Framework for Safety Control for Maintenance of Infrastructure Oil and Gas Project Using BIM

by

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Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR, PERAK

September 2022

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(NUR SYIRIN SYIFAA BINTI MAZLI)

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ABSTRACT

Oil and gas facilities will normally extend their operation beyond their designed lifespan as this will bring safety risks, business risks and operational challenges to the oil and gas industry. Thus, the oil and gas infrastructure like pipeline, platform, refineries must undergo maintenance to run the operation and business. Maintenance is a regular task usually will be conducted for any structure operate. The rate of occupational injuries and fatalities has dramatically grown because of the revolutionary changes in oil and gas infrastructure. Safety planning for maintenance activity will be the best action to identify the risk and for safety control during maintenance of oil and gas infrastructure. However, oil and gas industry more prefer to a traditional way of constructing the plan and maintenance which might lead to an inaccuracy of information and interpretation that might cause accidents during conducting the maintenance activity. Hence, the implementation of BIM in maintenance will be a great solution to oil and gas industry for their facilities and projects in managing safety control aspects. Nevertheless, adoption of BIM in maintenance of facility in oil and gas infrastructure projects is at a low level. For that reason, this study is conducted to analyze safety control for maintenance of infrastructure oil and gas projects that can be executed and develop a framework of it using BIM platform. Information such as safety control for maintenance, the challenges of BIM adoption has been collected through questionnaires survey and interviews. The data gathered has been analyzed using the statistic method that is relative importance index (RII). Software like Statistical Package for the Social Sciences (SPSS) was used to conduct many statistical processes such as the data normality test (Kurtosis and Skewness), the correlation test (Pearson's and Spearman's correlation) and Cronbach's Alpha reliability test. Based on the data analysis conducted, it is identified that "site layout and safety plan for maintenance and operation" as the highest RII for safety control aspects that can be executed by using BIM platform. "Lack of training, roles and responsibilities" has recorded as the highest RII for the most potential barrier in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia. Then, to develop the framework of safety controls for maintenance in oil and gas infrastructure projects based on the data gathered from questionnaires survey and interview, framework has been developed and verified by the BIM modeler, safety officer and facility manager.

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CHAPTER 1

INTRODUCTION

1.0 Background of Study

Malaysia is one of the largest oil producers in Asia. This is because the oil and gas sector are essential to Malaysia's economic growth and has made huge contributions to the government's development as well as the nation's development (Umeesh et al., 2018). Oil and gas infrastructure ranges from the structures, installations as well as the equipment required by energy companies to run their operations. Oil and gas facilities will normally extend their operation beyond their designed lifespan as this will bring safety risks, business risks and operational challenges to the oil and gas industry (Khan et al., 2020). To minimize the risks, it is critical that oil and gas infrastructure undergoes adequate maintenance regularly to improve safety and prevent injuries or accidents. Maintenance optimization might enhance accident associated with pollution management, save lives, and save operating costs.

Many historical disasters have occurred in oil and gas building projects like the one at the Chevron Refinery. This disaster occurred as a result of damage to the offending pipe caused by sulfidation corrosion, which is known to be extremely aggressive on carbon steel pipes (US Chemical Safety Board, 2015). It is believed that with proper maintenance and inspection on the steel pipes, the disaster can be combated. Failures in conducting a proper maintenance may results in significant financial losses and environmental consequences. It would decrease production and downtime losses and it is not an easy job to recover all of the losses because it would take a very long time. The biggest environmental concerns in oil and gas projects are oil and chemical spills, which harm essential biological factors including soil, natural habitat, and marine life (Kashwani & Nielsen, 2017).

According to a previous case study on the accident sources in industrial maintenance operations, 33 fatal accidents and 90 severe non-fatal accidents occurred during the maintenance of a project. It was frequently able to distinguish the accident types within both accident categories. Crushing or getting trapped in or between things was the most common form of catastrophe in both groups. Falling or jumping, as well as accidents caused by falling or tumbling objects, were the next most common accident types. Crushing or getting trapped in or between things accounted for 27% of fatal accidents and 39% of severe non-fatal accidents, whereas falling or jumping accounted for 27% of fatal accidents and 21% of severe non-fatal accidents followed by falling or tumbling objects with 15% of fatal accidents and 12% of severe non-fatal accidents (Lind et al. 2009). Based on U.S. Bureau of Labor Statistics, employees in oil and gas projects are frequently injured by being struck by things (32.5 percent of cases) or getting caught in objects, equipment, or material (21.2 percent of cases). The high percentage of crushing or getting trapped in or between things in both categories of fatalities, as well as the high percentage of being struck by things in the oil and gas project, should be a main consideration to conduct a proper framework for safety controls for maintenance of infrastructure oil and gas project and other similar projects.

There have been several fatalities during the maintenance of oil and gas infrastructure projects in the past such as falling from heights, struck by object, explosion at offshore platform, due to improper framework for safety controls. Framework for safety control is a methodical approach to detecting hazards and controlling risks. Specific training, materials educational for specific project site circumstances will be provided for the employees. These activities will simply provide an overview of the hazards in terms of 'work location', 'type of job', 'type of risk' and 'behavior risk exposure' (Park & Kim, 2013). The process of traditional way of constructing a framework for safety control will include the usage of safety checklists, safety training, and safety audits. These approaches, however, are insufficient since the accident rate in maintenance projects continues to rise and it can be time-consuming and expensive to conduct. Based on U.S. Bureau of Labor Statistics, from 2015 to 2019, general maintenance and repair work resulted in 109,890 nonfatal injuries and illnesses incidents that required days off work. It was identified that the leading causes of these maintenance accidents occur in during maintenance mostly due to falling, slipping and tripping. It can be concluded that it is difficult to identify the risks with traditional way of constructing a framework for safety control due to the insufficient, hence, advanced framework of safety control is required.

The adoption of BIM in all types of industry has grown over the previous decade and a half. BIM, also known as Building Information Modelling, is a collaborative technology that provides a digital information model to process, generate, discuss, and analyze building projects (Al-Ashmori et al., 2020). It is also being discussed in the paper that BIM can boost the productivity and efficiency, improve constructability, reduce mistakes, and save time and money. Building Information Modelling has been used to improve current safety management approaches and project quality by visualising safety planning with 3D engineering modelling and simulating with 4D engineering modelling of real maintenance site situations, including equipment, temporary facilities, stockyards, and workers. With BIM, all the information collected such as planning, designing, constructing, operating, and maintaining of facilities, together with accidents statistics or safety measures can be combined and at the end BIM will help in analysing and improving the safety management to be more adequate and following the OSHA safety and health standards. As a result, mistakes in building projects such as infrastructure or oil and gas infrastructure may be reduced, and facilities manager, and employees can comprehend the actual environment of a maintenance site by merging it into a 3D model.

1.1 Problem Statement

A safety control management system has been presented by Mwanza et al. (2017) to improve the safety performance in maintenance projects (see Figure 1.1). Implementing safety controls required consideration of a number of factors, including management, working conditions, existing machinery and equipment, and staff training.

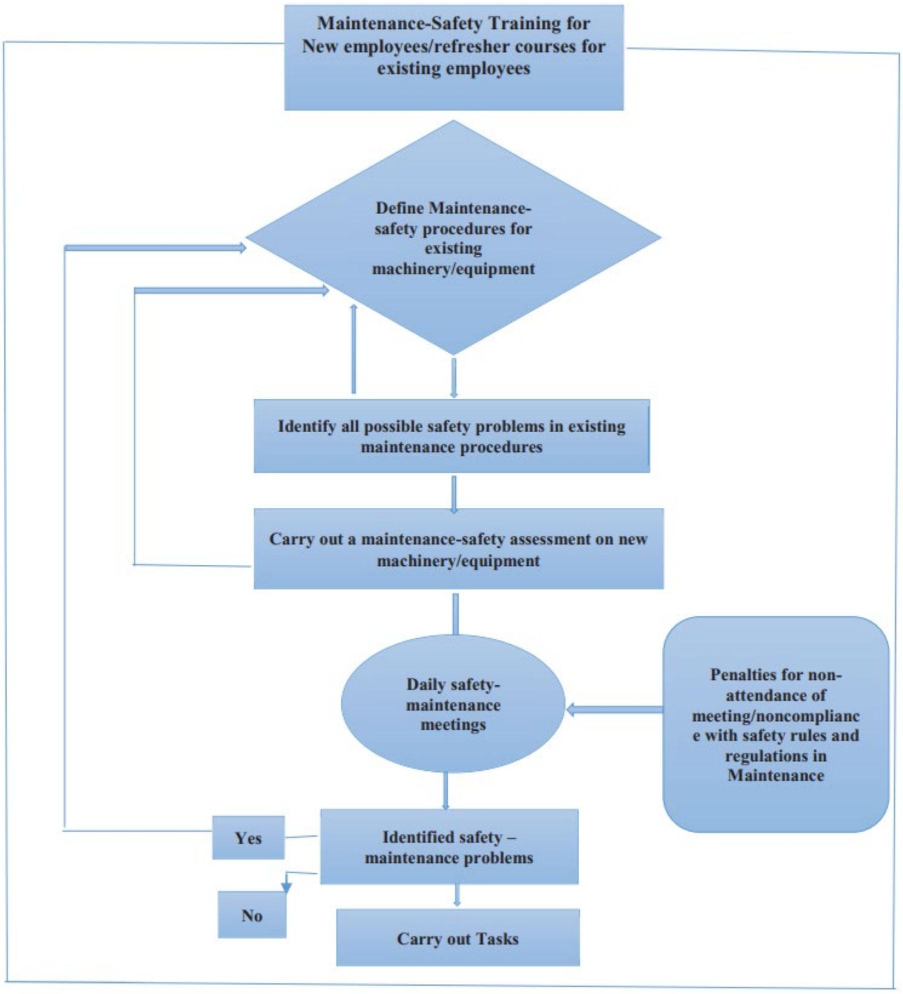

Figure 1.1: The framework for safety control for maintenance
(Mwanza et al. 2017)

The management of facility maintenance accounts for more than 65% of the entire cost of facility management. This is because the facility managers continue to use traditional methods to generate the information they need to run and maintain their assets in buildings (such as the location of building parts, machinery & equipment, dimension, material, and requirements) (Alavi et al., 2021). This type of management may lead to challenges such as difficulty in increasing the productivity, quality, and value due to preferences in using the traditional method (Zahrizan et al., 2013). An earlier study found that this was because the personnel had worked using traditional systems and procedures for the most of their life. They stated that the new approach has not been well embraced by the stakeholders. Stakeholders have stated several reasons, including the fact that their traditional methods continue to be effective and that they do not place a high priority on the need for digitalization (Siebelink et al., 2021). Structures in the oil and gas industry, in particular, will need a lot of documentation and drawings to be maintained. The massive number of records and drawings, which are often in paper-based format and are not effectively handled, will make traditional approaches inaccurate since this will lead to misunderstandings between the parties (Zahrizan et al., 2013). Typically, contractors would utilise CAD, which depicts the static and isolated design process, for safety planning. They are ineffective, nevertheless, at spotting dangers on work sites (Azhar et al., 2012). This will show the imperfection of old technique in executing the framework for safety control during the maintenance of oil and gas infrastructure projects.

Building information modelling (BIM) is extensively used during the architectural, engineering, and construction (AEC) phases, but its adoption has been delayed among facility management (FM) experts (Edirisinghe et al., 2017). According to a previous study that conducted in Vietnam, the number of BIM-FM publications in the O&M phase of buildings has increased to 113 articles since 2008. With 32 and 29 published articles, respectively, the years of 2018 and 2019 have seen an impress developing in terms of both the total publications by year and the number of citations by years. Despite the potential benefits of BIM for the industry's stakeholders, the utilisation of BIM, particularly in maintenance projects, is currently quite low (Hoang et al., 2020). Even most significant public owners that were earliest users of BIM, such as GSA, USACE, or Senate Properties, used it more for construction project management than for FM activities, not to mention small companies (Kiviniemi et al., 2014). As a result, it is necessary to draw attention to the constraints of implementing BIM for maintenance project in order to provide a solution and to manage safety in maintenance work.

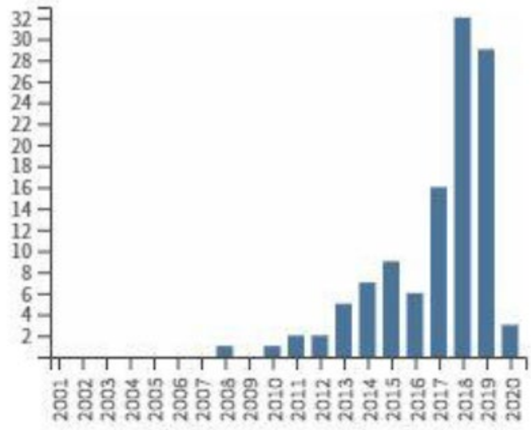

Figure 1.2: Total publications of BIM-FM articles by year in Web of Science database (Hoang et al., 2020)

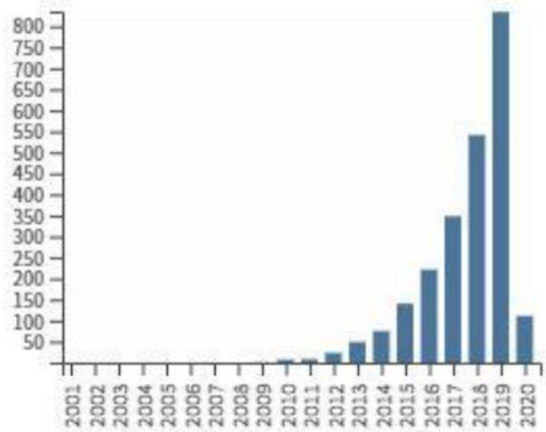

Figure 1.3: Total citations related to BIM-FM per year according to Web of Science database (Hoang et al., 2020)

1.2 Objectives

Through questionnaire surveys of oil and gas project stakeholders and a case study, this study aims to establish the framework for safety control for maintenance of infrastructure oil and gas projects using BIM. It also assesses the use of BIM in managing safety, particularly in oil and gas maintenance. The objectives are listed as follows:

- To analyze safety control for maintenance of infrastructure oil and gas projects that can be executed using BIM platform.
- To investigate the challenges to implement BIM in maintenance of infrastructure oil and gas projects.
- To develop a safety control framework for maintenance of infrastructure oil and gas projects using BIM.

1.3 Scope of Study

Through questionnaires, this study intends to identify the challenges stakeholders face in applying BIM in oil and gas maintenance projects and examine the safety control features that BIM could perform in maintenance projects for oil and gas infrastructure. The case study will concentrate on project stakeholders around Malaysia, including (i) the owner, (ii) the consultant, and (iii) the BIM modeler. This will allow for the analysis of the level of project stakeholder knowledge regarding the use of BIM for oil and gas maintenance projects and may be the solutions to manage safety. Depending on the case study chosen, the rated elements will be further examined and discussed through personal interviews. The adoption of BIM in controlling safety throughout the maintenance phase will be the primary emphasis of this study. The information gathered for this study will be utilised to build an effective framework for safety controls for maintenance in BIM-based oil and gas projects.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Building Information Modelling (BIM)

The adoption of BIM in construction industry has grown over the previous decade and a half. BIM, also known as Building Information Modelling, is a collaborative technology that provides a digital information model to process, generate, discuss, and analyse building projects. According to Gao & Pishdad-Bozorgi (2019), with BIM, the process of planning, design, construction, operation and maintenance can be enhanced by using a standardized machine-readable information model for each facility, new or old, that contains all relevant information created or gathered about that facility in a format that can be used by all stakeholders throughout its lifecycle. They also stated that BIM helps in representing the digital visualization for the designers and builders as well as providing them with more opportunities in achieving a successful project at a low cost and in a short period of time. Owners and operators can access information about the current status of facilities as well, from a virtual model of the facility using this information. Despite the fact that BIM was introduced in maintenance years ago, facility operators have yet to embrace the benefits of BIM and it is only being implemented in the design and construction phase, with only a small amount being implemented in the facility maintenance phase, according to a survey conducted in the Netherlands (Gao & Pishdad-Bozorgi, 2019).

With the availability of an integrated digital database, it is believed that the maintenance process would be more efficient with all of the information acquired pertinent to the projects (Akcamete et al., 2010). BIM also allows all project participants (clients, consultants, and contractors) to cooperate more precisely and effectively than with the conventional methods (Azhar, Khalfan, et al., 2012). When

BIM has been used as a decision-making tool, there will be significant improvement especially for the maintenance in infrastructure oil and gas projects since BIM able to provide information about the performance of the equipment as well as the providing historical data and duration of the equipment has been used and providing the immediate access to facility information through an easy interface (Oskouie et al., 2012). As a result, Building Information Modelling, have been used to improve safety controls for maintenance by visualising safety planning with 3D engineering modelling and simulating with 4D engineering modelling of real projects or facilities site situations, including equipment, temporary facilities, stockyards, and workers.

2.2 Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform

The application of BIM is not restricted to engineering and architectural tasks, it is also being applied by managers, fabricators, homeowners, and contractors as well (Kamel & Memari, 2019). According to Newsroom, BIM provides more than three dimensional models which are the time or schedule dimension (4D BIM), the cost dimension (5D BIM), the sustainability dimension (6D BIM), and the facility management dimension (7D BIM). As for now, there are already three new addition dimensions besides the seven dimensions which include safety during design and construction (8D BIM), lean construction (9D BIM) and construction industrialisation (10D BIM), (Newsroom, 2014). BIM concepts may be used as an overview of the project, to improve stakeholder communication, advanced analytics and optimization of maintenance information, and linkage of information sets of building lifetime. Collection of typical information such as drawings, accident reports, heuristic knowledge, materials, equipment, etc. are frequently will be merged into the BIM platform to establish safety controls during commencing the projects (Park & Kim, 2013).

Many significant BIM modelling software programmes are available, including Google SketchUp (Google), ArchiCAD (Graphisoft), Tekla Structures and Tekla Construction Management (Tekla), Revit and Navisworks (Autodesk), and Solibri Model Checker (Solibri Inc.). However, each software normally will be used with different functions since sometimes the software is lacking features or modelling functions. Shown below are the software that has been reviewed by Zhang et al. (2015):

(1) Autodesk Revit – for modelling and site layout
(2) Autodesk Navisworks – for scheduling and simulation
(3) Solibri Model Checker – for Industry Foundation Classes (IFC)-based and rule-checking
(4) Tekla Structures – for scheduling, simulation and modelling

Among these software, Google SketchUp has grown in prominence in the professional world. A handful of contractors in the United States have also utilised it for construction safety planning and project communication (Quoc Toan et al., 2021). They also stated that it is because Google SketchUp has a low-cost budget, simple representation of elevations under building plans, and support for easy sharing of 3D components built by users through the Internet-based 3D Warehouse. Another unique feature is the ability to import 3D models of structures into Google Earth.

There are five safety controls that can be executed for maintenance of Infrastructure Oil and Gas project using BIM based on the past research made previously which include; (1) Safety Training; (2) Identification of unsafe hazards in maintenance; (3) On-site maintenance supervision; (4) Exchange and cooperation in maintenance management; (5) Fall Prevention Planning.

2.2.1 Safety Training

According to the Occupational Safety and Health Administration (OSHA), employers are required to provide workers with safety training following the OSHA standards (OSHA, n.d.). Thus, the employers are encouraged to utilize BIM to perform safety training for their workers because under BIM, it would be easier to perform worker safety training. BIM would be able to depict and visualise maintenance activities in the same way as on the project site. As stated by Quoc Toan et al. (2021), BIM visualizes a real site condition and allows employees to interact and cooperate on the task they have been working on through 3D visualization. A good understanding on the task process will improve the safety control by pre-conducting it before actual commencing it at the real site. The employee will be more aware of their surrounding and safety while performing maintenance work. BIM also capable of providing the audio material as well during the 3D visualization for a better understanding during the safety training (Clevenger et al., 2011). Since most of the workers might consists of foreigners or not very fluent English speaker, language barriers may happen, thus this will affect the safety training skills among the workers. By providing the sounds in 3D visualization with variety of language will improve the safety during the maintenance. BIM offers various languages that they are familiar with especially for workers that are not fluent in English, so they can understand better about the safety. Based on past research, they developed the BIM-enabled safety training programme with Adobe Captivate 6 software. Captivate is an eLearning content production programme that can embed visuals and animations, as well as text and audio recordings, into interactive simulations, branching situations, and quizzes that are not part of the original, native software(s) (Clevenger et al., 2011).

2.2.2 Identification of unsafe hazards in maintenance

BIM may be used to acquire information about structures, hazardous locations and maintenance schedules, allowing an automated rule checking system to identify risks through 3D visualization (Quoc Toan et al., 2021). According to a case study, all of the project's hazards were identified and mitigation plans were established using BIM, resulting in no major or minor accidents on the job site. (Azhar et al., 2012). Autodesk Revit and Navisworks are suitable for the identification of the hazards in facility/maintenance project site through modelling and scheduling the information regarding the identified hazards (Zhang et al., 2015). The BIM representation assists in visually recognising and, more crucially, evaluating the characteristics of dangerous circumstances (Tsoupra et al., 2019). 4D-BIM also offers activities in both time and space to improve the accuracy of possible clash identification (Quoc Toan et al., 2021). There are three types of clashes that can be identified by BIM platform, which are; (1) Hard clash – Geometrical design clashes; (2) Soft clash – Object violates geometric limits established for other components; (3) Workflow clash – Schedule issues, equipment and material, (Spatial Corp, n.d.). With this type of identification in BIM, the quality of the project will increase, and the management will be smoother.

2.2.3 On-site maintenance supervision

As stated by Azhar et al. (2012), BIM significantly improves building's quality of the project supervision. It is believed that the quality of the project being improved by making sure that the client's project demands are fulfilled, and that the facility will operate for a long period by supervising the condition of the facility. Positioning technologies such as RFID, GIS and GPS will help represents as on-site maintenance supervision technologies. The representation of possible accident situations in real time will be enabled by information on the location of employees, facilities machines, and building materials on site acquired through these positioning technologies and it will be transmitted to the BIM model (Golparvar-Fard et al., 2009). The gadgets like passive tags and cameras will be installed on the equipment, employees, facilities machines and building materials and it will be connected to the BIM. As a result, the maintenance operator will not only be able to track and monitor the real-time oil and gas facility condition throughout the structure's lifetime and perform maintenance whenever required, but these technologies will also be able to track work management, invoice billing, tracking, and approval sign-off (Atkin et al., 2006).

2.2.4 Exchange and cooperation in maintenance management

BIM enables staff or experts to discuss on the building/maintenance process or arranging informational sessions for project stakeholders about the project updates (Quoc Toan et al., 2021). Since all of the design of the project is accessible to the project's stakeholders, any amendments and modifications can be notified in real time through the BIM software. They also asserted that BIM may break down communication barriers between all project stakeholders and make all building information accessible to everyone, regardless of position, ability to read or speak language. Based on what Azhar et al. (2012) has stated, BIM will convey and disseminate information to all personnel about safety arrangements or hazard warnings. Usually, Autodesk's BIM 360 Field will be utilised by the stakeholders to enhance site-to-site collaboration to allow communication among engineering staff, construction supervisors, contractors, health and safety supervisors and construction managers. This collaboration has proven that it may minimise the time required to provide information on ongoing implementation (health and safety issues, readiness reports, work commissioning, defects, and maintenance) so that managers and engineers can focus on their most important task (Dubas & Pasławski, 2017).

2.2.5 Fall Prevention Planning

Maintenance can happen in any position of the building especially at the higher place and oil and gas facilities normally extend their operation beyond their designed lifespan so maintaining at a high place may involves often in order for facility to operate smoothly. Thus, the workers will be exposed to fall hazards as they commence the maintenance task. As stated by Zhang et al. (2015), BIM can help discover possible fall risks and automatically model the recommended fall protection. BIM models may be used to determine the positions of employees' fall protection tie-off points, allowing permanent anchorage points to be included in the design (Azhar & Behringer, 2013). There are several types of fall protection that can be discovered and recommended by BIM other than tie off points such as guardrails, safety net and edge protections. Each location hazards of the facility identified in BIM platform will be evaluated by three types of categories: high risk zone, lower risk zone, no risk zone. This will allow the facility operator to propose and design protection safety system to prevent falling during maintenance at the locations that shows high risk of hazards.

2.2.6 Site layout and safety plan for maintenance and operation

The site layout and the safety plan are able to improve occupational safety, particularly with regard to maintenance and operation. It increases safety by offering ways to manage and visualise current plans and site status information as well as by supporting safety communication in a variety of contexts, such as informing site staff to take safety precautions in response to a specific risk or issuing warnings about various risks (Azhar & Behringer, 2013). The finished site plan that is being used during the construction of the oil and gas infrastructure can also be employed during the maintenance and operation of the infrastructure once it has been built. The employees can refer to the site layout in 3D and 4D site coordination models for the site's logistics and traffic layout and also to make significant improvements by reducing the amount of time spent travelling and waiting, as well as by boosting worker morale by demonstrating a better and safer working environment.

2.3 The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project

There are several opportunities that BIM may bring for maintenance in oil and gas infrastructure projects, particularly in Malaysia. According to Nasly et al. (2014), the benefits of BIM adoption include: (1) reducing project management mistakes; (2) being able to visualise the model for better comprehension; (3) clash detection; and (4) saving time and money. Despite the various benefits of using BIM, there are still several challenges to using BIM in the maintenance of infrastructure oil and gas projects. According to the author's research, there are seven major challenges to implementing BIM in maintenance of infrastructure oil and gas project which are; (1) Perception of BIM; (2) High Cost; (3) Interoperability and Incompatibility Issues; (4) Training, roles and responsibilities; (5) Poor knowledge and skills; (6) Lack of Demand from the clients; (7) Resistance to Change.

2.3.1 Perception of BIM

Due to lack of evidence of benefits in implementing BIM in facility management, facilities manager/clients refused to use BIM (Farghaly et al., 2016). Typically, they would respond that regarding available project methods and the prevailing fast track mentality, its implementation would need a significant amount of effort and time (Enegbuma et al., 2015). Other than that, the ambiguity of BIM implementation as well as the criteria for effective BIM adoption in facility management become one of the perceptions that becomes the challenges to implement BIM in maintenance project (Farghaly et al., 2016). This is may due to the facility manager did not know the requirements that usually being applied and suitable as an input to the BIM platform with maintenance practice. Farghaly et al. (2016) also stated that, the delay of adopting BIM in operation and maintenance due to a lack of guidelines and standards has led facility managers to grow disinterested in BIM adoption in this sector. Thus, the compatibility and benefits of BIM implementation in Operation and Maintenance phase, needs to be explored and assessed through real projects to obtain the details requirements.

2.3.2 High Cost

Investing in this new technology made the cost of the project rises as a result of the change in prior processes and standards (Farghaly et al., 2016). It means that when there are any changes on the previous operation and maintenance processes and standards, it will cause rising in costs that may have a financial impact at the start of the changes in facility management, and the cost to bear would be quite high and would take a long time to recover. There are only few proofs that BIM could save cost and time especially in operation and maintenance which leads the stakeholders uninterested in investing on this new technology (Othman et al., 2021). The costs that must be addressed include the cost of BIM software, hardware, training and upskilling, recruitment qualified new BIM experts, and employing a BIM consultant to supervise the project implementation on the BIM platform and ensure the project is on the right track (Rafindadi et al., 2020). Furthermore, a lack of government subsidies may prevent upper management from sending their employees to BIM training (Syed Jamaludin et al., 2022).

2.3.3 Interoperability and Incompatibility Issues

One of the main challenges in implementing BIM in maintenance is when interoperability happens because of the differences between BIM platforms and facility management platforms practice (Farghaly et al., 2016). While file incompatibility occurs when various organisations use different software or different versions of the same software (Memon et al., 2014). Due to these problems, operation managers think by preventing the implementation of BIM is the best way to avoid this problem since it will cause to time consuming or delay of the project.

2.3.4 Training, roles and responsibilities

Training needs to be provided since most of the facility management personnel lack the fundamental BIM knowledge required to apply the guidelines, standards and processes in facility management practise (Farghaly et al., 2016). Rafindadi et al. (2020) believed that training for utilization of BIM will take a lot of time in recruiting for new employees that experts in BIM and effort to learn and expert in a new software. Even though it would take a long time to be fully master on the new software and the difficulty and complicated of how steep the BIM software are, the outcome will be very effective and bring benefits for maintenance and operation especially in oil and gas industry. In addition, difficulty and time consuming of training personnel occurs due to no BIM related course being conducted in any universities in Malaysia.

2.3.5 Poor Knowledge and Skills

Inadequate BIM technological expertise and experience as well as the hesitancy of the owner become the challenges to implement BIM for maintenance in oil and gas projects (Hoang et al., 2020). This is might due to the less exposure to this advanced technology in facility management especially to oil and gas companies. They do not know what exactly BIM capable of, specifically in safety controls of operation and maintenance and mainly will give benefit to the design and construction phase only (Hoang et al., 2020). Lack of knowledge and skills also caused by the lack of guidelines and standards of BIM platform related to facility management. To summarise, it is critical for all stakeholders in operation and maintenance to acknowledge the application in BIM and the capability of the software in order to facilitate the work process.

2.3.6 Lack of Demand from the Clients

Since there is a lack of exposure regarding the BIM implementation in operation and maintenance and clients' lack of knowledge and expertise in BIM, no requests of BIM utilization in projects are actually demanded (Bosch-Sijtsema et al., 2017). Most of the stakeholders stated that BIM is better suited for large projects and furthermore, its deployment in Malaysia is still in its early stages (Haron et al., 2017). These issues become the factor of less implementation of BIM in Malaysia specifically for operation and maintenance phase in oil and gas infrastructure projects. BIM deployment in Malaysia will be substantially lower if there is no client demand.

2.3.7 Resistance to Change

According to Haron et al. (2017), stakeholders are fine with the results of old methods to design the projects. This is because the results of the safety controls using the traditional way has always satisfied their needs, thus, BIM implementation is not required since it will also bring the same results. Honestly, with utilization of BIM it will bring more benefits than traditional method such as increasing of project management quality, save time and cost, improve safety management and more compared to the old method. As stated by Siebielink et al. (2021), the reason why the stakeholders resist to change their method is they have spent the majority of their life utilising the old technique (Siebelink et al., 2021). It is difficult to change any processes that have been utilized for years in a project. From author's point of view, perhaps there is no collaboration between employees who are experts using the old method and employees who are experts using the new method. Thus, the senior employees decided not to change any processes of the project management. Besides, it is believed that stakeholders cannot handle the uncertainty since BIM implementation will incur costs and disrupt the previous processes (Nasly et al., 2014).

Table 2.1: Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform

Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform				
Aspect	Researcher	Key Statement	GAP	Author's POV
Safety Training	1) Quoc Toan et al., 2021 2) Clevenger et al., 2011	1) BIM visualizes a real site condition and allows employees to interact and cooperate on the task that they have been working on through 3D visualization. 2) BIM is capable of providing the audio material as well during the 3D visualization for a better understanding during the safety training.	• How does a good understanding on the task process able to improve the safety control? • By providing the sounds in 3D visualization, how does it improve the safety during maintenance?	• The employee will be extremely concerned about their safety while performing maintenance work. • Language barriers may exist, thus, BIM offers various languages that they are familiar with especially for workers that are not fluent in English, so they can understand better about the safety.
Identification of unsafe hazards in maintenance	1) Quoc Toan et al., 2021 2) Quoc Toan et al., 2021 3) Tsoupra et al., 2019	1) BIM may be used to acquire information about structures, hazardous locations, and maintenance schedules, allowing an automated rule checking system to identify risks through 3D visualization. 2) 4D-BIM offers activities in both time and space to improve the accuracy of possible clash identification. 3) The BIM representation assists in visually recognizing and, more crucially, evaluating the characteristics of dangerous circumstances.	• What software that is suitable for the identification of the hazards in facilities/maintenance project site? • What types of possible clashes can be identified? • How the results of evaluation of the characteristics of dangerous circumstances will be notified to the workers?	• Autodesk Revit has a tool that analyses the 3D model and automatically detects potential risks. • Hard clash: Geometrical design clashes; Soft clash: Object violates geometric limits established for other components; Workflow clash: Schedule issues, equipment and material delivery conflicts, etc. • They will receive notifications regarding any information updates once they have subscribed to the project in BIM.

Table 2.1: Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform (continued)

Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform				
Aspect	Researcher	Key Statement	GAP	Author's POV
On-site maintenance supervision	1) Golparvar-Fard et al., 2009 2) Ma et al., 2016	1) The representation of possible accident situations in real time will be enabled by information on the location of employees, facilities machines, and building materials on site acquired through positioning technologies such as RFID, GIS, and GPS and transmitted to the BIM model. 2) BIM significantly improves building's quality of the project supervision.	• How does the equipment, employees, facilities machines and building materials will be tracked by these technologies? • How does it improve the quality of project supervision?	• Gadgets like passive tags and cameras will be installed and connected to the BIM. • By making sure that the client's project demands are fulfilled, and that the facility will operate for a long period by supervising the condition of the facility.
Exchange and collaboration in maintenance management	1) Quoc Toan et al., 2021 2) Azhar et al., 2012	1) BIM enables staff or experts to discuss on the building/maintenance process or arranging informational sessions for project stakeholders about the project updates. 2) BIM will convey and disseminate information to all personnel about safety arrangements or hazard warnings.	• How can we make sure that particular project information will remain private and secured since it will be shared among project stakeholders? • How can BIM communication tools encourage cooperation and safety in maintenance project?	• Increasing cyber security by customising access and sharing permissions for appropriate parties, or by using separate BIM communication tools. • Any changes or updates made upon the project, all parties will be notified.

Table 2.1: Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform (continued)

Safety Control Aspect for Maintenance of Infrastructure Oil and Gas project that can be executed by using BIM platform				
Aspect	Researcher	Key Statement	GAP	Author's POV
Fall Prevention Planning	1) Zhang et al., 2015 2) Azhar & Behringer, 2013	1) BIM can help discover possible fall risks and automatically model the recommended fall protection. 2) BIM models may be used to determine the positions of employees' fall protection tie-off points, allowing permanent anchorage points to be included in the design.	• What types of fall protection that can be discovered and recommended by BIM other than tie off points?	• Guardrails, safety net and edge protections
Site layout and Safety Planning for Maintenance and Operation	1) Azhar & Behringer, 2013	1) Offering ways to manage and visualise current plans and site status information. 2) Supporting safety communication in a variety of contexts, such as informing site staff to take safety precautions in response to a specific risk or issuing warnings about various risks.	• Where do the clients can obtain the site layout from? • What level of perspective of site layout can be viewed?	• After the completion of the oil and gas infrastructure, clients can demand the facility layout from the consultants. • BIM offers 3D and 4D perspective level to view the site layout.

Table 2.2: The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project

The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project				
Aspect	Researcher	Key Statement	GAP	Author's POV
Perception of BIM	Farghaly et al., 2016	1) Facilities manager/clients refused to use BIM due to lack of evidence of benefits in implementing BIM in facility management. 2) The ambiguity of BIM implementation as well as the criteria for effective BIM adoption in facility management. 3) Lack of guidelines and standards.	• What should we do to strengthen the evidence of benefits in implementing BIM in facility management? • How do we make implementation of BIM and criteria for effective BIM less ambiguous in facility management? • How do we overcome the lack of guidelines and standards?	• The government can list out the companies that implement BIM in their projects as an award. • Big company such as PETRONAS must be the initiator to make BIM implementation less ambiguous in FM. • Guidelines and standards should be organised and provided by the company.
High Cost	1. Farghaly et al., 2016 2. Rafindadi et al., 2020	1) The cost will rise as a result of the change in prior processes and standards. 2) The cost of hiring or training employees to utilise BIM.	• How to convince the operation manager when the cost of it will rise?	• BIM implementation may last for a very long period, has good accuracy, and can be repeated many times in numerous projects at a cheaper cost than the old method. The first cost will be higher, but it will drop for future projects.

Table 2.2: The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project (continued)

The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project				
Aspect	Researcher	Key Statement	GAP	Author's POV
Interoperability and Incompatibility Issues	1. Farghaly et al., 2016 2. Memon et al., 2014	1) Because of the differences between BIM platforms and facility management platforms. 2) File incompatibility occurs when various organisations use different software or different versions of the same software.	• How to overcome the differences? • How do we make sure that each organisations utilize the same version of the same software?	• Training and ensure it is conveyed in the right manner. • Ensure each organization uses the same software and government should develop a standard guideline for all organization.
Training, roles and responsibilities	1. Farghaly et al., 2016 2. Rafindadi et al., 2020	1) Most of the facility management personnel lack the fundamental BIM knowledge required to apply the guidelines, standards and processes in facility management practise. 2) It would take a long time to recruit and conduct a training for employees to implement BIM.	• How do we overcome the lack of fundamental BIM knowledge? • How to reduce the time taken to go through recruitment and training?	• Develop a dedicated team that consists of experts and beginners to support and help each other. • Add a BIM application course in university.
Poor Knowledge and Skills	Hoang et al., 2020	Inadequate BIM technological expertise and experience, but also because of the owner's hesitancy.	What can be done to improve the inadequate BIM technological expertise, experience, and hesitancy?	Provide seminars that invite BIM specialist from big company or overseas that can convey the BIM in the right manner.

Table 2.2: The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project (continued)

The Challenges to Implement BIM in Maintenance of Infrastructure Oil and Gas Project				
Aspect	Researcher	Key Statement	GAP	Author's POV
Lack of Demand from the Clients	1. Bosch-Sijtsema et al., 2017 2. Haron et al., 2017	1) No requests of BIM utilization in projects from the clients due to clients' lack of knowledge and expertise in BIM 2) BIM is better suited for large projects, and its deployment in Malaysia is still in its early stages.	• What can be done to convince them to request/invest the BIM utilization in the maintenance project? • How to make sure that smaller projects implement the BIM in maintenance phase?	• Government can grant the companies that implement BIM when they reach a certain level of safety with an award. • Small projects/companies may be eligible for government loans.
Resistance to Change	1. Haron et al., 2017 2. Siebelink et al., 2021 3. Nasly et al., 2014	1) Stakeholders are fine with the results of old methods to design projects, etc. 2) The personnel have spent the majority of their life utilising the old technique. 3) Stakeholders cannot handle the uncertainty since BIM implementation will incur costs and disrupt the previous processes.	• How to make the stakeholders see the difference between old method and new method? • What can be done to change their mind? • What needs to be done to overcome the uncertainty of stakeholders?	• Government can introduce to stakeholders the comparison of both method and elaborate the benefits. • Collaboration between employees who are experts using the old method and employees who are experts using the new method. • Show previous ROI of BIM-related projects.

CHAPTER 3

METHODOLOGY

Exploratory research including a case study, web sources, and questionnaire survey was employed to carry out the study. During this step, all of the components for the questionnaires, survey, and case study will be finalized. Following that, the results from the questionnaire survey will be examined using the Statistical Package for the Social Science (SPSS) and Relative Importance Index (RII) (SPSS). The oil and gas facility managers will assess the framework for safety control for maintenance of oil and gas infrastructure once it has been designed using BIM. At the conclusion of this chapter, a flowchart illustrating this study approach will be shown.

3.1 Research Strategy

Exploratory research has been chosen to carry out this study since the use of BIM in maintenance for oil and gas infrastructure projects is still new, particularly in Malaysia. Two methods—primary and secondary—will be used to get more information on this research using the questionnaires survey, interview and case study, online sources, literature review. Qualitative research will be utilized as data collection during the exploratory research. This will aid comprehension of human experiences and knowledge, as well as individuals' cultures, ideas, and values on a specific issue (Kalu, 2017). Therefore, the purpose of this research is to investigate and comprehend what and how the framework for safety control is carried out using the BIM platform, as well as why the application of BIM is still lacking in the maintenance of oil and gas infrastructure projects.

3.1.1 Literature Review

To obtain a better knowledge of this research and conduct a thorough literature review, previous studies on the framework for safety control in maintenance of oil and gas infrastructure projects, how Building Information Modelling (BIM) works, and BIM implementation in facility management from published and unpublished work are carefully chosen. Reading resources, such as books, articles, journals, and conference papers, serve as references in the literature review. So far, over 20 reading materials have been mentioned in the literature review to assure the quality of the research. A solid combination of these resources will offer important details.

3.1.2 Web Sources

The Internet is a fantastic resource for retrieving and obtaining all accessible information about a certain study topic from across the world. When referencing a reference, the data and information obtained must be reviewed and the credibility of the sources must be confirmed. The statistical data, accident history, and current knowledge of BIM adoption in Malaysia for this study were acquired from internet sources. This information was primarily obtained from the websites of the government or approved organizations.

3.2 Data collection

3.2.1 Questionnaires Survey

A questionnaire survey will be created to get the oil and gas stakeholders' perspectives about BIM implementation for maintenance projects. The sample of the questions will be determined from the literature review. This questionnaire survey aims to establish the framework for safety control aspects for maintenance in oil and gas projects as well as to identify the challenges for implementing BIM for maintenance in the oil and gas industry. Before conducting the actual survey and distributing it on a larger scale, a pilot survey will be developed first and act as a preliminary survey. It will be shared with the 12 respondents that will consist of four project engineers, four BIM coordinators and four BIM modelers. The preliminary survey is conducted because it is to identify the understanding and completeness of the sample questions given to the respondents. The targeted respondents must know the concept of BIM to answer the questionnaires. In order to obtain good precision in this research, the respondents' personal information will be collected. This questionnaires survey will be shared through online platform to the targeted respondents consists of client, owner, facility manager and contractor. By determining the sample size from the population, it is possible to determine the total number of respondents required for questionnaire surveys. Shown below is the formula to represent proportion (Israel, 2012):

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

Where, sample size will be taken as n, population size as N and level of precision (0.05 in this case) as e. The average online survey responder rate typically reaches 30% of the population (Fincham, 2008).

3.2.2 Case Study

This research utilized a case study to determine the level of BIM implementation in managing safety controls, identify safety controls to establish a maintenance framework, and analyze the challenges of adopting BIM in maintenance for oil and gas infrastructure projects. This case study will take place in and around Malaysia only. Through careful observation, reconstruction, and analysis of the instances under inquiry, case studies can effectively explain both the process and the outcome of a phenomena (Zainal, 2007). This interview will contribute to a better understanding of the research issue. Before conducting the interview, it must be well-structured to avoid drifting from the topic of the study. Because this research topic is mostly about safety controls for maintenance in oil and gas infrastructure, BIM implementation, and safety control framework, the interviewees will be a consultant, a BIM modeler, and a BIM coordinator because they have experience managing safety and facility as well as BIM implementation. Throughout the interview, each of them will be evaluated.

3.3 Data Analysis

After all of the data has been properly collected via questionnaires survey, the data will be evaluated and ranked using RII using SPSS software to find the most influential data among various responders.

3.3.1 Relative Importance Index (RII)

The Relative Significance Index (RII) method is used to define the relative importance of many components for safety control framework that may be implemented by BIM platform and various issues that generate challenges in adopting BIM among stakeholders. The RII equation is as follows:

$$\text{RII} = \frac{\sum \text{W}}{\text{A x N}}$$

W = weight given to each factor by the respondents from 1 (extremely disagree) to 5 (extremely agree); A = the highest weight (i.e., 5 in this case); N = the total number of respondents. RII value is ranged between zero and one, thus the highest the value of RII, the higher the rank is. The perspectives of the facility managers, owners, and contractors will be ranked. Finally, the total RII rating will be established.

3.4 Statistical Package for the Social Science (SPSS)

SPSS is a software program that comprises of many statistical processes that has been designed to manage and analyze scientific data. SPSS software is the most widely used as an all-purpose tool with multi-purpose versatility. Four types of statistical operations will be performed on the data collected by using this tool in order to analyze the safety control framework that could be deployed by the BIM platform and numerous issues that cause difficulties in the adoption of BIM among stakeholders.

3.4.1 Correlation test

The nonparametric options are represented by Spearman's correlation. It is a method of statistical analysis that is used to determine the strength and direction of the nonlinear and monotonic connections that exist between two variables. It is useful in determining how closely the number and the possible outcomes are related to one another. In the context of this study, a correlation test was being conducted on the viewpoints of the maintenance experts in order to determine the nature of the relationship that exists between the perspectives of one group and those of another group. The response obtained from the correlation test must be somewhere between -1 and 1. If the number is very near to -1, this suggests that the correlation is negative. If the number is close to zero, it suggests that there is no connection between the two variables, however if the number is close to one, it shows that there is a correlation between the two variables. As the correlation between the data that have been matched grows stronger, the level of agreement that can be expected from the respondents will also grow stronger.

3.4.2 Cronbach's Alpha Reliability Test

This test is used to determine the questionnaires' internal consistency and stability, or how closely connected they are to one another throughout each part. Additionally, the range of alpha values is typically between 0 to 1. The scaled value's components have the highest internal consistency and stability, with a Cronbach's Alpha coefficient of 1.0 being the closest. There is also a range of value to define the internal consistency of the alpha. Greater than 0.9 indicates it's somehow excellent, greater than 0.8 indicates it's somehow good, greater than 0.7 indicates it's somehow acceptable, greater than 0.6 indicates it's somehow uncertain, greater than 0.5 indicates it's somehow poor, and lower than 0.5 indicates it's somehow unacceptable.

3.4.3 Validity Test

The validity test provides assistance in describing how well the data obtained cover the real area that is being investigated. It has been demonstrated, both in practice and in the academic literature, that in order for the researchers to be able to have confidence in the findings of a study, they need to ensure that the evaluation instrument is both trustworthy and validated. The information was collected from reputable sources of responders who play an essential position in relevant departments in order to ensure its accuracy. The literature study, which was derived from the ideas that were addressed, served as the basis for the development of the research questions. In this context, a correct measurement does not always indicate reliability, and vice versa. When the p-value of the unstandardized estimates achieves a score that is lower than 0.05, the item in question is regarded as valid.

3.5 Flowchart of Research Methodology

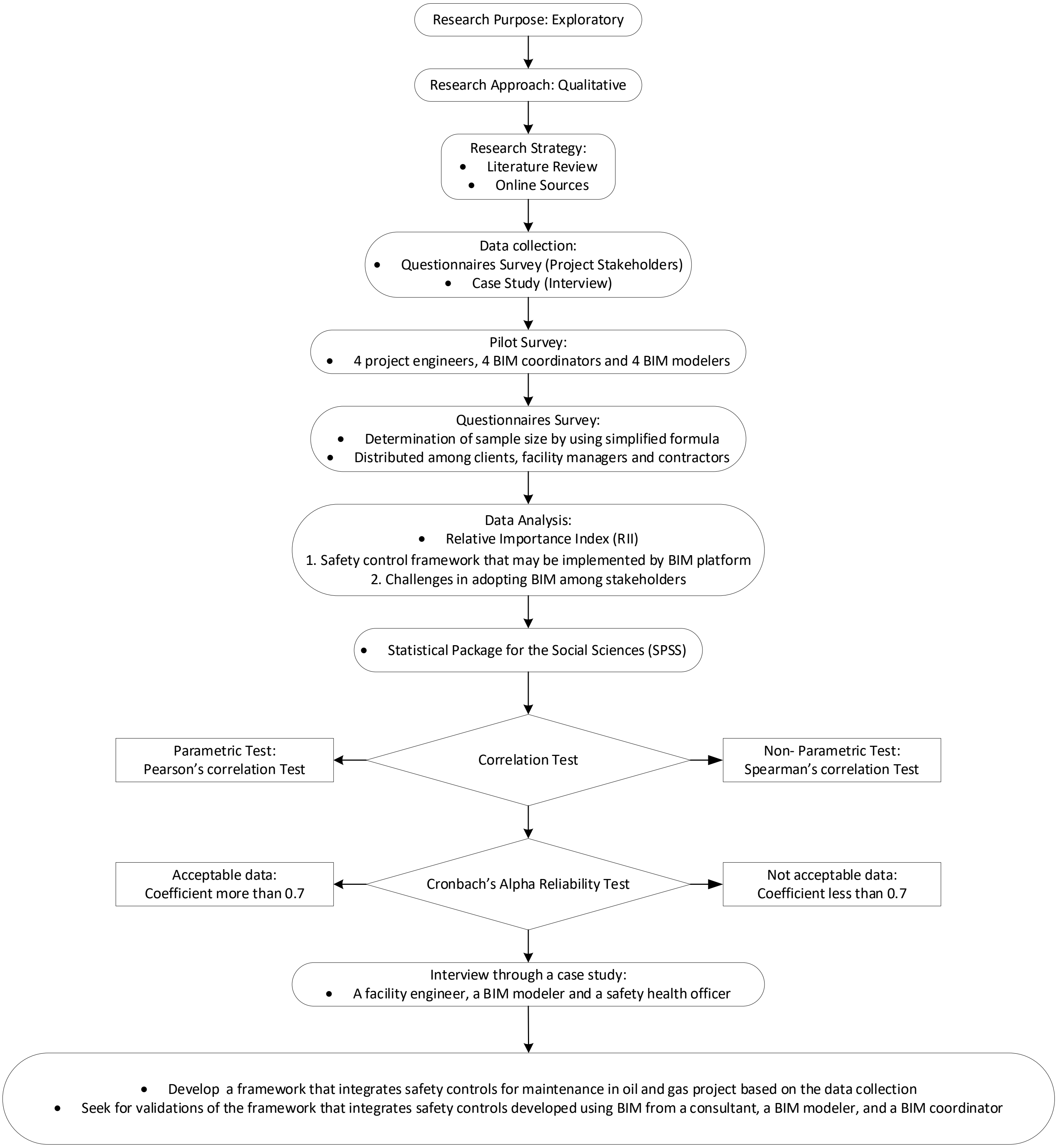

Figure 3.1: Flowchart of research methodology

CHAPTER 4

RESULTS AND DISCUSSION

The goal of this chapter is to analyze and further investigate the study's findings utilizing the triangulation approach. Before conducting the actual questionnaire survey to gather a large number of respondents, a pilot survey was developed to get input on the questionnaire survey in order to deliver reliable findings for this project. When the questionnaire survey is improvised and prepared to be executed, the sample size is then determined for the questionnaire survey based on the formula given by Israel. For many weeks, using Microsoft Form, data from the questionnaire survey is collected from contractors, engineers, modelers, and clients who are familiar with BIM and have used it in their oil and gas projects. While collecting the data from the questionnaire survey, a few interviews has been conducted with engineers, modelers and contractors. These interviewees are selected based on their background such as familiar with BIM and has been involved in oil and gas projects. The respondents and interviewees are selected through LinkedIn, email, social media and phone calls. Following that, the acquired data will be analyzed and provided in tables displaying RII, Average Index, and SPSS data analysis. During the interview session, an in-depth discussion was held on the current industry in safety control utilizing BIM. At the end of the chapter, a framework for BIM implementation for safety control in oil and gas maintenance projects, as well as solutions to possible challenges in implementing BIM in oil and gas maintenance projects, will be discussed.

4.1 Pilot Survey

The purpose of performing a pilot survey before executing the actual questionnaire is to ensure that the questionnaires are complete in fulfilling the objectives in the most effective and thorough way possible. In addition, by performing the pilot survey, the data acquired during the actual questionnaire survey will be more trustworthy and comprehensive for data analysis. There are 10 questionnaires being distributed using Microsoft Form to 4 project engineers, 4 BIM coordinators and 4 BIM modelers through LinkedIn. The questionnaires have been filled out by them and they were few feedbacks has been received related to the quality of the questionnaire such as utilization of question wordings and explanation or example that can point out the key point of the questions given so that respondents remained interested and focused on the purpose of the survey. All the feedbacks related to the layout were evaluated and taken into consideration as well resulting in a more user-friendly Microsoft Form layout accomplished by splitting the questions into multiple categories, notably elements impacting safety, safety control aspects in BIM, and impediments to BIM adoption.

4.2 Demographic of Respondents

The questionnaire was created in Microsoft Form and shared via internet platforms such as LinkedIn. The online survey was chosen because it allows respondents to complete the survey on their own time and schedule. They are usually less costly than paper surveys. They don't need interviewers, printers, or transcribers. It is also user-friendly since online survey questions may be chosen to be necessary, optional, or a combination of both. This gives the researcher the ability to compel individuals to respond (POLARIS, 2012). With online survey, the data obtained can be transferred and analyzed efficiently without the need to key in one by one into Microsoft Excel and SPSS.

The Israel (2012) method was used for sample selection, yielding a total of 70 sample size from an 84 population of BIM employees in the oil and gas sectors, with an emphasis on Malaysia.

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

$$n = \frac{84}{1 + (84)(0.05)^2}$$

$$n = 69.42 = 70$$

The response rates are acceptable because they are greater than 30%, as stated in the preceding chapter.

Respondents’ rates**:**

$$\frac{70}{84} \times 100 = 83.33\%$$

The questionnaire obtained 77 valid replies from respondents. The respondents are involving of 57 males and 20 females, who are somewhat imbalanced at 74% and 26%, respectively, and are predominantly between the ages of 20 to 29. The remaining 24, 3, and 2 respondents are between the ages of 30 to 39, 40 to 49, and above 50, representing 31.2%, 3.9%, and 2.6%, respectively. The respondents with the most credentials had a bachelor's degree, accounting for 77.9% of the total number of 77 respondents. Other credentials include a diploma and a master's degree, with a diploma accounting for 13% of the total and a master's degree accounting for 9.1%.

The respondents' designation is largely "BIM Modeler," representing for 45.5% of the total of 77 respondents. This is followed by "Other" with a designation not specified on the choices, which includes maintenance and reliability engineers, consultants, new graduates, and students who have finished their internship using BIM software, totaling 15 people and accounting for 19.5% of the sample size. BIM Coordinators are the respondents with the third most designation, accounting for 15.6% of the total number of 77 respondents. This is followed by the client and the BIM Manager, who have roughly the same frequency of 6 and 5, with percentages of

7.8% and 6.5%, respectively. The remaining 2.6%, or 2 responses, are consultants and site engineers. Their working experience is largely less than three years (29 respondents, 37.7%), followed by less than seven years, less than ten years, and more than ten years (26, 14, and 8 respondents, respectively). Because the respondents are largely from the industry and have been working for a long time, their depth of expertise is appropriate for this research. With 12, 55, and 10 respondents out of 77, the respondents' degree of expertise on Building Information Modelling (BIM) is assessed as limited, intermediate, and comprehensive.

The respondents' highest level of work in the BIM dimension is 3D (2D + visualization) with 30 respondents, followed by 4D (3D + schedule) with 17 respondents and 5D (4D + cost) with 14 respondents. This equates to 39%, 22.1%, and 18.2%, respectively. They are mostly aware that BIM can be used for safety control in maintenance projects, responding "Yes" at 59.9%, with 46 respondents out of 77, while a few respondents responding "Maybe" at 22.1%, with 17 respondents, because they are unsure about the safety control in maintenance projects, and respondents responding "No" at 18.2%, with 14 respondents, because they are unaware about the safety control in maintenance projects. The impact of BIM use in safety control in maintenance projects in Malaysia is regarded to be generally improved, with 39 respondents selecting "Improved" and 25 selecting "Greatly improved," with 50.6% and 32.5%, respectively. Tables shown below have further information about this data.

Table 4.1: Gender

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	57	74.0	74.0	74.0
	Female	20	26.0	26.0	100.0
	Total	77	100.0	100.0	

Table 4.2: Age

Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20-29 years old	48	62.3	62.3	62.3
	30-39 years old	24	31.2	31.2	93.5
	40-49 years old	3	3.9	3.9	97.4
	>50 years old	2	2.6	2.6	100.0
	Total	77	100.0	100.0	

Table 4.3: Highest Qualification

Highest Qualification					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bachelor's Degree	60	77.9	77.9	77.9
	Diploma	10	13.0	13.0	90.9
	Master's Degree	7	9.1	9.1	100.0
	Total	77	100.0	100.0	

Table 4.4: Designation

Designation					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Client	6	7.8	7.8	7.8
	Consultant	2	2.6	2.6	10.4
	BIM Manager	5	6.5	6.5	16.9
	BIM Coordinator	12	15.6	15.6	32.5
	Site Engineer	2	2.6	2.6	35.1
	BIM Modeler	35	45.5	45.5	80.5
	Other	15	19.5	19.5	100.0
	Total	77	100.0	100.0	

Table 4.5: Working Experience

Working Experience					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 3 years	29	37.7	37.7	37.7
	Less than 7 years	26	33.8	33.8	71.4
	Less than 10 years	14	18.2	18.2	89.6
	More than 11 years	8	10.4	10.4	100.0
	Total	77	100.0	100.0	

Table 4.6: Depth of Knowledge

Depth of Knowledge					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Little Knowledge	12	15.6	15.6	15.6
	Moderate Knowledge	55	71.4	71.4	87.0
	Extensive Knowledge	10	13.0	13.0	100.0
	Total	77	100.0	100.0	

Table 4.7: Highest Work Level

Awareness of BIM safety					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	46	59.7	59.7	59.7
	No	14	18.2	18.2	77.9
	Maybe	17	22.1	22.1	100.0
	Total	77	100.0	100.0	

Table 4.8: Awareness of BIM Safety

Highest Work Level					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2D (CAD Drawing)	2	2.6	2.6	2.6
	3D (2D + Visualization)	30	39.0	39.0	41.6
	4D (3D + Schedule)	17	22.1	22.1	63.6
	5D (4D + Cost)	14	18.2	18.2	81.8
	6D (5D + Lifecycle)	5	6.5	6.5	88.3
	7D (6D + Operation and Maintenance)	5	6.5	6.5	94.8
	8D (7D + Safety)	3	3.9	3.9	98.7
	None of the above	1	1.3	1.3	100.0
	Total	77	100.0	100.0	

Table 4.9: Impact of BIM in the industry

Impact of BIM in the industry					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not sure	12	15.6	15.6	15.6
	No effect	1	1.3	1.3	16.9
	Improved	39	50.6	50.6	67.5
	Greatly Improved	25	32.5	32.5	100.0
	Total	77	100.0	100.0	

4.3 Safety Control Aspects That Can Be Executed by Using BIM Platform

This study investigates the safety control features that may be implemented utilizing a BIM platform to ensure that stakeholders such as engineers, facility managers, and contractors can successfully use them in Building Information Modelling (BIM) software for their oil and gas maintenance projects. There are six aspects of safety control that helps the stakeholders to perform them in BIM software. Among them is safety training, identification of unsafe hazards in maintenance, on-site maintenance supervision, exchange and cooperation in maintenance management, fall prevention planning and site layout and safety plan for maintenance operation.

Each aspect of the safety control that can be executed by using BIM platform is identified from A1 to A6 to avoid misunderstanding and assure proper analysis. The RII formula is then used to determine the most critical part of safety control that can be carried out utilizing the BIM Platform. The data are entered into Microsoft Excel, and the Average Index is calculated, yielding the rank and internal consistency as shown in Table 4.10 below.

Table 4.10: Rank and Internal Consistency of Safety Control Aspects That Can be Executed by Using BIM Platform

<table>
<tr><th>Label</th><th>Safety Control Aspects That Can Be Executed by Using BIM Platform</th><th>RII</th><th>Ranks</th><th>AVI</th><th>Internal Consistency</th></tr>
<tr><td>A1</td><td>Safety Training</td><td>0.79740</td><td>6</td><td>3.987013</td><td rowspan="5">High</td></tr>
<tr><td>A2</td><td>Identification of unsafe hazards in maintenance</td><td>0.836364</td><td>2</td><td>4.181818</td></tr>
<tr><td>A3</td><td>On-site maintenance supervision</td><td>0.825974</td><td>3</td><td>4.12987</td></tr>
<tr><td>A4</td><td>Exchange and cooperation in maintenance management</td><td>0.820779</td><td>5</td><td>4.10390</td></tr>
<tr><td>A5</td><td>Fall prevention planning</td><td>0.823377</td><td>4</td><td>4.116883</td></tr>
<tr><td>A6</td><td>Site layout and safety plan for maintenance and operation</td><td>0.872727</td><td>1</td><td>4.363636</td><td>Very High</td></tr>
</table>

Based on the results of the Relative Importance Index (RII), the most critical aspect of safety control that can be executed by using BIM platform for oil and gas maintenance projects is "A6: Site layout and safety plan for maintenance and operation" with RII of 0.87, followed by "A2: Identification of unsafe hazards in maintenance" and "A3: On-site maintenance supervision" with RII of 0.84 and 0.83, respectively. Based on the aforementioned results, the least significant part of safety control that can be carried out using a BIM platform for oil and gas maintenance projects is determined to be "A1: Safety training" with a RII of 0.90. According to the findings, BIM is more beneficial for site layout and safety plans for maintenance and operation. The internal consistency of the safety control aspects is high, as the average index (AVI) falls in the range of $3.40 < x < 4.20$, resulting in an AVI ranging from 3.99 to 4.12, with the exception of the number one ranked safety control aspect, site layout and safety plan for maintenance and operation, which is labelled as A6, which has an internal consistency of "very high" falling in the AVI range of $4.20 < x < 5.00$.

From the data analysis shown above, all project stakeholders appear to agree that BIM is able to conduct site layout and safety plan for maintenance and operation. This is might be because in Malaysia the majority of projects that are using BIM have the capability to visualise and simulate the project; thus, it is conceivable for the site layout and safety plan to be done using the simulation that is offered by BIM. Next, a wide variety of stakeholders came to the conclusion that BIM is capable of identifying unsafe hazards that are present in maintenance. BIM's clash detection feature, which helps discover hazards more quickly and comprehensively, is one of the many benefits of utilisation of BIM. The workers' exposure to the hazard will be minimized as a result of this, and the danger may be eliminated sooner rather than later, before it becomes much worse.

On the other hand, all of the stakeholders believe that the third highest position should go to on-site maintenance supervision. The stakeholders are able to oversee the potential accident circumstances in real time when they are monitoring the condition of the facility. This ensures that the facility will function for a long number of years while being safe for the workers. The fall prevention planning is placed fourth by the respondents because BIM can assist in the identification of potential fall hazards and can automatically model the fall protection that is advised. The facility operator will have the ability to suggest and construct a protection safety system to prevent falling during maintenance in spots that exhibit a high risk of dangers.

The fifth place goes to the fact that all of the stakeholders appear to be in agreement that BIM may be utilized in exchange and cooperation in maintenance management. Any revisions and modifications may be informed in real time using the BIM software since all of the design of the project is accessible to the project's stakeholders. Any misunderstandings in communication between the many parties involved may therefore be avoided. The stakeholders have come to the conclusion that the safety training aspects that are made available by BIM are the ones that have the least significant influence. This is due to the fact that, similar to the situation in Malaysia, the workers still do regular toolbox meetings before beginning their job. It is possible that utilizing BIM during the toolbox session may have provided the worker with a more accurate simulation of the operations that they will be performing. As a result, they will be more mindful of their own well-being and safety while carrying out the activity.

4.4 Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia

Based on the literature review, a number of the barriers in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia have been highlighted. There are six barriers in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia. The barriers are perception of BIM, high cost, interoperability and incompatibility, lack of training, roles and responsibilities, poor knowledge and skills, lack of demand from the clients and resistance to change.

Table 4.11: Rank and Internal Consistency of Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia

Label	Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia	RII	Ranks	AVI	Internal Consistency
B1	Perception of BIM	0.561039	7	2.805195	Medium
B2	High Cost	0.758442	5	3.792208	High
B3	Interoperability and Incompatibility	0.722078	6	3.61039	
B4	Lack of training, roles and responsibilities	0.849351	1	4.246753	Very High
B5	Poor knowledge and skills	0.818182	3	4.090909	High
B6	Lack of demand from the clients	0.805195	4	4.025974	
B7	Resistance to Change	0.831169	2	4.155844	

Each barrier in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia is labelled from B1 to B6 to avoid misunderstanding and assure proper analysis. The RII formula is then used to determine the most critical part of barriers in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia. The data are entered into Microsoft Excel, and the Average Index is calculated, yielding the rank and internal consistency as shown in Table 4.11 above.

It is crucial to understand the most critical barrier in implementing BIM for safety controls for infrastructure oil and gas projects in Malaysia, so that stakeholders are aware of the importance and benefits of BIM. As a result, the Relative Importance Index (RII) is used to identify the most significant constraints in this sector. According to the findings, the most critical barrier in the implementation of BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Projects in Malaysia is "B4: Lack of training, roles, and responsibilities," with a RII of 0.85, followed by "B7: Resistance to change" and "B5: Poor knowledge and skills," with RIIs of 0.83 and 0.82, respectively. Following the results, the least essential part of the barrier in using BIM for safety controls in infrastructure oil and gas projects in Malaysia is "B1: Perception of BIM," with a RII of 0.56. According to the findings, BIM implementation is more difficult when there is a lack of training, roles, and responsibilities in the sector. The internal consistency of the barriers to BIM implementation obtained is classified as medium, high, and very high, with an average index (AVI) of $2.81 < x < 4.20$. Lack of training, roles, and responsibilities is defined as very high internal consistency, whereas perception of BIM is rated as medium internal consistency. High internal consistency is assigned to the other factors, which include high cost, interoperability and incompatibility, poor knowledge and skills, a lack of client demand, and resistance to change.

Lack of training, roles, and responsibilities can make it hard for oil and gas projects and infrastructure maintenance to use BIM for safety control. When the level of BIM experience on a design team varies from person to person, BIM can't reach its full potential. One of the most important parts of using BIM successfully is how much all the key disciplines involved in the project are involved. If not, all parties use BIM as their standard method, the model that is made may only take into account some of the systems. Sometimes, the fact that the project's old staff didn't know anything about BIM also made it hard to use BIM.

The stakeholders also believe that resistance to change becomes the second barriers for oil and gas projects and infrastructure maintenance to use BIM for safety control. This is because many workers felt more comfortable with the traditional working method, which resulted in a resistance on the part of workers to adopt new technology and modifications in traditional procedures. Due to employees' unwillingness to adapt their working patterns, the business is unable to fully use BIM. The stakeholders have decided that a lack of knowledge and skills should come in third place after the first two factors. As for consultants, they may have an adequate understanding of BIM; however, facility managers and safety health officers will be expected to refer to the BIM as part of their supervision of the facility maintenance; consequently, it may be difficult for these individuals to adjust to something that is very unfamiliar to them.

However, lack of demand from the clients placed fourth in the potential barriers which has been agreed by the respondents. In the oil and gas industry, the client's request for safety control and maintenance might be good enough as it is. But there are still not enough demands for BIM to be used for safety control in oil and gas maintenance projects. Even though the firms are aware of the benefits of this new way of handling maintenance projects, most clients are not on board with the idea. BIM is only used in a maintenance project when the client asks for it.

The majority of them do not want to change since BIM would not only affect their working environment but also require them to purchase new licensed software to be deployed and hire qualified BIM employees for the projects. This causes them to be resistant to change. The total cost of their project will go up as a result of all of these alterations. It is clear from this that the use of BIM is reserved almost exclusively for large-scale projects and is not used at all for smaller-scale projects.

Interoperability and incompatibility are placed sixth and has become one of the challenges to BIM implementation. According to the responders, this issue is not as significant as a possible barrier, but it is an issue in some cases. For example, when advanced software is provided by multiple companies, and different project stakeholders may utilize different software packages during the project, incompatibility and interoperability issues may arise.

The stakeholders agreed that the most insignificant barrier is perception of BIM. In this case, most stakeholders may agree that BIM provides significant benefits for their projects, particularly in building, but owing to a lack of proof of benefits in implementing BIM for oil and gas maintenance projects, facilities managers/clients are hesitant to employ BIM. Due to a lack of guidelines and standards, facility managers have been disinterested in BIM adoption in this industry.

4.5 Spearman's Rank Correlation Coefficient Test – SPSS

In this study, the equivalence of two population correlation coefficients will be checked as part of study objectives, which are utilized as estimations of the population parameters, using the Spearman's correlation test. The answer for the correlation tests falls between -1 and 1 indicating the correlation between the parameters, whether positive, negative, or zero correlation. If the number is close to -1, it indicates a negative correlation. If the number is close to 0, it indicates a zero correlation while if the number is close to 1, it indicates a positive correlation. The degree of agreement among the responders will increase as the correlation between the matched data increases. The correlation test is done to each variable in the variables impacting aspect of the safety control that can be executed by using BIM, and the barriers in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia.

4.5.1 Correlations in Safety Control Aspects that can be executed by using BIM

Table 4.12 demonstrates that there is a significant correlation between several of the components; the first aspect, "A1: Safety training", has a significant correlation with A2, A4, A5, and A6 at the 0.01 and 0.05 level. It demonstrates a significant relationship with A1, A3, A4, A5, and A6 for "A2: Identification of unsafe hazards in maintenance". Following that, "A3: On-site maintenance supervision" has a strong correlation with A2, A4, A5, and A6. It demonstrates a significant correlation to A1, A2, A3, A5, and A6 for "A4: Exchange and cooperation in maintenance management". It has a significant correlation to the A1, A2, A3, A4, and A6 for "A5: Fall prevention planning". Meanwhile, it is significantly correlated to A1, A2, A3, A4, A5, and A6 for "A6: Site layout and safety plan for maintenance and operation".

Table 4.12: Spearman's Rho for A1 to A6

Spearman's Rho	A1	A2	A3	A4	A5	A6
A1	1	.613**	0.212	.432**	.479**	.244*
A2	.613**	1	.443**	.455**	.572**	.506**
A3	0.212	.443**	1	.423**	.399**	.455**
A4	.432**	.455**	.423**	1	.622**	.549**
A5	.479**	.572**	.399**	.622**	1	.533**
A6	.244*	.506**	.455**	.549**	.533**	1

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

* Correlation is significant at the 0.05 level (2-tailed).

4.5.2 Correlations in Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia

Table 4.13 demonstrates that there is a significant correlation between several of the components; the first aspect, "B1: Perception of BIM", has a significant correlation with B4, B5 and B7 at the 0.01 and 0.05 level. It demonstrates a significant relationship with B3, B4 and B7 for "B2: High cost". Following that, "B3: Interoperability and incompatibility" has a strong correlation with B2 only. It demonstrates a significant correlation to B1, B2, B5, and B6 for "B4: Lack of training, roles and responsibility". It has a significant correlation to the B1, B4, B6 and B7 for

"B5: Poor knowledge and skills”. Next, it is significantly correlated to B4 and B5 for "B6: Lack of demand from the clients". Meanwhile, for “B7: Resistance to change” it is significantly correlated to B1, B2, and B5.

Table 4.13: Spearman's Rho for B1 to B7

Spearman's Rho	B1	B2	B3	B4	B5	B6	B7
B1	1	0.173	0.213	.248*	.356**	0.145	.367**
B2	0.173	1	0.305**	.333*	0.149	0.171	.274*
B3	0.213	.305**	1	0.172	0.148	0.121	-0.138
B4	.248*	.333**	0.172	1	.479**	.428**	0.21
B5	.356**	0.149	0.148	.479**	1	.412**	.441**
B6	0.145	0.171	0.121	.428**	.412**	1	0.222
B7	.367**	.274*	-0.138	0.21	.441**	0.222	1

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

* Correlation is significant at the 0.05 level (2-tailed).

4.6 Cronbach's Alpha Reliability Test – SPSS

This test is used to determine the questionnaires' internal consistency and stability, or how closely connected they are to one another throughout each part. Additionally, the range of alpha values is typically between 0 to 1. For each question, the scale input is Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree, with weightages of 5, 4, 3, 2, and 1 accordingly. The scaled value's components have the highest internal consistency and stability, with a Cronbach's Alpha coefficient of

1.0 being the closest. There is also a range of value to define the internal consistency of the alpha. Greater than 0.9 indicates it's somehow excellent, greater than 0.8 indicates it's somehow good, greater than 0.7 indicates it's somehow acceptable, greater than 0.6 indicates it's somehow uncertain, greater than 0.5 indicates it's somehow poor, and lower than 0.5 indicates it's somehow unacceptable.

4.6.1 Reliability in Safety Control Aspects that can be executed by using BIM

The reliability statistics are shown in Table 4.14, which gives the Cronbach's Alpha value of 0.829 for the safety control aspects that can be executed using BIM in oil and gas infrastructure maintenance projects. This demonstrates that there is no need for concern in this area, as it is more than 0.8. However, the Cronbach's Alpha for this aspect is greater than 0.80, which is considered good. The greater the value, the more reliable the answers (Cortina, 1993). Furthermore, for a list of less than ten items, the acceptable Cronbach's Alpha is greater than 0.5, indicating that the Cronbach's Alpha is acceptable given that the items mentioned are just six, from A1 to A6.

Table 4.14: Reliability in Safety Control Aspects that can be executed by using BIM

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.829	0.829	6

The Item-Total Statistics are shown in Table 4.15 below, with the middle column, "Corrected Item-Total Correlation," displaying the correlation of each item with everything else combined; for example, item A2 correlated with items A1, A3, A4, A5, and A6 combined yields a value of 0.684. Item A3 has the lowest Corrected Item-Total Correlation at 0.436, but it is still more than 0.4, which is acceptable because all of the safety control aspects are associated with everything else combined. If the Corrected Item-Total Correlation is less than 0.4, it might be because the item is not related to or agreed upon by all other items combined. The values in this column are all low since there are less than ten entries. The final column, "Cronbach's Alpha

If Item Deleted," indicates that the removal of a specific item significantly increases or decreases the Cronbach's Alpha; the most significant item if deleted is the lowest value, A5 at 0.779, indicating that deleting item A5 will result in the most significant consistency within the question.

Table 4.15: Item-Total Statistics A1 to A6

Item-Total Statistics					
	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach's Alpha if Item Deleted**
A1	20.90	6.305	0.519	0.483	0.819
A2	20.70	5.791	0.684	0.574	0.782
A3	20.75	6.899	0.436	0.253	0.832
A4	20.78	6.201	0.650	0.501	0.791
A5	20.77	5.945	0.703	0.515	0.779
A6	20.52	6.279	0.612	0.468	0.799

4.6.2 Reliability in Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia

The reliability statistics are shown in Table 4.16, which gives the Cronbach's Alpha value of 0.655 for the barriers in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia. This demonstrates that there is an issue of concern for this aspect, as it is lower than 0.7. The Cronbach's

Alpha for this aspect is lower than 0.70, which is considered uncertain. The greater the value, the more reliable the answers (Cortina, 1993). Furthermore, for a list of less than ten items, the acceptable Cronbach's Alpha is greater than 0.5, indicating that the Cronbach's Alpha is acceptable given that the items mentioned are just seven, from B1 to B7.

Table 4.16: Reliability in Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
0.655	0.668	7

The Item-Total Statistics are shown in Table 4.17 below, with the middle column, "Corrected Item-Total Correlation," displaying the correlation of each item with everything else combined; for example, item B5 correlated with items B1, B2, B3, B4, B6 and B7 combined yields a value of 0.51. Item B3 has the lowest Corrected Item-Total Correlation at 0.192, and it is lower than the minimum which should be 0.4. This may be because the item is not related to or agreed upon by all other items combined. The values in this column are all low since there are less than ten entries. The final column, "Cronbach's Alpha If Item Deleted," indicates that the removal of a specific item significantly increases or decreases the Cronbach's Alpha; the most significant item if deleted is the lowest value, B5 at 0.574, indicating that deleting item B5 will result in the most significant consistency within the question.

4.7 Validity of Data – SPSS

The validity of data demonstrates the accuracy of a technique to assess the study's purpose, which is separated into two sections: safety control aspects that can be executed by using BIM, and barriers in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia. This validity number suggests that there is substantial evidence that the data is statistically significant.

Table 4.17: Item-Total Statistics B1 to B7

Item-Total Statistics					
	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach's Alpha if Item Deleted**
B1	23.92	11.257	0.393	0.248	0.617
B2	23.97	10.184	0.338	0.259	0.631
B3	24.16	11.291	0.192	0.293	0.675
B4	23.52	10.621	0.456	0.331	0.597
B5	23.68	9.775	0.510	0.405	0.574
B6	23.74	9.958	0.423	0.274	0.601
B7	23.61	11.030	0.306	0.407	0.636

4.7.1 Validity in Safety Control Aspects that can be Executed by Using BIM

The validity of this aspect for the sum of all the elements in relation to each other is proven to be accepted, since all the values lies below the 0.05 limit of the row Sig (2-tailed). The p-value of less than 0.05 indicates that the items A1 through A6 are statistically significant, with all aspects having values close to zero and very low in comparison to the limit. Table 4.18 shows that the interpretation of the data to each other totaled is appropriate.

Table 4.18: Validity test of A1 to A6

Correlations								
		A1	**A2**	**A3**	**A4**	**A5**	**A6**	**Total**
A1	Pearson Correlation	1	.642**	0.153	.405**	.470**	.266*	.685**
	Sig. (2-tailed)		0.000	0.183	0.000	0.000	0.019	0.000
A2	Pearson Correlation	.642**	1	.362**	.415**	.556**	.505**	.803**
	Sig. (2-tailed)	0.000		0.001	0.000	0.000	0.000	0.000
A3	Pearson Correlation	0.153	.362**	1	.400**	.379**	.409**	.597**
	Sig. (2-tailed)	0.183	0.001		0.000	0.001	0.000	0.000

Table 4.18: Validity test of A1 to A6 (Cont.)

Correlations								
		A1	**A2**	**A3**	**A4**	**A5**	**A6**	**Total**
A4	Pearson Correlation	.405**	.415**	.400**	1	.617**	.574**	.767**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000
A5	Pearson Correlation	.470**	.556**	.379**	.617**	1	.539**	.809**
	Sig. (2-tailed)	0.000	0.000	0.001	0.000		0.000	0.000
A6	Pearson Correlation	.266*	.505**	.409**	.574**	.539**	1	.740**
	Sig. (2-tailed)	0.019	0.000	0.000	0.000	0.000		0.000
Total	Pearson Correlation	.685**	.803**	.597**	.767**	.809**	.740**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

4.7.2 Validity in Barriers in Implementation BIM for Safety Controls for Maintenance of Infrastructure Oil and Gas Project in Malaysia

The validity of this aspect for the sum of all the elements in relation to each other is proven to be accepted, since all the values lies below the 0.05 limit of the row Sig (2-tailed). The p-value of less than 0.05 indicates that the items B1 through B7 are statistically significant, with all aspects having values close to zero and very low in comparison to the limit. Table 4.19 shows that the interpretation of the data to each other totaled is appropriate.

Table 4.19: Validity test of B1 to B7

Correlations									
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**Total**
B1	Pearson Correlation	1	0.148	0.207	0.185	.340**	0.154	.373**	.549**
	Sig. (2-tailed)		0.199	0.071	0.106	0.003	0.180	0.001	0.000
B2	Pearson Correlation	0.148	1	.325**	.277*	0.098	0.141	0.215	.582**
	Sig. (2-tailed)	0.199		0.004	0.015	0.395	0.222	0.061	0.000

Table 4.19: Validity test of B1 to B7 (Cont.)

Correlations									
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**Total**
B3	Pearson Correlation	0.207	.325**	1	0.104	0.107	0.140	-0.194	.449**
	Sig. (2-tailed)	0.071	0.004		0.368	0.353	0.225	0.091	0.000
B4	Pearson Correlation	0.185	.277*	0.104	1	.429**	.438**	0.131	.619**
	Sig. (2-tailed)	0.106	0.015	0.368		0.000	0.000	0.258	0.000
B5	Pearson Correlation	.340**	0.098	0.107	.429**	1	.420**	.426**	.685**
	Sig. (2-tailed)	0.003	0.395	0.353	0.000		0.000	0.000	0.000
B6	Pearson Correlation	0.154	0.141	0.140	.438**	.420**	1	0.217	.633**
	Sig. (2-tailed)	0.180	0.222	0.225	0.000	0.000		0.058	0.000

Table 4.19: Validity test of B1 to B7 (Cont.)

Correlations									
		B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**Total**
B7	Pearson Correlation	.373**	0.215	-0.194	0.131	.426**	0.217	1	.516**
	Sig. (2-tailed)	0.001	0.061	0.091	0.258	0.000	0.058		0.000
Total	Pearson Correlation	.549**	.582**	.449**	.619**	.685**	.633**	.516**	1
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
**. Correlation is significant at the 0.01 level (2-tailed).									
*. Correlation is significant at the 0.05 level (2-tailed).									

4.8 Framework for Safety Control for Maintenance of Infrastructure Oil and Gas Project Using BIM

The utilization of BIM in the development of a framework for the control of safety risks during the maintenance of oil and gas infrastructure was necessary in order to accomplish the third goal of this project. If this framework is developed, it is essential to demonstrate that the project's safety has enhanced. This may be done by obtaining again the BIM database for the oil and gas structure and gathering all of the information pertaining to the facility's comprehensive safety measures. This framework will have a significant possibility of assisting workers, facility managers, and safety managers in reducing the number of maintenance accidents, worker injuries and fatalities, and property damage that occur while carrying out maintenance procedures. It is crucial to ensure safety during the process of executing maintenance works because this helps to reduce costs such as worker's compensation, health insurance claims, regulatory fines, litigation, and a wide variety of other potential issues. By utilizing BIM, one can guarantee that all of the stakeholders will have access to high-quality information as well as the ability to visually represent the necessary data (Alavi et al., 2021).

The framework designed is mainly focused on the elimination of the hazards in workplace, putting awareness and government support for BIM adoption at the first process. This makes it possible for efforts to be taken to increase the usage of BIM first and foremost in the Malaysian sector, with the goal of making this approach the standard procedure for contractors, owners, and engineers. Not only is the policy significant for ensuring that this framework can be implemented, but it also serves as the first stage in the process. Second, there has to be an increase in people's knowledge, and third, the hardware of BIM itself needs to be publicly available and simple to use.

Next, the infrastructure oil and gas maintenance project started with deciding whether to use BIM or conventional method as a platform to execute safety control. If the conventional method is chosen, stronger awareness and government support for BIM adoption must be undertaken. Then, the maintenance work is initiated. After that, all the safety information from safety related native BIM model, safety related non-3D and facility maintenance safety related information are gathered and appropriate tool in BIM is used to execute the safety controls such as safety training, identification of unsafe hazards in maintenance, on-site maintenance supervision, communication, fall prevention planning and site layout and safety planning for maintenance and operation. When these phases of the BIM approach are performed, the success of the safety control in the project will be determined using the data of the safety hazards that occur while the project is being maintained. Should there be no reported hazard, then the BIM can be considered as fully adopted in the safety management system. If there were some hazards, then the process takes all stakeholders back to improve efficiency and tear down barriers to implement BIM in the safety management system. If there was no reported hazard, then the BIM can be considered as fully adopted in the safety management system.

The validation process for the framework depicted in Figure 4.1 below involved comments from and interviews with facility managers conducted on the LinkedIn site. The framework was made available online so that it could be verified as to whether it was appropriate and practical to use in the sector. Positive response was received from the three site managers and BIM coordinators who were questioned, and the framework is valid to be used in the actual working environment of oil and gas infrastructure maintenance projects.

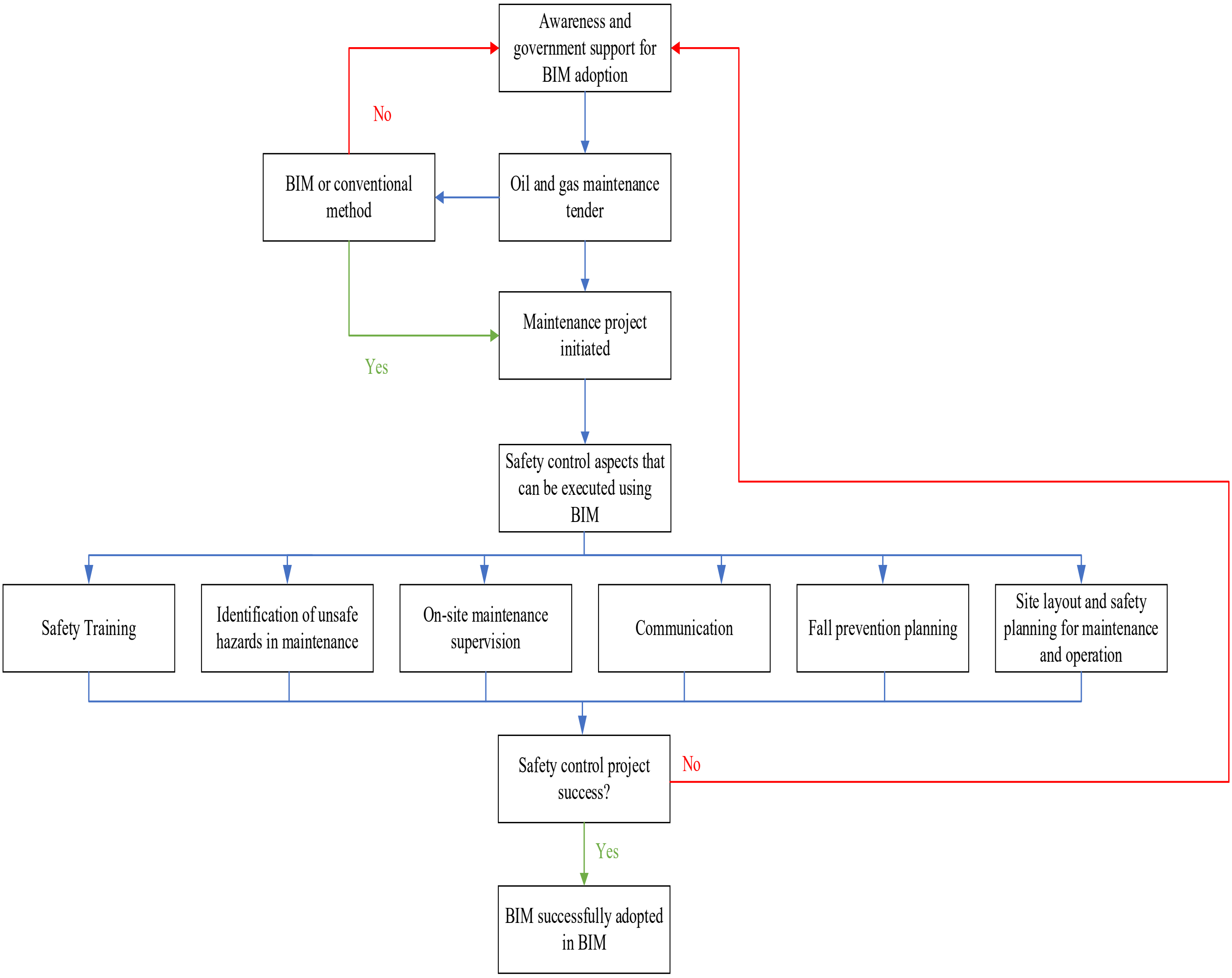

Figure 4.1: Framework for Safety Control for Maintenance of Infrastructure Oil and Gas Project Using BIM

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this chapter, we will discuss the entirety of the study that was carried out in order to evaluate not only the reliability of the outcomes but also the aims of this particular study. In order to ensure that the goals of this study are successfully accomplished, a summary of the findings that have been completed along with some recommendations will be prepared.

As a last thought, it is important to note that the method of Building Information Modelling has been extensively employed in the oil and gas business in safety control. The oil and gas industry has made significant progress in building information modelling (BIM), particularly in oil and gas infrastructure construction projects but not in maintenance projects. BIM needs to be applied by industry players especially for oil and gas infrastructure maintenance project in order to improve safety management in the industry and to eliminate workplace dangers. The conclusion of this research was reached after responses were gathered using an online survey and few interviews, and SPSS, RII, and AVI were used to analyze the collected data.

Based on the data analysis conducted, it is identified that “site layout and safety plan for maintenance and operation” as the highest RII for safety control aspects that can be executed by using BIM platform. This might be because in Malaysia the majority of projects that are using BIM have the capability to visualize and simulate the project; thus, it is conceivable for the site layout and safety plan to be done using the simulation that is offered by BIM. “Lack of training, roles and responsibilities” has recorded as the highest RII for the most potential barrier in implementation BIM for safety controls for maintenance of infrastructure oil and gas project in Malaysia. BIM for safety control in oil and gas projects and infrastructure maintenance can be difficult without training, roles, and responsibilities. BIM's potential is limited when a design team's BIM experience varies. BIM success depends on how much all project disciplines are involved. If not, everyone will use BIM as their standard method, and the model may only include some of the systems. Sometimes it was hard to use BIM because the old staff on the project didn't know anything about it.

Following the completion of these results, a framework for the safety control and maintenance of infrastructure oil and gas projects utilizing BIM has been successfully developed. This is to ensure that BIM tools are fully optimized to produce hazard profiles, predict and take preventative actions against them during the initial stages of maintenance work. During the process of developing the framework, the barriers and safety controls components were examined in great detail, and validation from industry participants that are already engaged in oil and gas projects was taken.

This study assists the oil and gas industry in identifying, ranking, and overcoming challenges that are associated with the implementation of BIM in oil and gas infrastructure maintenance project. As a recommendation, since there are only a few of studies related to maintenance, oil and gas infrastructure, with BIM, it is suggested to extend the research mainly focus on the safety control for maintenance project using BIM. This will help the oil and gas industry players to draw attention to the constraints of implementing BIM for maintenance project in order to provide a solution and to manage safety in maintenance work. The next suggestion is to broaden the scope of the study such that it includes not only Malaysia but also other western and eastern regions of the world. The study will be able to contribute to the strengthening of the study for the benefits of BIM implementation in the oil and gas infrastructure maintenance project using the data that is afterwards collected. When the data that was collected in other regions is compared to the data that was collected in Malaysia, it is possible to identify the primary problem that makes it difficult for BIM to be applied in maintenance projects in Malaysia. On the other hand, a more comprehensive and detailed framework for safety control and maintenance of infrastructure oil and gas projects utilizing BIM can be created.

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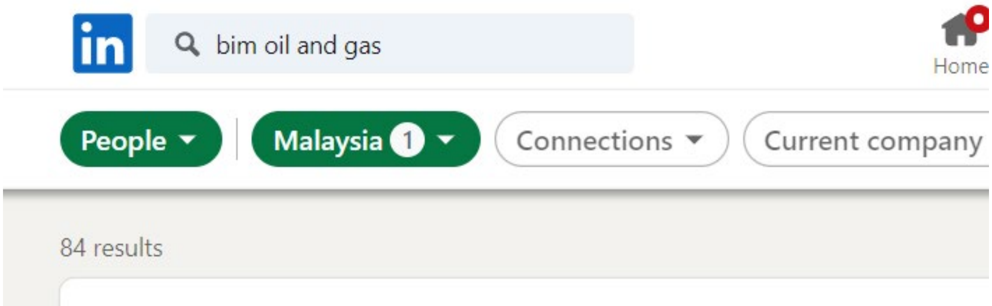
APPENDICES

Appendix A: Sample Size and Population



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

$$n = \frac{84}{1 + (84)(0.05)^2}$$

$$n = 69.42 = 70$$

In view of the fact that there are 84 people now employed in the BIM oil and gas business in Malaysia, the required sample size for the questionnaire survey that will be conducted using Microsoft Form has been determined to be 70.

Appendix B: FYP Demographic of Respondents in Histogram

2. Gender

More Details   Insights

Male	61
Female	21

3. Age

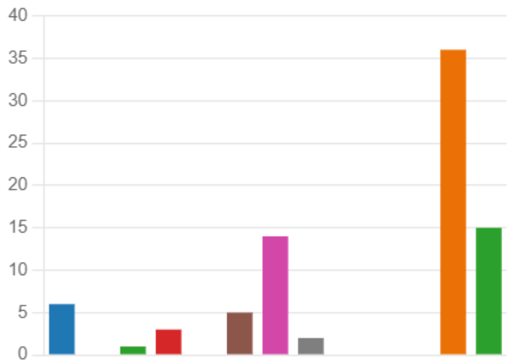
More Details

20-29 years old	50
30-39 years old	26
40-49 years old	4
> 50 years old	2

5. Designation

More Details

Client	6
Facility Manager	0
Contractor	1
Consultant	3
Safety Health Officer	0
BIM Manager	5
BIM Coordinator	14
Site Engineer	2
Project Engineer	0
Project Director	0
Project Manager	0
BIM Modeler	36
Other	15



6. Working Duration

More Details

Less than 3 years	30
Less than 7 years	27
Less than 10 years	16
More than 11 years	9

7. Depth Knowledge of BIM

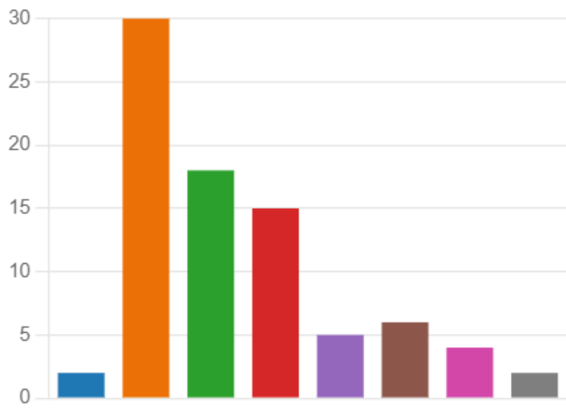
More Details

No Knowledge	1
Little Knowledge	12
Moderate Knowledge	57
Extensive Knowledge	12

8. Highest Level of Work Used in BIM Dimension

More Details

2D (CAD Drawing)	2
3D (2D + Visualization)	30
4D (3D + Schedule)	18
5D (4D + Cost)	15
6D (5D + Lifecycle)	5
7D (6D + Operation and Mainte...	6
8D (7D + Safety)	4
None of the above	2



Appendix C: Questionnaire Survey

Section 1: Personal and Company Details

* Required

PERSONAL DETAILS

This section is to understand who the respondents are and the depth of their knowledge in Building Information Modelling (BIM).

1. Name *

Enter your answer

2. Gender *

○ Male

○ Female

3. Age *

○ 20-29 years old

○ 30-39 years old

○ 40-49 years old

○ > 50 years old

4. Highest Qualification *

Enter your answer

5. Designation *

- ◯ Client
- ◯ Facility Manager
- ◯ Contractor
- ◯ Consultant
- ◯ Safety Health Officer
- ◯ BIM Manager
- ◯ BIM Coordinator
- ◯ Site Engineer
- ◯ Project Engineer
- ◯ Project Director
- ◯ Project Manager
- ◯ BIM Modeler
- ◯ Other

6. Working Duration *

- ◯ Less than 3 years
- ◯ Less than 7 years
- ◯ Less than 10 years
- ◯ More than 11 years

7. Depth Knowledge of BIM *

- ◯ No Knowledge
- ◯ Little Knowledge
- ◯ Moderate Knowledge
- ◯ Extensive Knowledge

8. Highest Level of Work Used in BIM Dimension *

◯ 2D (CAD Drawing)

◯ 3D (2D + Visualization)

◯ 4D (3D + Schedule)

◯ 5D (4D + Cost)

◯ 6D (5D + Lifecycle)

◯ 7D (6D + Operation and Maintenance)

◯ 8D (7D + Safety)

◯ None of the above

Section 2: Safety Control Aspects that can be Executed using BIM

9. Do you aware that BIM can be used for safety control for maintenance of infrastructure oil and gas project? *

◯ Yes

◯ No

◯ Maybe

10. From your P.O.V, what is the impact of utilizing BIM for safety control for maintenance of infrastructure oil and gas project in Malaysia? *

◯ Not sure

◯ No effect

◯ Improved

◯ Greatly Improved

BIM Implementation For Safety Control For Maintenance of Infrastructure Oil and Gas Project

11. Please rate the safety control that can be executed by using BIM platform *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Safety Training	○	○	○	○	○
Identification of unsafe hazards in maintenance	○	○	○	○	○
On-site maintenance supervision	○	○	○	○	○
Exchange and cooperation in maintenance management	○	○	○	○	○
Fall prevention planning	○	○	○	○	○
Site layout and safety plan for maintenance and operation	○	○	○	○	○

Section 3: Challenges in implementing BIM in safety control for maintenance of infrastructure oil and gas project

Challenges in implementing BIM in safety control for maintenance of infrastructure oil and gas project

12. Why are BIM not widely implemented for safety controls for maintenance of infrastructure oil and gas project in Malaysia? *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Perception of BIM	○	○	○	○	○
High Cost	○	○	○	○	○
Interoperability and Incompatibility	○	○	○	○	○
Lack of training, roles and responsibilities	○	○	○	○	○
Poor Knowledge and Skills	○	○	○	○	○
Lack of demand from the clients	○	○	○	○	○
Resistance to Change	○	○	○	○	○

Current Practices on Safety Control By Using BIM and the Implementation of BIM for maintenance of infrastructure oil and gas project

13. Does your current maintenance of infrastructure oil and gas project utilize any BIM application to manage safety control? *

◯ Yes

◯ No

14. If yes, state the BIM application used and for what kind of safety practice? (example: 3D modelling, visualization, simulation, scheduling, etc.) *

Enter your answer

15. In your opinion, what are the factors contributing to challenges of BIM implementation for safety control in maintenance of infrastructure oil and gas project? *

Enter your answer

16. What are your suggestions towards implementing BIM for safety control in maintenance of infrastructure oil and gas project? *

Enter your answer

Appendix D: Interview Questions

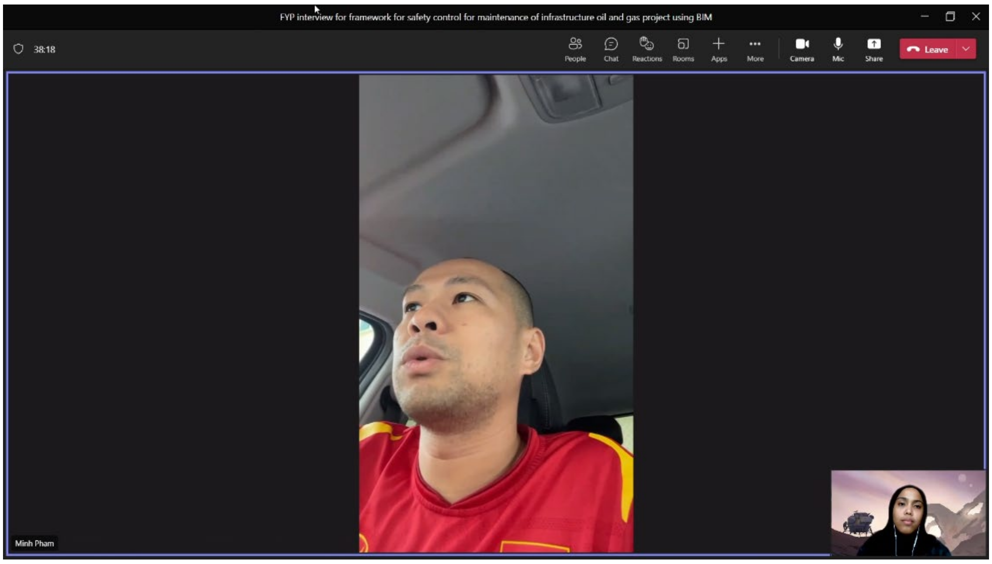
1. Kindly explain yourself, as well as the name of your company, the location of your workplace, the designation you hold at the organization you currently work for, and the number of years you have been employed there.
2. What is the depth of your expertise regarding BIM, in addition to the maximum level of work that can be done in BIM dimension, such as 3D, 4D, 5D, etc.?
3. What is the most recent project you've worked on, and what is the background of your company?
4. What are your thoughts regarding the level of safety that is currently being maintained in your project?
5. Based on your experience and knowledge, what do you understand about BIM?
6. Have you ever used BIM in your maintenance project? Why not?
7. What role does BIM play in the maintenance project you're working on, and what kinds of tools do you utilise?
8. How BIM give impact towards your current project?
9. In light of your prior experience, can you identify any key differences between projects that use BIM and those that do not use BIM for the purpose of safety control?
10. In context of question number 9, which of these do you believe BIM will have the most significant impact on when it comes to managing the safety control? Kindly elaborate on your response, thank you.
11. Based on your experience or from you point of view, how do you think BIM can help safety control aspect below:
    a. identification of unsafe hazards in maintenance
    b. safety training and education
    c. site layout and safety plan for maintenance and operation
    d. fall prevention planning
    e. on-site maintenance supervision
    f. exchange and cooperation in maintenance management
12. Based on the potential barrier to implement BIM such as:
    a. perception of BIM
    b. high cost
    c. interoperability and incompatibility

d. lack of training, roles and responsibilities
e. poor knowledge and skills
f. lack of demand from the clients
g. resistance to change

which of the following do you believe to be the most significant factor preventing project stakeholders from utilizing BIM for safety control, and why do you believe this?

13. What advice would you give to ensure that more project stakeholders are interested in implementing BIM, particularly for the purpose of controlling safety concerns associated with maintenance projects in the oil and gas industry?
14. Do you have any comments, questions, or ideas that you'd like to share with me? Or is there something else that I can do for you? Perhaps I could produce a report or something else for you to look through.

Appendix E: Interview sessions

Designation	Consultant – Offshore Solutions 
Company name	Bentley, previously at Subsea 7
Duration of working	3 years
Location of work	Malaysia, Singapore
Safety control aspects that can be executed using BIM	• With the help of BIM 3D Model, we can visualize everything then the hazards can be optimized. • Site layout and safety plan is the best when it comes to logistic arrangement; how to move the equipment, how to move people around in the facility, location for services. • Site supervision in real time in BIM is very useful as well. But due to lack of skill/knowledge most of the facility managers, it is quite difficult to apply. • Increase communication between stakeholders.
Suggestion to implement safety controls using BIM widely	• Show the stakeholders benefits especially in terms of cost, time and quality of the project.

Designation	BIM Modeler 
Company name	Reveron Consulting
Duration of working	2 years
Location of work	Malaysia
Safety control aspects that can be executed using BIM	• BIM is very helpful for training of the employees. For example, safety personnel can study BIM model to identify any potential hazards and they can conduct training prior what to be done in order to avoid any incident or injuries. Other than that, employees also able to educate themselves about the suitable materials and equipment that must be used for the task assigned. • With BIM 3D model, it helps in visualizing the real site condition • Increase the efficiency when BIM able to visualize the real site condition. For example, the exact location of broken pipeline that needs to be repaired. • Increase communication between stakeholders. E.g.: Maintenance team will always be notified and updated if there is any issue at the oil and gas infrastructure.
Suggestion to implement safety controls	• By advertising the BIM to the stakeholders and always offer them BIM even though there is no demand from them.

using BIM widely	• Seminar for the stakeholders. Show them what is the difference when BIM is applied and not applied in the project. • Introduce BIM in university such as in career fair etc.

Designation	BIM Coordinator 
Company name	Reveron Consulting, previously at UMW Oil & Gas Corporation Berhad
Duration of working	5 years
Location of work	Malaysia
Safety control aspects that can be executed using BIM	• Increase the safety work environment and improve communication. For example, when there is a problem at the pipeline, BIM will notify everyone including the workers who are doing their task to isolate the location where the problem arise as safety measures. • Improve safety planning and layout. For equipment, it can be put at the most strategic location so that no one will get injured due to poor housekeeping and there will be no time consuming to grab the equipment. • For communication, CDE (Common Data Environment) is a project server. Everyone is connected in here and will be able to upload pictures related to project. So, live and clearer information is gained.
Suggestion to implement safety controls	• Government or any big company should organize a campaign to show awareness how impactful BIM is if it's being applied in a project. • Provides financial benefits to businesses who integrate BIM into their project workflows.

using BIM widely	• It is necessary that government in Malaysia increase their allotment of trained workers.