Moreover, the respondents suggested that the provision of subsidies or incentives by the CIDB would be a great driving force to encourage the adoption of drone technology.

One of the respondents thinks that the top ten contracting companies in Malaysia should support this technology to encourage more contracting companies to adopt drone technology. Having the leading contracting companies to lead and support the technology would increase the confidence of the other contracting companies in the technology, especially when the benefits of drone technology are realised and proven in the leading contracting companies.

4.8 Summary

This study had achieved a response rate of 27.33 %. The findings in this chapter were generated from the data collected from 123 construction professionals in the contracting companies within the Klang Valley area. A series of tests was conducted to interpret the data, including the Cronbach's alpha reliability test, descriptive analysis, Kruskal-Wallis test, and Mann-Whitney U test. The respondents' awareness towards drone technology, the applications and challenges of drone technology are discussed in this chapter. Lastly, comments and suggestions received from the respondents are also presented to provide additional insights about increasing the awareness towards drone technology and encouraging drone adoption in the construction industry.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Chapter 5 presents the conclusions of the study. Subchapter 5.2 describes the accomplishment of objectives. The refined theoretical framework for drone adoption in the Malaysian construction industry is presented in subchapter 5.3. Subchapter 5.4 highlights the implications of the research to the Malaysian construction industry, while subchapter 5.5 highlights the research limitations. Finally, the study is wrapped with recommendations for future research improvements in subchapter 5.6.

5.2 Accomplishment of Research Objectives

The objectives set for this study have been achieved. The detailed descriptions of the accomplishment are presented in subchapter 5.2.1 to subchapter 5.2.3.

5.2.1 Objective 1: To investigate the awareness of the Malaysian construction industry towards drone technology

The first objective was achieved by examining the respondent's frequency of hearing about drone technology, and their awareness towards the applications and benefits of drone technology. The findings revealed that the Malaysian contracting community's awareness on drone technology is of moderate level.

The applications and benefits of drone technology were identified from the literatures reviewed in Chapter 2. Review of journal articles, conference papers, books, and websites were conducted. The respondent's agreement towards the nine applications and 20 statements pertaining benefits of drone technology were analysed to determine their awareness towards the drone technology. The findings revealed that the respondents aged between "25 to 34 years old" are most aware of drone technology, followed by the respondents aged "35 to 44 years old". The respondents aged "below 25 years old" are least aware of drone technology because most of the respondents in this age group have rarely heard about drone technology.

5.2.2 Objective 2: To determine the applications of drone technology in the Malaysian construction industry

The current drone adoption level in the Malaysian construction industry is low (17.89 %), with only 22 respondents out of 123 respondents have adopted drone technology. The companies who have adopted drone technology are the Grade 7, 6 and 5 contracting companies. Among the 22 contracting companies that have adopted drone technology, six companies have adopted drone technology for less than one year, four of them have adopted less than two years, while 12 contracting companies have adopted drone technology for two years and above.

The findings revealed that the top three applications of drone technology in the Malaysian construction industry are (1) progress monitoring, (2) safety inspection, and (3) security surveillance. The ranking on the applications of drone technology in the Malaysian construction industry are summarised in Table 5.1.

Table 5.1: Applications of Drone Technology in the Malaysian Construction Industry.

Applications of Drone Technology	Rank
Progress monitoring	1
Safety inspection	2
Security surveillance	3
Pre-construction topographic survey	4
Earthwork survey and analysis	5
Structure inspection	6
Pre-construction planning and design	7
Inventory tracking	8
Post-construction maintenance inspection	9

5.2.3 Objective 3: To investigate the challenges of drone adoption in the Malaysian construction industry

The study revealed that the top three challenges of drone adoption in the Malaysian construction industry are the (1) top management - top management’s support, (2) costs - operational and maintenance costs, and (3) costs - initial costs. Therefore, the top management's support, operational and maintenance costs, and the initial costs are the most significant challenges that need for the successful drone technology adoption. The challenges of drone adoption in the Malaysian construction industry are summarised in Table 5.2.

Table 5.2: Challenges of Drone Adoption in the Malaysian Construction Industry.

Challenges of Drone Adoption	Rank
Top management - top management's support	1
Costs - operational and maintenance costs	2
Costs - initial costs	3
Legal restrictions	4
User's fear and resistance	5
Ease of operation of drone software	6
User's reluctance to change	6
Professional skills	8
Top management's knowledge	8
Adaptability of drone	10
Durability of drone	11
Individual privacy	12
Ease of use of drone	12
Data privacy	14
Portability of drone	15
Limited flight time	16
Weather constraints	17
Safety concerns	18

5.3 Refined Theoretical Framework for Drone Adoption in the Malaysian Construction Industry

The theoretical framework proposed has been modified to demonstrate the key findings in this study. The framework further affirmed the achievement of the objectives of this study, as illustrated in Figure 5.1.

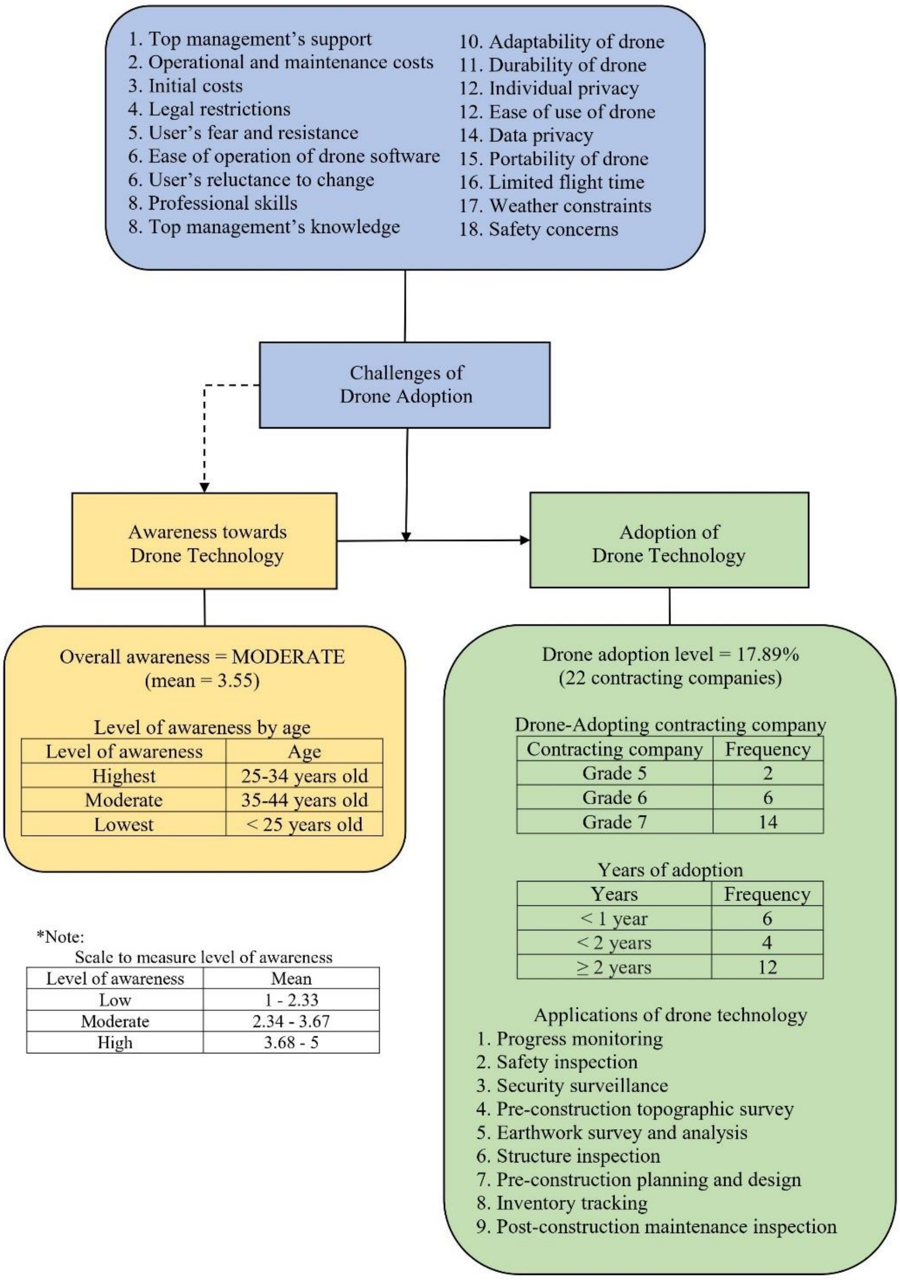

Figure 5.1: Theoretical Framework Demonstrating Key Findings in the Study.

5.4 Research Implications

As Industry 4.0 comes to light, the Malaysian construction industry shall prepare themselves for Industry 4.0. The adoption of technology is fundamental for the sustainability of the construction industry under this revolution. As drones are one of the major pillars in Industry 4.0, it is now gaining attention from construction industry players. However, the findings of this study revealed that the adoption level of drone technology in the Malaysian construction industry is rather low at the moment. The literatures and findings in this study would shed light to the construction industry on the benefits, applications, and challenges of drone technology. The insights provided in this study could enhance the industry's knowledge on drone technology and therefore increase the drone adoption rate in the Malaysian construction industry.

Besides, it is vital that the challenges of drone technology are fully understood before it can be promoted to the construction industry and/or being actively adopted by the construction community. Though there have been literatures on the challenges of drone technology in the construction industry developed by the researchers in the other countries, the literatures in the context of the Malaysian construction industry which reveal the true obstacles encountered is much demanded for, as the findings may differ from country to country. Through this study, the construction industry can understand the challenges in the adoption of drone technology and thereafter develop strategies to overcome the obstacles so that the adoption of drone technology would not be hindered.

5.5 Research Limitations

This study has some notable limitations. The scope of this study has been limited to the applications of drone technology among the contracting community. The applications of drone technology by other construction professionals such as consultants and the developers are not researched under this study though drone technology could also be applied to the working structure of the consultant and the developer firms. The limitation in the scope therefore hindered an all-round perspective for this study as the opinions from the consultants and the developers are not being considered.

There is a limitation in the sampling size in this study as well. The sampling in this study is limited to the contracting companies within the Klang Valley area. As the sampling was limited to the Klang Valley area, hence the overall response rate could only achieve 27.33 %. Moreover, all the data in this study was contributed by the private contracting companies. There is no returned response received from the public sector. Therefore, the outcome of this study may not be adequately reflecting the Malaysian construction totality.

5.6 Research Recommendations

Several recommendations are suggested to address the shortcomings in this study. First, in future studies, the scope of the study can be expanded to obtain a more comprehensive result that demonstrates the opinions of various professionals in the industry. The opinions from the consultants and the developers could yield a different finding for the study.

A greater sample size and a greater coverage of the questionnaires distributions across the regions/states in Malaysia is recommended to obtain a more comprehensive and valid results that could represent and reflect the real states of the art for drone technology in the Malaysian construction industry. A longer duration for the data collections is recommended to increase the response rate as well. Moreover, it is recommended to distribute the questionnaires through several channels so that the respondents can be successfully reached to provide their opinions to the study.

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APPENDICES

APPENDIX A: Questionnaire

Drone Technology and its Implications to the Malaysian Construction Industry

To Whom It May Concern,

Dear Sir/Madam,

I am Caerin Law Hui Yen, a final year undergraduate student pursuing Bachelor of Science (Honours) Quantity Surveying at Universiti Tunku Abdul Rahman (UTAR). Currently, I am conducting a study on "Drone Technology and its Implications to the Malaysian Construction Industry" as a prerequisite for the degree. The objectives of this study are to identify the applications of drone technology, the level of awareness on drone usage, and the challenges of drone adoption in the Malaysian construction industry.

I am pleased to invite you to participate in this survey. It will take you approximately 15 minutes to complete. I would be grateful if the survey is completed to facilitate the data analysis by 1st March 2021 (Monday).

All the information collected through this survey will be kept strictly private and confidential. Should you have any inquiries or require additional information, please do not hesitate to contact me at caerin0810@1utar.my or +60 19-664 8982.

Thank you for taking the time to assist me in my educational endeavour.

Yours faithfully,
Caerin Law Hui Yen
Universiti Tunku Abdul Rahman

* Required

Section A: Demographic Profile

1. What is your age? *

   Mark only one oval.

   - ◯ Below 25 years old
   - ◯ 25 - 34 years old
   - ◯ 35 - 44 years old
   - ◯ 45 - 54 years old
   - ◯ 55 - 64 years old

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

Mark only one oval.

- ◯ Less than 3 years
- ◯ 3 - 5 years
- ◯ 6 - 8 years
- ◯ 9 years and above

3. Please indicate the CIDB contractor registration of your organisation. *

Mark only one oval.

- ◯ Grade 1
- ◯ Grade 2
- ◯ Grade 3
- ◯ Grade 4
- ◯ Grade 5
- ◯ Grade 6
- ◯ Grade 7

4. Which of the following development does your organisation undertakes? (Please select all that apply) *

Check all that apply.

- ☐ Residential Development (Condominium, Landed Property, etc.)
- ☐ Commercial Development (Office, Shoplot, etc.)
- ☐ Mix-used Development
- ☐ Industrial Development (Factory, Warehouse, etc.)
- ☐ Infrastructure Development (Road, Railway, etc.)

Section B: Awareness on Drone Technology

5. How frequent do you hear of the usage of drone technology in the construction industry *

Mark only one oval.

- ( ) Never
- ( ) Rarely
- ( ) Sometimes
- ( ) Often
- ( ) Always

6. From where did you hear or get to know about drone technology? (Please select all that apply) *

Check all that apply.

- [ ] Advertisement (Promotional Videos, Television, etc.)
- [ ] Internet (Search Engines, Social Media, etc.)
- [ ] Event (Webinar, Seminar, etc.)
- [ ] Word of Mouth
- [ ] None of the above

Other: [ ] ______________________

7. In your perception, to what degree do you agree with the following statement. *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Drone can be used to perform pre-construction topographic survey	◯	◯	◯	◯	◯
Drone can be used for pre-construction planning and design	◯	◯	◯	◯	◯
Drone can be used for earthwork survey and analysis	◯	◯	◯	◯	◯
Drone can be used to capture construction progress	◯	◯	◯	◯	◯
Drone can be used to perform safety inspection on construction site	◯	◯	◯	◯	◯
Drone can be used to perform security surveillance	◯	◯	◯	◯	◯
Drone can be used to inspect building structure	◯	◯	◯	◯	◯
Drone can be used to track the location of the inventory on construction site	◯	◯	◯	◯	◯
Drone can be used to perform post-construction maintenance inspection	◯	◯	◯	◯	◯

8. In your opinion, to what extent do you agree with the following statement. *

Mark only one oval per row.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Drone offers cost saving by prevent costly misaligned construction due to poor pre-construction planning	◯	◯	◯	◯	◯
Drone offers cost saving in surveying task as compared to traditional survey method	◯	◯	◯	◯	◯
Drone offers cost saving by early construction deviation detection in periodical progress tracking	◯	◯	◯	◯	◯
Drone offers time saving by reducing field time	◯	◯	◯	◯	◯
Drone offers time saving by enable efficient data collection and report	◯	◯	◯	◯	◯
Drone offers time saving by enable faster decision making	◯	◯	◯	◯	◯
Drone mitigates the worker safety risk associated with inspection task on hard-to-reach area	◯	◯	◯	◯	◯
Drone reduces site accident by early safety hazard identification	◯	◯	◯	◯	◯
Drone improves site security by regular security patrol over the site	◯	◯	◯	◯	◯
Drone mitigates risk of fire by early fire hazard detection using thermal camera	◯	◯	◯	◯	◯
Drone reduces human errors in data collection thus producing accurate survey	◯	◯	◯	◯	◯

Drone reduces the need for re-work and re-measurement by generating high accuracy data					
Drone improves communications between project stakeholders by provide on-demand visual imagery through cloud based platform					
Drone improves communication on jobsite by real-time jobsite monitoring and site inspection					
Drone promotes better jobsite photo documentation by consistent progress capture and centralised documentation in cloud based platform					
Drone promotes better post-project documentation for future construction quality improvement benchmarking purposes					
Drone helps to avoid dispute by early information discrepancy detection through pre-construction topographic survey					
Drone enable speedy dispute reconciliation as drone data and imagery provide clear evidence against the mistakes					
Drone improves business competitiveness by enable contractor to make more ambitious bids					
Drone improves business competitiveness by enable better workflow management					

Section C: Application of Drone Technology

9. Have your organisation adopted the drone technology? *

Mark only one oval.

- Yes
- No

10. How long have your organisation adopted the drone technology? *

Mark only one oval.

- Have not adopted
- Less than 1 year
- Less than 2 year
- 2 years and above

11. How likely will you advocate the adoption of drone technology in your organisation? *

Mark only one oval.

- Very unlikely
- Unlikely
- Undecided
- Likely
- Very likely

12. In your opinion, who normally uses the drone technology? (Please select all that apply) *

Check all that apply.

- [ ] Site officer
- [ ] Project manager
- [ ] Technical manager
- [ ] Construction manager
- [ ] Quantity surveyor

Other: [ ] ______________________

13. In your opinion, which of the following software normally integrated with the drone operation? (Please select all that apply) *

Check all that apply.

- [ ] DroneDeploy platform
- [ ] FlytBase platform
- [ ] Autodesk ReCap Pro
- [ ] Autodesk AutoCAD
- [ ] Autodesk Civil 3D software
- [ ] Autodesk BIM 360 software
- [ ] Procore software
- [ ] Bluebeam Revu software

Other: [ ] ______________________

14. In your opinion, how often the drone technology is adopted in the following construction project? *

Mark only one oval per row.

	Never	Rarely	Sometimes	Often	Always
Residential development	◯	◯	◯	◯	◯
Commercial development	◯	◯	◯	◯	◯
Mix-used development	◯	◯	◯	◯	◯
Industrial development	◯	◯	◯	◯	◯
Infrastructure development	◯	◯	◯	◯	◯

15. Normally, in what circumstances will drone technology be deployed in the construction project? Please rank from 1 (the least important circumstances) to 5 (the most important circumstances). *

Mark only one oval per row.

	1	2	3	4	5
Under the request of the client	◯	◯	◯	◯	◯
To enhance the overall delivery of the construction project	◯	◯	◯	◯	◯
To enhance the competitiveness of the organisation in the construction industry	◯	◯	◯	◯	◯
Special grants and incentives are given on drone adoption in the construction project	◯	◯	◯	◯	◯
To resolve certain problem arouse in the construction project	◯	◯	◯	◯	◯

16. To what extent your organisation is using drone technology for the following construction activities? *

Mark only one oval per row.

	Using now	Expected to use in 2 years	Expected to use in 5 years	No planning to use
Pre-construction topographic survey	◯	◯	◯	◯
Pre-construction planning and design	◯	◯	◯	◯
Earthwork survey and analysis	◯	◯	◯	◯
Progress monitoring	◯	◯	◯	◯
Safety inspection	◯	◯	◯	◯
Security Surveillance	◯	◯	◯	◯
Structure inspection	◯	◯	◯	◯
Inventory Tracking	◯	◯	◯	◯
Post-construction maintenance inspection	◯	◯	◯	◯

Section D: Challenges on Drone Adoption

17. In your opinion, to what extent will the following challenges influence the adoption of drone technology in the Malaysian construction industry? *

Mark only one oval per row.

	No influence	Very low influence	Low influence	High influence	Very high influence
Safety concern (Drone could cause injuries to individual)	○	○	○	○	○
Weather constraints (Drone is not operational in unfavorable weather)	○	○	○	○	○
Limited flight time (Limitation in flight time limits the capability and efficiency of drone in opeation)	○	○	○	○	○
Initial cost (Increasing cost contribution to increase the capability of drone with high technology features)	○	○	○	○	○
Operational and maintenance costs (Periodic maintenance is required to ensure optimal performance of drone)	○	○	○	○	○
Individual privacy (Concern on privacy infringement during drone operation)	○	○	○	○	○
Data privacy (Data security is not foolproof as drone can be hijacked)	○	○	○	○	○
Legal restrictions (Drone regulation imposing limitations on drone operation)	○	○	○	○	○
Professional skills (Drone need to be operated by highly trained personnel)	○	○	○	○	○
Ease of operation of drone	○	○	○	○	○

software (Knowledge is required to produce usable information by integrating drone data with specialised construction and drone software)					
Ease of use of drone (User friendliness of drone to beginner)	◯	◯	◯	◯	◯
User's reluctance to change (People are more used to traditional method and have no trust on new technology)	◯	◯	◯	◯	◯
User's fear and resistance towards new technology (Technophobia due to lack of comprehensive understanding on drone technology)	◯	◯	◯	◯	◯
Durability (Ability of drone to stay pristine in typical construction site environment)	◯	◯	◯	◯	◯
Portability (Degree of convenient of drone to be carry from one site to another)	◯	◯	◯	◯	◯
Adaptability (Feasibility of drone to fit into the existing operation)	◯	◯	◯	◯	◯
Top management's knowledge (Awareness and understanding on impact of drone adoption to the organisation growth)	◯	◯	◯	◯	◯
Top management support (Allocation of adequate resources to support drone adoption and operation)	◯	◯	◯	◯	◯

Section E: Additional Comments/Suggestions

18. Please comment if you have any other comments/suggestions to encourage the adoption of drone technology, and increase its level of awareness as well as overcoming the challenges of drone adoption in the Malaysian construction industry?