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QUALITATIVE STUDY OF PREVENTIVE MAINTENANCE
PRACTICES IN MALAYSIAN OIL AND GAS INDUSTRY

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ABSTRACT

Organisations in the oil and gas (O&G) sector are extremely susceptible to the forces of supply and demand. Therefore, their viability depends heavily on efficient maintenance procedures and technologies. Given the ever-increasing global competitive pressure, particularly for the O&G operators, it is vital that companies equip themselves with a proper understanding of maintenance management programmes to enhance both the overall equipment effectiveness and throughput. This study was conducted at Pengerang Integrated Complex (PIC), PETRONAS's most significant downstream investment. The objective of this study was to investigate the preventive maintenance practices, criteria for third-party vendor selection, the effect of preventive maintenance on PIC performance, and the preferred maintenance option for PIC. The qualitative paradigm was employed in this study with the triangulation method to explain the similarities of a phenomenon from the various study data collection methods, namely interview, observation, and document review. The study's findings showed that maintenance staff members described their roles as "executors" and were well familiar with PIC's maintenance procedures. Respondents also cited that many criteria will be given consideration to select third-party vendors, such as experiences, adequate resources, and sufficient manpower. The findings also showed that PIC performance was at the desired level of 97% reliability score, which further supports why preventive maintenance is the preferred strategy for PIC. Even though limitations exist in maintenance activities, they can be overcome with the enhancement of the work procedures. This study highlighted the significant relationship between preventive maintenance and the intent to maintain a competitive edge, which ultimately leads to real performance. Study limitations and recommendations for future research are also covered in this study.

Keywords: Preventive maintenance, Pengerang Integrated Complex, Third-party vendor, Downstream

ABSTRAK

Organisasi dalam sektor minyak dan gas (O&G) sangat terdedah kepada kuasa bekalan dan permintaan. Oleh itu daya maju mereka banyak bergantung kepada prosedur dan teknologi penyelenggaraan yang cekap. Memandangkan tekanan persaingan global yang semakin meningkat terutamanya bagi pengendali O&G, adalah penting bagi syarikat untuk melengkapkan pekerja dengan pemahaman yang betul tentang program pengurusan penyelenggaraan untuk meningkatkan keberkesanan peralatan keseluruhan dan daya pengeluaran. Kajian ini dijalankan di Kompleks Bersepadu Pengerang (PIC) iaitu pelaburan hiliran PETRONAS yang paling ketara. Objektif kajian ini adalah untuk menyiasat amalan penyelenggaraan pencegahan, kriteria pemilihan vendor pihak ketiga, kesan penyelenggaraan pencegahan terhadap prestasi PIC dan opsyen pilihan penyelenggaraan di PIC. Paradigma kualitatif digunakan dalam kajian ini dengan kaedah triangulasi untuk menjelaskan persamaan fenomena daripada pelbagai kaedah pengumpulan data kajian, iaitu temu bual, pemerhatian dan semakan dokumen. Penemuan kajian menunjukkan bahawa ahli kakitangan penyelenggaraan menggambarkan peranan mereka sebagai "pelaksana" dan sudah biasa dengan prosedur penyelenggaraan yang digunakan dalam PIC. Responden juga menyatakan bahawa banyak kriteria akan diberi pertimbangan untuk memilih vendor pihak ketiga, seperti pengalaman, sumber yang mencukupi dan tenaga kerja yang mencukupi. Penemuan juga menunjukkan bahawa prestasi PIC berada pada tahap yang dikehendaki iaitu 97% skor kebolehpercayaan, yang seterusnya menyokong penyelenggaraan pencegahan adalah strategi penyelenggaraan pilihan untuk PIC. Walaupun terdapat batasan dalam aktiviti penyelenggaraan, ia boleh diatasi dengan menambahbaik prosedur kerja. Kajian ini menonjolkan hubungan yang signifikan antara penyelenggaraan pencegahan dan niat untuk mengekalkan kelebihan daya saing yang akhirnya membawa kepada prestasi sebenar. Batasan kajian dan cadangan untuk penyelidikan masa depan turut diliputi dalam kajian ini.

Kata kunci: Penyelenggaraan pencegahan, Kompleks Bersepadu Pengerang, Vendor pihak ketiga, Hiliran

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LIST OF ABBREVIATIONS

AR	Action Research
CAPEX	Capital Expenditure
CBM	Condition-Based Maintenance
CM	Corrective Maintenance
DOE	The Government and Department of Environment
DSS	Decision Support System
EIA	The environmental impact assessment
GDP	Gross Domestic Product
IM	Improvement Maintenance
KM	Knowledge Management
MIR	Maintenance Inspection Record
MMS	Maintenance Management System
MOSTI	Ministry of Science, Technology and Innovation
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
NCR	Non-Conformance Record
ORJI	Observe, React, Judgment, Intervention Model
OTF	Operate To Failure
PDM	Predictive Maintenance
PM	Preventive Maintenance
RCM	Reliability-centered maintenance
RTB	Run To Breakdown
RTF	Run To Failure
SD	System Dynamic
TAM	Turnaround Maintenance
TPM	Total Productive Maintenance

CHAPTER 1

INTRODUCTION

1.0 Background of The Study

The oil and gas industry are essential for a well-functioning modern economy. The industry supplies the fuels required for transportation and heating, as well as the primary raw materials used in construction, paving and chemical manufacturing. Oil is a truly world-class industry. It can be transported worldwide and refined into gasoline or petroleum, which can then be processed into a series of other products such as lipstick or cameras (Ranken Energy, 2017; Pasqualetti, 2021). Natural gas tends to be more regional in nature because it depends on pipelines for transmission and distribution. Natural gas is used in the production of electricity, fuel and heating (Environmental and Energy Study Institute, 2021).

The oil and gas industry are exploring the best path forward while at the same time, addressing the challenges of the energy transition, decarbonization and oil price volatility, increased international competitiveness and more sophisticated governmental regulation. In addition, the industry has also faced sustainability challenges with respect to how to ensure that the business is managed as effectively and efficiently as possible. Many obstacles must be overcome before oil and gas (O&G) operators can reach excellence in their operations. Preliminary studies have identified a support function that can have a direct impact on operations and even cripple the entire company if it is not managed properly - the management of maintenance (Olugu, Wong, Ee, & Mammedov, 2022; Sattari, Lefsrud, Kurian, & Macciotta, 2022; Faghihi, 2022). Oil industry assets are typically complex, extremely costly and require special attention to be replaced or repaired. Therefore, effective and well-implemented maintenance strategies are critical to maintaining O&G companies' operations.

The research main objective is to explore the preventive maintenance practices in Malaysian oils and gas industry, particularly in Pengerang Integrated Complex (PIC), Petronas's largest refinery facilities. In general, the O&G industry always be associated with the capital-intensive ventures, which potentially will have a severe financial and environmental consequences if a disastrous malfunction occur (Telford, Mazhar, & Howard, 2011; Lampreia, Morgado, Navas, Cabrita, & Requeijo, 2021). Asad, et al. (2019) further expressed that insufficient management of the maintenance of working conditions, work tools and machines in the O&G industry will not only harm workers but will also have a major impact on marine life and the environment as a whole.

Certain occurrences such as loss of control of containment facilities, for example the well sites and processing/refineries/petrochemical plants can possibly result in life-threatening injury to the people involved as well as the environment. In short, a proper maintenance procedure as well as policy needs to be implemented to avoid such nuisance, take place in O&G companies' activities. In relation to that, an efficient and an effective method of managing maintenance is critical to the sustainability of the O&G company's operations plus the practice also needs to be conducted in a safe and reliable manner (Rastegari, 2015; Liedberg, 2021).

Workers involved in the O&G industries face many risks in their line of duty such as explosions and fires, ergonomic hazards, high pressure tools and lines, confined spaces, machine vulnerabilities, electrical threats and other energy hazards, vehicle collisions, falls and struck-by or caught-in or caught-between (United States Department of Labor, 2020). In Malaysia, there is no national standard in terms of specific ergonomic requirements for the Malaysian offshore production of the restricted public access compound (Hilmi & Ghazilla, 2018). According to the United States Department of Labor's Bureau of Labor Statistics, 1,566 workers died from injuries from O&G operations and related fields between 2008 and 2017 (Morris, 2018).

Severe impact on the generation of income for the nation laid additional pressure for national oil companies (NOC) such as Petronas to implement a proper health and safety practices, environmental friendly systems and effective production approach to mitigate any risks that will impede the business operation (Tasmin, Muazu, Nor Aziati, & Zohadi, 2020). As the second largest producer of oil and natural gas in South-East Asia and the fifth largest exporter of liquefied natural gas (LNG) worldwide based on 2019 figures, Malaysia oil and gas sector's practices are crucial in ensuring Malaysia's global position well protected (Petronas, 2020). Due to the uniqueness of the industry that faces all sorts of operational risk, the push for operational excellence that will warrant operator's safety, safeguard the company's assets and ultimately guarantee the flow of income for the nation cannot be avoided (Eby, 2019). At the moment, oil and gas industry always been associated with potentially serious consequences for the lives and health of workers, environmental pollution, direct and indirect economic losses (Hamel, 2020).

According to the U.S. Centers for Disease Control and Prevention, the fatality rate for workers involved in O&G operation is seven times higher than any other industries (Hamel, 2020). The all-time famous disaster which happened in 1988 that took 167 lives known as "The Piper Alpha" was traced to inadequate maintenance and risk assessment (Total Safety, 2015). Mitigating these risks should be one of the main focuses for companies involved in oil and gas activities as it has great impact on safety, economic and reputation (Free, 2015; Zakaria, Nawawi, & Salin, 2016; Jannat, Alam, Ho, Omar, & Lin, 2021).

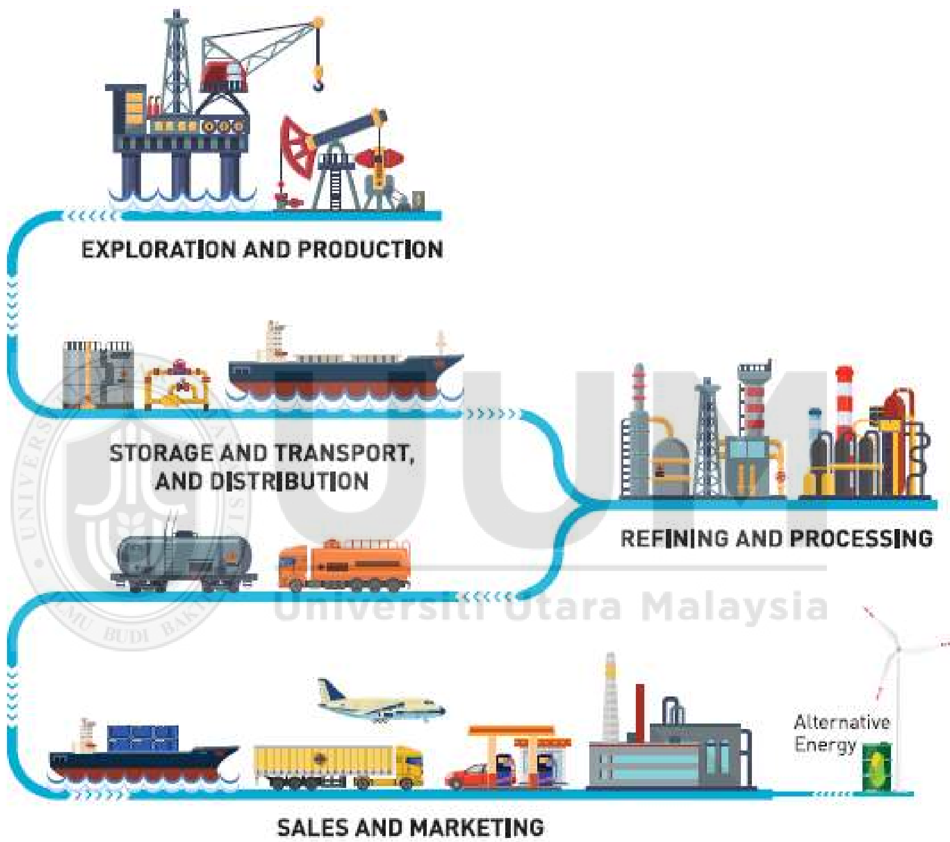
1.1 Introduction to Oil and Gas Industry

The most significant source of energy in the world has always been oil since the mid-1950s (UKOG, 2020). The combination O&G supplies more than half of the world's energy requirements (Overholt, 2016; Ponomarenko, Marinina, Nevskaya, & Kuryakova, 2021). According to United Nations Development Programme (UNDP), oil and gas accounts for 57% of the world fuel consumption. The products or by-products associated with oil have modernized the society across the globe, supplying energy to industry sectors and provide fuel for transportation purposes such as carrying people and goods for the well-being of human and also the nation (Owusu & Asumadu-Sarkodie, 2016; Sarkodie, 2021). Asad et al. (2019) further stated that O&G industries play a vital role in fast-tracking the world's economy. Although "renewable" and "sustainable" energy being introduced in conjunction with the technology advancement, none of it could contribute the same amount of energy as what can be provided by the O&G energy (Stevens, 2016; Manivanna, Mohamed, Velappan, & Abudhahir, 2021). Employment opportunities are another significant contribution of the O&G industry to the global marketplace (Addison & Roe, 2018; Basile, Capobianco, & Vona, 2021).

International Labour Organization (ILO) reported that nearly 6 million people are directly working in oil and gas industry and over 60 million others are indirectly hired regarding this economic activity (ILO Library, 2020). O&G industry, also known as the petroleum industry or the oil patch involves three main activities regarding petroleum products, namely upstream (exploration, extraction, production), midstream (refining, processing, transportation) and downstream (distribution, marketing, sale to end users or businesses) (Darko, 2014; Hazrati, 2021). Report by Mojarad, Atashbari and Tantau (2018) and Hadi and Baskaran (2021) further explained that the upstream sector is known as "E & P" which stands for Exploration & Production, midstream sectors main activities relates to logistics which involved the movement of goods from well to processing facilities such as refineries and downstream sectors that involves the processing of crude oil and natural gas to produce gasoline, petrol, diesel, asphalt, LNG, LPG and petrochemicals. Distribution to end users and also business consumers also part of downstream sectors.

The largest volume of products for O&G industry comes from the downstream activities in the forms of fuel oil and gasoline (petrol) or also known as petroleum (Muspratt, 2019). According to Fernandes, Relva, Alem and P. Barbosa-Póvoab (2016), petroleum is the main material for many other industries such as pharmaceuticals, fertilisers, solvents and plastics. United Nations Development Programme (2017) illustrates the activities relates to the O&G as per shown in Figure 1.0.

Figure 1.0
Oil and Gas Main Activities



Note: The oil and gas industry process. From Mapping The Oil And Gas Industry To The Sustainable Development Goals: An Atlas by PIECA, 2017, https://www.ipieca.org/media/3093/mapping_og_to_sdg_atlas_lr_2017.pdf. Copyright 2017 by PIECA.

The major player in O&G industry can be categorized into two major types which are national oil companies (NOC), i.e. Petromin (Saudi Arabia), Petro-Canada (Canada), Petronas (Malaysia) (Manley, Mihalyi, & Heller, 2019) and international oil companies

(IOC), for example, BP, Shell, ExxonMobil and Total (Al-Fattah, 2013; Mojarad, 2021). These NOCs and IOCs companies generally conduct their business in an integrated manner, incorporating both upstream and downstream functions forming the landscape of the petroleum industry (Whitson, 2009; Mojarad, Atashbari, & Tantau, 2018). Another type of company that also involved in oil business is Oilfield Services Companies (OFSCs) such as Canary, LLC, Transocean Ltd., and Diamond Offshore Drilling (KPMG, 2016; Berneis, Bartsch, & Winkler, 2021). According to the figures stated on IG International Limited website, the top oil producer in 2020 is the U.S. with 19.51 million bpd (barrels per day), followed by Saudi Arabia (11.81 million bpd) and Russia (11.49 million bpd). The top ten oil producers in the world are shown in the Table 1.0. These top 10 producers supply more than 71% of the world's oil demand, translating to more than 100 million barrels per day (Killian, 2020).

Table 1.0
Top 10 Oil Producers in 2020

No.	Country	Oil production (bpd)
1.	United States	19.51 million
2.	Saudi Arabia	11.81 million
3.	Russia	11.49 million
4.	Canada	5.50 million
5.	China	4.89 million
6.	Iraq	4.74 million
7.	United Arab Emirates (UAE)	4.01 million
8.	Brazil	3.67 million
9.	Iran	3.19 million
10.	Kuwait	2.94 million

Note: Reprinted from IG International Limited (2020) https://www.ig.com/en/trading-strategies/world-s-biggest-oil-producers-200722

Regarded as being the biggest contributor sector in the world trade in the terms of value, plus with millions of job opportunities and hundreds of billions of dollars generated globally, the O&G industry is considered the cornerstone of human and national well-being. The American Petroleum Institute reported in their Oil & Natural Gas Factsheet (2019), O&G company hired more than 10.3 million workers and contributed approximately 8% of U.S. GDP. In terms of expenditure, O&G company spent USD227 billion from 2012 to 2016 for their business operation. The massive figures indicate that this industry operates in capital intensive. In 2019, E&P companies recorded staggering USD546 billion in CAPEX (drilling and completing the well) (Oil & Gas Journal, 2020). On that note, all the procedures and policy implemented by the oil and gas companies' operation need to able to mitigate any possible risk that will influence the survival of the company.

1.2 The Importance of Maintenance in Oil and Gas Industry

O&G industry players are very vulnerable to the force of supply and demand, therefore their sustainability depends greatly on effective maintenance practice and technologies used (Zeinalnezhad, Chofreh, Goni, & Klemeš, 2020; Kumar & Narula, 2020; Prasad, Kunyankandy, & Joseph, 2020). Even though the problem faced differs between countries and amongst companies, but some common maintenance challenges can be found across the globe such as i) minimizing production cost (Pashakolaie, Khaleghi, Mohammadi, & Khorsandi, 2015; Osetoba, Barinyima, & Rex, 2019; Devold, Graven, & Halvorsrød, 2017; Jong, et al., 2017), ii) environmental concern (Ngene, Tota-Maharaj, Eke, & Hills, 2017; Johnston, Limb, & Roh, 2019; Robertson & Chilingar, 2017), iii) assets, maintenance

(Iqbal, Tesfamariam, Haider, & Sadiq, 2016; Mohamed, 2016; Mahmood, Rahman, & Deros, 2011; Velmurugan, 2019), iv) availability of talent (Kumari & Bahuguna, 2012; Dickson, Tilghman, Bonny, Hardin, & Mittal, 2020; Hudik, 2019; Vogt, 2020), and v) improving safety (Haridoss, 2017; International Labour Organization, 2015; Berry, 2020; Howard, 2018).

The sector is under huge pressure from the top management to improve the productivity and the efficiency of its assets (Hassan, Barakat, & Sobh, 2020). Hence, many approaches being introduced in terms of the maintenance system. Petroleum industry regarded maintenance as "necessary evil" in the early days, but soon recognized it contribution as the means to eradicate unnecessary repairs, avoid catastrophic equipment failures, reduce negative impacts on personnel involved in operation and the company's production (Mohamed, 2016; Mobley R. K., 2004; Gharoun, Hamid, & Torabi, 2021). The earlier generation of maintenance method was known as Corrective Maintenance (CM) which considers immediate reduction in maintenance cost (Eyoh & Kalawsky, 2018; Zhang & Chin, 2021). World War 2 brought the change in terms of appreciation of maintenance as demand for products increased tremendously (Hupjé, 2020). Hence, the second generation of maintenance known as preventive maintenance (PM) or proactive maintenance has been introduced which focused on taking action before the system breakdown (Pintelon & Parodi-Herz, 2008; Nordal & El-Thalji, 2021). This new approach has been very well accepted in the oil and gas industry due to its highly competitive environment and the many risks confronting industry stakeholders.

PM procedures performed by many companies to overcome the risks associated with oil and gas industry (Phillips, 2017; Seitia, Hafezalkotobb, Najafia, & Khalaj, 2019; Bigliani,

2013) as it is regarded as a crucial component of an effective maintenance programme (Telford, Mazhar, & Howard, 2011; Lampreia, Morgado, Navas, Cabrita, & Requeijo, 2021). Preventative Maintenance (PM) fulfilled the central goal of maintenance, which is to evade or alleviate the impact of equipment malfunction (Phillips, 2017; Cadi, Gharbi, Dhouib, & Artiba, 2021). However, in O&G industry, preventing failures before they actually happened is a relatively new insight (Ab-Samat, Jeikumar, Basri, Harun, & Kamaruddin, 2012; Oke, Abafi, & Adewole, 2021). Given the ever-increasing global competitive pressure, particularly for the O&G operators, it is indispensable that companies equip themselves with a proper understanding of maintenance management program in order to enhance both the overall equipment effectiveness and throughput (Fraser, Hvolby, & Tseng, 2015; Ingemarsdotter, Kambanou, Jamsin, Sakao, & Balkenende, 2021).

O&G firms need to be aware that the efficiency of the maintenance system is also correlated with the capacity to match the appropriate resources to the task (Tebow, 2009; Alyatama, 2021). According to Parida and Kumar (2006) and Amos, Au-Yong and Musa, (2021), Internal effectiveness (reliability and efficiency of resource allocation, productivity, skill, and competences) and external effectiveness (customer satisfaction, which translates to the increasing profit) are two ways to assess the success of a maintenance system. (Stefano, 2021)In the O&G sector, inadequate maintenance management techniques will have an influence on the company's financial performance as well as safety concerns and fatalities (Sinha, 2015; Prasad & Bhardwaj, 2021)

1.3 The Overview of Oil and Gas Industry in Malaysia

The British Malaysian Chamber of Commerce (2018) and Zainal, Aziz and Salleh (2021) reported that O&G sector play an essential function in Malaysia's economy, contributing approximately 20% of Malaysia's national Gross Domestic Products ("GDP"). The first oil well in Malaysia was discovered on Canada Hill in Miri, Sarawak in 1910 by a foreign company, Shell (Bank Pembangunan, 2011). "Miri No. 1" or now known as "The Grand Oil Lady" was spudded on 10 August 1910 (Shell, 2020). According to Malaysia Productivity Corporation Report (2016), there was no other drilling activity in Borneo or Peninsular Malaysia until the 1950s.

Petroleum activities increased sharply during the late 1960s with the development of offshore field in Bornes and Peninsular with Shell as the main player followed by Esso, Mobil Aquitaine, Oceanic and Teiseki. These foreign companies were given the exclusive rights to explore and produce oil products by the state governments in return for royalties and taxes (Malaysia Productivity Corporation, 2016). As a result of the economic nationalism advocated in New Economic Policy (NEP), Petronas was incorporated in 1974 under the 1965 Companies Act.

The industry in Malaysia regarding O&G industry is unique as Petronas, an acronym for Petroliam Nasional Berhad. Petronas is a Malaysian vertically integrated oil and gas company that was founded on 17 August 1974 (Petronas, 2020). The facility is the exclusive property of the Government of Malaysia, which is responsible for all of Malaysia's oil and gas resources (Petroleum Economist, 2019). Petronas acts as both the regulators as well as an operator in the oil and gas industry in Malaysia. Companies involved in O&G industry need to comply with Petronas' rules and regulations if they wish to operate in the O&G industry in Malaysia (British Malaysian Chamber of Commerce, 2018). The license to explore and produce granted to the foreign companies by the state government previously were ceased to effect with the passing of the Petroleum Development Act in 1974 (Malaysia Productivity Corporation, 2016).

Petronas grants the right to explore and produce oil and gas to foreign companies under a Production Sharing Contract (PSC) (Petroleum Arrangement Contracts, 2020). The PSC Contractor has to provide all the financing requirements and must bear all risks related to exploration, development and production activities in return for a share of total production (Petronas, 2020).

In their Annual Economic Survey 2018 for the reference year 2017, the Department of Statistics Malaysia (DOSM) showed that the value linked with mining, oil, and gas climbed by 7.3% per year to RM138.6 billion from RM120.4 billion recorded in 2015. In the same period, sales of value-added goods and services increased 7.8% annually, from RM98.8 billion to RM114.8 billion.

The number of people working in this sector decreased to 36,776 in 2017 from 41,698 in 2015, with RM6.9 billion in salary and wages being paid (Department of Statistics Malaysia, 2019). A person working in the oil and gas, energy, or mining industries in Malaysia typically earned around RM6, 080 per month, according to SalaryExplorer.com (2020). Based on this data, it is clear that the oil and gas (O&G) industry is crucial to both the economic development and expansion of the country, so it must be run as efficiently and effectively as possible.

1.4 Petroliam Nasional Berhad (Petronas)

Petronas, Malaysia's National Oil Company (NOC) is a global corporation that has interest all over the world and listed amongst the largest corporations on Fortune Global 500® (Petronas, 2020). Based on Petronas's Annual Report for 2019, the corporation recorded RM240.3 billion in revenue, providing 47, 669 job opportunities and contributing RM84.6 billion to the Federal and State Governments of Malaysia amounting to RM1.2 trillion since the inception of the corporation in 1974.

The Petroleum Development Act (1974) has given the ownership and exclusive right to Petronas on the hydrocarbon resources of Malaysia and Petronas falls directly within the competence of the Prime Minister of Malaysia (Bank Pembangunan, 2011). With regards to that, Petronas has the right to the fifth largest oil reserves in Asia Pacific Region after China, India, Vietnam and Indonesia and 28th in the world and also 13th largest natural gas reserve in the world (Malaysia Productivity Corporation, 2016). The importance of Petronas for Malaysia's economy has grown enormously and regarded as the major driving force that will lead Malaysia to a greater height in terms of economic growth (income for the nation) and economic development (the well-being of the people).

In relation to the importance of Petronas to the Malaysian as well as Malaysia's economy, Petronas, to ensure its operation do not suffer any setback or disruptions. Efforts have been made to prevent any accident, however the risk of accident cannot be eliminated (Okoh & Haugen, 2013; Batson, 2021). According to Official Website Department of Occupational Safety and Health (2020), 73 fatalities and 214 permanent disabilities have been reported in year 2019 compared to 62 fatalities and 197 permanent disabilities recorded in 2018 at manufacturing and petroleum industries in Malaysia.

In addition, the latest technology advancement in oil and gas business requires innovative strategy to minimize the risk factors (Asad, et al., 2019). A typical modern maintenance programme includes an equipment status assessment, historical data, and other best practises in addition to optimising traditional maintenance techniques (Eyoh & Kalawsky, 2018; Zhang & Chin, 2021). Effective maintenance is dependent on basic task such as inspection, human senses, sensor and thresholds – the items focused on preventive maintenance approach (Mobley, 2004; Gharoun, Hamid, & Torabi, 2021)

Petronas engages in a wide range of oil-related activities, such as upstream exploration, oil and gas production, and oil refining downstream; marketing and distribution of petroleum products; trade; gas processing and liquefaction; operation of the gas transmission pipeline network; marketing of liquefied natural gas; manufacturing and marketing of petrochemicals; delivery; automotive engineering; and real estate investments (Petronas, 2020). Upstream is the biggest contribution to Petronas earning which stand on RM22.2 billion, followed by gas and new energy at RM9.8 billion, downstream with RM5.2 billion and corporations and others at RM4.7 billion. All these figures were based on profit after tax (PAT) for the year of 2019 (Petronas, 2019). Petronas Annual Report 2019 also stated that the capital investments or also known as capital expenditure (CAPEX) based on market segment as follows;

- Upstream = RM24.3 billion (51%)
- Downstream = RM10.7 billion (22%)

- Gas and New Energy = RM8.3 billion (17%)
- Corporate and Others = RM4.5 billion (10%)

Although, downstream activities only the third contributor to Petronas earn, CAPEX for this segment was the second highest. Based on these statistics, a study was conducted to understand the scenario in the downstream sector in order to address any prevailing issues that can be rectified to enable Petronas to achieve more profits by reducing unnecessary cost to its operation.

Petronas downstream activities involved "*operations in gas processing and transportation, regasification, utilities, marketing, power generation, and the provision of technical and engineering solutions to the entire Petronas Group, as well as the trading, manufacturing, and marketing of crude oil and petroleum products.*" (Petronas, 2020). The downstream activities and its subsidiaries as shown in the table 1.1

Table 1.1
Petronas's Downstream Activities and Companies

Activities	Companies
Refining & Trading	▪ PETCO Trading Labuan Company Ltd (PTLCL) ▪ PETRONAS Penapisan (Terengganu) Sdn Bhd [PP(T)SB] ▪ Malaysian Refining Company Sdn Bhd (MRCSB)
Retail & Lubricants	▪ PETRONAS Lubricants International Sdn Bhd (PLI) ▪ PETRONAS Dagangan Berhad (PDB) ▪ Engen Petroleum Limited
Petrochemicals	▪ PETRONAS Chemicals Group Berhad (PCG)
Gas & Infrastructure	▪ PETRONAS Gas Berhad (PGB)

Note: The list of companies listed under Petronas. Reprinted from Petronas website (2020) https://www.petronas.com/our-business/downstream

Petronas's revenue-based revenue for fiscal year 2019 was RM240.3 billion, primarily contributed by oil products and LNG, which accounted for 36% and 21% of revenue respectively. On that note, the study will be focused on refining business as it considered as the main activity in the downstream segment and will be based on the largest Petronas refinery facilities in Pengerang, Johor or also known as Pengerang Integrated Complex (PIC). Other refining facilities owned by Petronas are located in Kerteh, Terengganu. With a daily capacity of 124,000 barrels of crude oil, Malaysian Refining Company Sdn Bhd (MRCSB) and Petronas Penapisan (Terengganu) Sdn Bhd [PP(T)SB] refine indigenous crude oil into high-value petroleum products for domestic and export markets, respectively. MRCSB is based in Melaka, and its primary business is the refinement of indigenous crude oil into such products. A daily capacity of 300,000 barrels of crude oil may be processed at the refinery. Compared to another Petronas facility in Melaka that produces Euro 2 rated gasoline, with CAPEX investment at RM1.5 billion, PIC's oil CAPEX is anticipated to be RM4.3 billion (Aziz, Jung, & Wei, 2019).

With a 27 billion USD investment, PIC is Petronas' largest investment in Malaysia. "PIC supports the government's overarching Economic Transformation Programme (ETP) and will put Malaysia in a position to benefit from the region's rising need for petrochemical goods and energy in the coming 20 years. This will accelerate the expansion of Malaysia's oil and gas downstream industry and propel our nation into a new era of technological and economic advancement (Petronas, 2020). The Petronas Refinery and Petrochemical Corporation (PRPC), a vital Petronas subsidiary, is responsible for developing the PIC. The

PIC will create a variety of refined petroleum products, such as diesel and petrol that adhere to Euro 5 fuel standards. Additionally, the refinery will provide raw materials for the integrated petrochemical complex of the PIC. The PIC sought to be among the top in the world for sustainability and efficiency (Tiing & Lim, 2021). Pengerang Refining and Petrochemical (PRefChem), a strategic collaboration between Petronas and Saudi Arabian Oil Company, Saudi Aramco, through an equal ownership in two joint venture companies, is the owner and operator of the refinery and several petrochemical units inside the PIC. As a result, choosing PIC for this study was justified because of how important it is to Petronas and the country as a whole.

1.5 Problem Statement

The importance of the O&G sector to the wellbeing of society and the nation has emphasized the need to make sure that the sector is being run in the most profitable mode. In achieving these objectives, one of the aspects that need to be addressed is the maintenance management practices by O&G companies. Inadequate maintenance practices are known to cause severe loss and property damage in the O&G industry (Asad M. , Hassan, Soomro, & Sherwani, 2017; Waqar, Othman, Shafiq, & Mansoor, 2023). High profile accidents such as the 1) Deepwater Horizon oil spill in the Gulf of Mexico in 2010; 2) San Bruno pipeline explosion in California, United State of America in 2010; 3) Pemex gas plant explosion in Reynosa, Tamaulipas, Mexico in 2012; 4) British Petroleum refinery fire at Cherry Point, Northwest Washington, United States of America; 5) Chevron Oil Refinery fire in Richmond, California, United States of America; and 6) Amuay oil refinery fire blast in Falcon state, Venezuela served as strong reminders about the importance of utilizing a proper maintenance practice (Asad, et al., 2019). Therefore, preventive management should be the number one priority for companies involved in oil and gas operations (Al-Rbeawi, 2023; Hakami & Hamzah, 2023). Hence, the study would like to uncover the preventive maintenance practices in PIC as stated in Research Question (RQ1)

The analysis from the Center for American Progress stated that the rate of injuries increased by 21% in 2018 and 2019 compared with the previous two-year period of 2016-17 (Sneath, 2020). Petronas in Malaysia had the worst group safety record ever in 1998 with 31 fatalities, followed by 13 and 17 fatalities in each of the following years, respectively (UK Essays, 2021). Additionally, Petronas' most recent external assessment and benchmarking exercise was completed in August 2010, which may have contributed to a number of recent accidents like the oil tanker that exploded and caught fire at the jetty of Petronas Chemicals Methanol Sdn Bhd on July 26, 2012, the fire that broke out on the Tukau B Platform of Petronas Carigali offshore Miri on June 11, 2012, and the explosions at the Petronas gas processing plant in GPP Complex A in Kerteh explosions that killed a worker on the spot while 23 others were injured on 11 May 2012; drain containment incident at Petronas LNG Complex in Sarawak on 31 August 2020 which killed a worker; a fire and explosion that killed five people at Petronas refining and petrochemicals complex in Pengerang Johor on 15 March 2020, and many more which reported in the news and Petronas press statements. This highlighted the need for Petronas to re-evaluate safety standards as well as the performance of maintenance vendors. The researcher acknowledged that there was a lack of research on PM management in the PIC due to the complex has just started their fully operating in the second quarter of 2021 (Malay Mail, 2021). With a USD27 billion investment, PIC hopes to put Malaysia in a position to benefit from Asia's rising demand for energy and commodities petrochemical products over the next 20 years (Petronas, 2021). Hence, the preventive maintenance practice should be explored to provide an understanding with regards to this issue and its impacts to PIC. Consequently, the RQ4 was formulated to address this issue.

O&G industry regarded as the capital-intensive industry with machines, facilities, automations and systems are the main elements in their line of operations (Abor, Abugre, Donkor, & Karimu, 2023). According Eyoh and Kalawsky (2018), in oil and gas industry, maintenance is the key cost driver. Companies invested billions of dollars to make the equipment withstand any breakdown as unplanned downtime can cause drillers hundred thousands of dollars per day (Wallace, 2015). BehrTech (2020) reported that unplanned downtime estimated cost for industrial manufacturers per year is USD50 billion and in relation to O&G industry it is USD39 million. Maintenance is seen as playing an important role in achieving organizational objectives that require a significant investment of physical and human resources in the delivery of the support function (Milana, Khan, & Munive, 2014; Kabeel, El-Said, & Dafea, 2019). According to Mobley (2004) and Gharoun, Hamid and Torabi (2021), maintenance costs account for the majority of the operational budget of most industrial facilities. In this respect, oil and gas operators such as PIC must follow appropriate maintenance practices and policies to remain competitive and sustainable during these turbulent times. The researcher found a methodological gap in terms of qualitative research for preventive maintenance in Malaysia's O&G industry due to saturation and the inadequacy of current preventive maintenance's dimensions, best practices, and critical success factors for the oil and gas industry. This research need to implement Qualitative Method in answering the gap. Qualitative research methodology was chosen as it offers a deeper knowledge of experiences, events, and context while addressing the "how" and "why" research issues (Savin-Baden & Major, 2023; Holmes, 2020). To better comprehend human experience, qualitative research enables the researcher to pose questions that are difficult to answer with figures (Hatch, 2023). In order to solve RQ2, the researcher is working to create a novel research design that takes a qualitative approach to preventative maintenance practice in the PIC.

The general notion of the maintenance function is to prevent the failure of occurrence, however, to clearly identify the reason of failure requires an additional set of insight and tools. Even though the knowledge and information pertaining to maintenance field is expanding with the establishment of new maintenance methods such as Preventive Maintenance (PM); Time-Based Maintenance (TBM); Turn Around Maintenance (TAM); Failure Finding Maintenance (FFM); Risk Based Maintenance (RBM); Condition Based Maintenance (CBM); Predictive Maintenance (PDM); Corrective Maintenance (CM); Deferred Corrective Maintenance; and Emergency Maintenance (EM), the main segregation of actual maintenance practice perform is always Corrective Maintenance (CM) and Preventive Maintenance (PM) (Hupje, 2018; Duffuaa & Daya, 2004; Shou, Wang, Wu, & Wang, 2021).

The PM is a proactive maintenance strategy with the focus to perform certain action before the failure occurs (Hupje, 2018; Shou, Wang, Wu, & Wang, 2021). Development of engineering concepts such as reliability, maintainability, affordability and cost optimization during the operation and maintenance phase should be integrated into the operation to reduce equipment downtime in order to remain operational, particularly in highly competitive industries such as the O&G industry (Kiran, 2017; Rauzy, 2021). Hence, the concept of preventive or predictive maintenance must be formulated, accepted and practiced in order to achieve sustainability (Kanisuru, 2017; Ramiya & Suresh, 2021). In O&G industry, preventive maintenance is regarded as the key ally to prevent the domino effects of O&G operations break down (Murray, 2019).

Data and analytics firm GlobalData stated companies use the technology to assess the condition of their operating equipment and predict maintenance needs, to reduce the likelihood of failure. Industry giants such as Royal Dutch Shell, ExxonMobil, BP, Chevron, Repsol and Total are among those spearheading the use of artificial intelligence and internet of things (IoT) technologies as tools in preventive maintenance to save costs and optimize machinery (Caminiti, 2020). As a result, the benefits of preventive maintenance brought attention to the necessity of researching the use of preventive maintenance in PIC's operations, particularly in light of the involvement of third-party vendors. The researcher acknowledged, in light of the review of previous research, that there is a population gap. Most of the research in O&G field were based on Petronas as a main company (Khan, Mad, Osman, & Aziz, 2019; Ng, et al., 2020; Tang, 2021). The PIC was identified as having been the subject of unexplored and insufficient research. Research on third-party vendor selection maintenance practices appears to be important and worthy of investigation in the context of the PIC. Hence, the RQ3 was devised as an investigation in this field is important because it can be crucial to the well-being of the company and the nation (Gupta, 2023; Ali, Edghiem, & Alkhalifah, 2023)

In conclusion, the Pengerang Integrated Complex (PIC) maintenance management system at the Petronas plant was investigated in light of how crucial its operation is to the health of the country. The manner in which a function has accomplished its intended goals can be used to gauge a maintenance management system's effectiveness, which is often assessed based on the user-perceived quality of the good or service offered. The issues of high casualties in terms of personnel, millions of dollars in losses due to the unexpected shutdown of operations, environmental threats and the impact on the country's income should be addressed. PIC’s maintenance system efficiency practices. the selection of suppliers, the influence of preventive maintenance on company performance and the rationale for choosing PM for downstream activities were considered in the interest of the nation.

1.6 Research Question

The problem statement is referenced in the current study questions to clarify how preventive maintenance procedures are used in PIC. The framework of the research should be able to be explained in more detail once the problems raised in the research questions have been recognized and understood. The research questions are written as follows because the study has chosen a qualitative research methodology:

1. What are the preventive maintenance practices in PIC?
2. Why is preventive maintenance the preferred option for downstream operators?
3. How is third party vendor selection done in PIC?
4. How does preventive maintenance affect PIC performance?

On that note, this current research will not only focusing on providing the theoretical claims, but also on applications of the effective maintenance system, yielding advice to management concerning the maintenance practice of existing systems as the prior research conducted in this areas have uncovered a variety of causes in many accidents occurred in recent years have tended to switch more and more towards organizational and management issues rather than equipment or system issue.

1.7 Research Objectives

The objective of the study is to investigate the role of preventive maintenance carried out by PIC. According to the study by Ansell, Holmes, Evans, Pasquire, and Price (2009) and Kissi, Adjei-Kumi, Twum-Ampofo and Debrah (2020), the best maintenance system to be applied really depends on a number of factors, such as, the maintenance approach as it should have the option to determine the problem, delivered within the budget, insignificant activity disruption and able to avoid any hazards. Four key objectives for the current study project were established in light of the aforementioned perspective. The following are the study's objectives:.

1. To study the extent of preventive maintenance practices in PIC.
2. To examine the preventive maintenance selection reasons by the downstream operators.
3. To explore the selection process of 3rd party vendor for PIC.
4. To understand the effect of preventive maintenance on the performance of PIC.

1.8 Significance of The Study

In addition to everything mentioned above, the lack of a central explanation, technical limitations, financial restraints, and safety considerations have all led to the extension of the maintenance management system. Finding the best balance between costs and benefits has, thus far, primarily involved optimizing the maintenance management system. (Dekker, 1996; Gharoun, Hamid, & Torabi, 2021). Maintenance management system embedded in decision support systems should be able to provide an objective and quantitative means for proper decision-making process which is defendable since it allows the authorities as well as oil and gas companies to evaluate the economic, satisfaction and safety consequences of the decisions.

The purpose of this research is to identify weaknesses in the implementation of an efficient maintenance practice in the Pengerang Integrated Complex (PIC). The primary focus is to offer opportunities for establishing a new perspective in the study of preventive maintenance management. This study provided an accurate understanding of the maintenance management system in the oil and gas industry and its relationship to the contribution to the welfare of the country and the human being. It also made recommendations for improvements in the system's implementation to cut down on wasteful spending by government entities, oil and gas companies, and oil and gas workers themselves. The study also addressed pertinent questions related to preventive maintenance in terms of practices, the reason why this became the preferred option for downstream operators, selection processes of third-party vendors and the impact on performance.

1.9 Limitation of The Study

The scope of a study details the parameters of the current investigation as well as the depth to which the research field was examined in the work. (Editage Insights, 2019). As a result, the objective of this study was to assess maintenance management techniques under the PIC. No research has been done on the relationship between the safety of O&G operators and the effectiveness of the preventive maintenance management system. Certain information was withheld due to sensitivity and confidentiality concerns in order to prevent information leaks to third parties that might endanger the reputation of the company being studied. The study has limitations in terms of budget, length of formal interviews, on-site survey, data availability, documentation, etc. The related maintenance management system models reviewed also mostly from foreign O&G companies and scenarios, making it difficult to map it to Malaysia conditions. Other than that, additional maintenance objectives was incorporated to make the recommended maintenance management system more practical; for example, maximizing maintenance work and minimizing maintenance time requirements.

1.10 Organization of The Study

Five chapters make up this document. The context of the study, the problem statement, the research questions, the research objectives, the significance of the investigation, and the study's limits are all attempted to be justified in *Chapter 1*. This research primarily focuses on interviews with Malaysia's oil and gas company. This research's objectives were to discover more specifically how to put the preventive maintenance management system in place and enhance the systematic maintenance process..

In *Chapter 2*, a selection of relevant literature was offered to aid in-depth examination and comprehension of the recent findings. The review of the literature discusses pertinent theories concerning maintenance management systems, definitions of maintenance, selection and optimization of maintenance strategies, difficulties in implementing maintenance management systems for oil and gas companies, monitoring activities, and record documentation management..

After that, *Chapter 3* described how this research was conducted. In order to gather pertinent data for PIC, this study used a triangulation of literature analysis, interviews, and observations. The research design, sample selection, data collection and management techniques, reliability and validity concerns, and data analysis strategies are all covered in this chapter.

Interviews, observations, and document evaluations that have been produced as identified topics, categories, or trends are used in *Chapter 4* to describe the research's findings. Descriptive statistics were used to make a comprehensive description of the demographics of the study sample such as gender, race, age, and working experience of study participants. The Atlas.ti application used to conduct qualitative data analysis provided functionality to identify and visualize the content that was used for main text analysis.

Finally, *Chapter 5* explores the conclusions and provides examples of the findings from the evaluation of the study findings and the review of the relevant literature. The section includes suggestions for future research as well as discussing the study's effects on practise..

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will address the current and historical practice of the preventive maintenance management system in the global and Malaysian context. Surveys are conducted to determine the pros and cons of past and existing techniques used to foster an in-depth review and understanding of current research. The most important aspect is that the information acquired is asked to be held accountable for providing a suitable solution that frequently tends to be lacking in currently used techniques utilised in Malaysian oil and gas company's maintenance management system. The literature review for this study is selective and concentrates on the applicable maintenance management system and user acceptance due to the scope of the research field. Textbooks, conference proceedings, websites, business journals, reports, and journals were all reviewed. in print and online from a scholarly library that has access to a wide selection of periodicals and journal databases.

The chapter will discuss the concepts of maintenance management, the implementation of maintenance management towards the practise done in the context of maintenance management, and the evolution of maintenance strategies in the oil and gas industries. The majority of the articles in this chapter were recently released in scholarly journals. The study should be able to provide a basic maintenance structure that includes the three processes of problem characterization, appraisal of the machine's current condition, and techniques of maintenance decision-making.

2.1 The Evolution of Maintenance Strategies in Oil and Gas Industries

The maintenance management framework is an instrument to increase the share of the underlying asset level required to achieve the desired productivity at the expense of various levels of employment, equipment, and material use, subject to spending constraints (Manoj, Shariat, Abdullah, & Devkota, 2012; Li, et al., 2020). The maintenance management system has shifted from simple accounting orders to more sophisticated performance measurement systems (Burde, 2008; Ghani, 2018). For instance, air switches, transmitters, valves, and pumps are tools used in oil and gas production facilities. Their capabilities and usefulness are constrained. When this equipment totally malfunctions, maintenance is performed. This kind of maintenance system is also known as primitive maintenance philosophy (Eyoh & Kalawsky, 2018; Gharoun, Hamid, & Torabi, 2021).

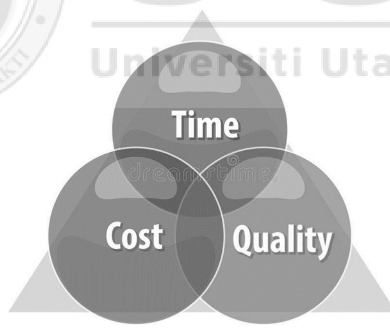
Unplanned or breakdown maintenance is viewed as a reactive maintenance programme in which the system is started up until it is shut down due to a system failure and no maintenance is performed until after that (Sullivan, Melendez, Pugh, & Hunt, 2010; Cheng, Wang, & Liao, 2021). The industrial systems were operated up to the system failure, where the affected tools or equipment have been repaired or replaced, consistent with the popular maintenance philosophy "Fix it when it fails or breaks" (Eyoh & Kalawsky, 2018).

The reactive maintenance applauds the idea that faults should not be prevented or detected in advance. (Burde, 2008; Ghani, 2018; Ardeshiri, Lotfi, Behkam, Moradzadeh, & Barzkar, 2021). The maintenance method performed was on demand-based, generally due to major equipment breakdown or failure (Eyoh & Kalawsky, 2018; Gharoun, Hamid, & Torabi, 2021). The maintenance ideology seems to disappear from the stage after the Second World War because of the impacts of industrialization on the world economy.

Due to the intense push for better quality goods and services as well as the need for higher productivity, the post-Second World War era adopted a distinct maintenance philosophy. The notion came from Dr. William Edwards Deming's (October 14, 1900 – December 20, 1993) advice that businesses should increase the quality of the products they sell, cut costs, and boost efficiency in order to acquire greater market share in the emerging business environment (Henshall, 2020). The success of this approach is emphasized by the achievements of Japanese companies such as Toyota, Fuji and Sony (Andrew Stotz , 2019).

Deming's management methodology laid the foundation for one of the most successful management approaches, Total Quality Management (TQM) is a methodology that may be used to improve any business function or industry, including marketing, finance, design, engineering, and production. In order to fulfil client demands and organizational goals (Hashmi, 2020). The main concepts mooted by TQM can be simplified to three main elements which is i) Time (Continuous improvement), ii) Cost (Get it right, first time) and iii) Quality (Customer focus) as showcased in figure 2.0 (Aminu, 2018; Kaplan Financial, 2020).

Figure 2.0:
TQM Main concept



Note: The Total Quality Management Concept (TQM) by Kaplan Financial, 2020. https://kfknowledgebank.kaplan.co.uk/total-quality-management. Copyright 2020 by Kaplan Financial.

Figure 2.0 showcased one of the major the concept of TQM is a cost which relates to the approach of organization in managing its operating cost. The fact that oil and gas industry is one of the world biggest industry with $3,325,4 billion revenue in 2020 (Ibis World, 2020), it is also considered as one of the largest industry that has a very high expenditure with $1 trillion was spent on operational expenditures (OPEX) in 2018 (Jones V. , 2019), therefore oil and gas players have a golden opportunity to make a very strategic business decision in ensuring the well-being of the company. TQM considers that the costs of prevention are less than the costs of correction (Kaplan Financial, 2020). This principle can be related back to one of the maintenance philosophies which is preventive maintenance.

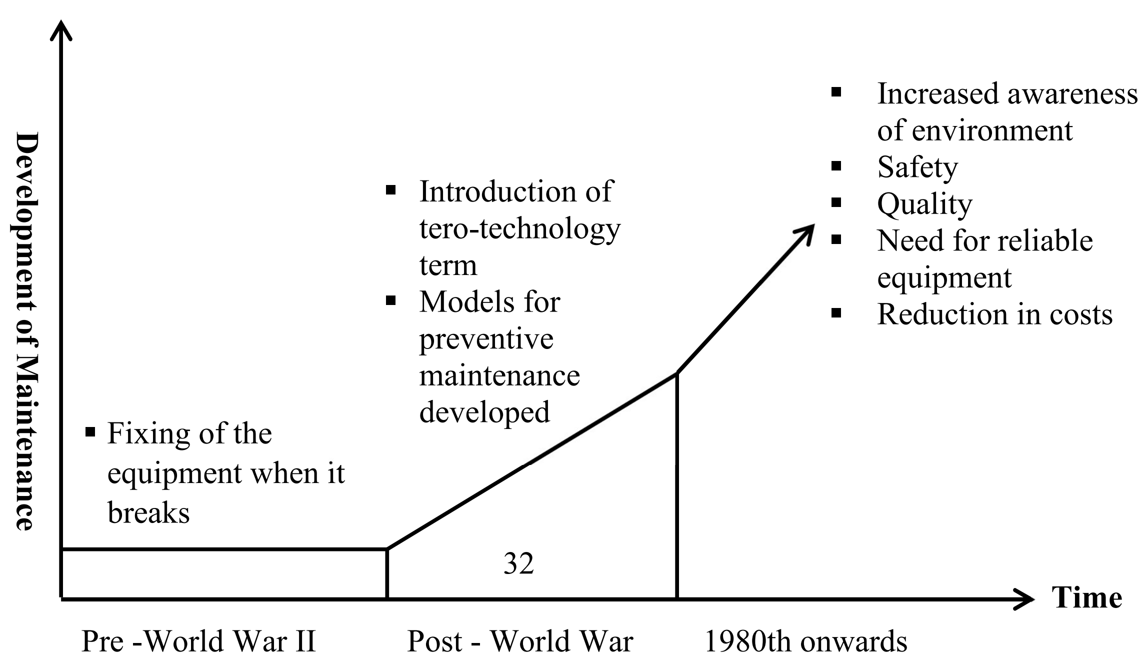
2.2 Definitions of Maintenance

The term maintenance changed radically following World War II. During the pre-World War II period, people viewed maintenance as a monetary value added to the plant that did not increase the value of the finished products. In this manner, the maintenance was kept to fix the unit when it breaks considering the way that it was the most efficient method than the other option (Schokry, 2010; Lentzsch & Herrmann, 2021). In this first maintenance methodology, no action is made to identify the onset of breakage as well as damage prevention, this methodology is known as reactive maintenance (Alsyouf, 2007; Nordal & El-Thalj, 2020).

The period of during and after the World War II, the advancement of innovation and scientific technology were introduced due to the growing interest in the creation, individuals made many different types of maintenance, which are much cheaper, for example, preventive maintenance. People of that period classified maintenance as a function of the production system (Schokry, 2010; Lentzsch & Herrmann, 2021). Periodic, planned and preventive maintenance were introduced during this time (Kister & Hawkins, 2006; Fredriksson & Larsson, 2012; Sehgal, Singh, Kaur, & Kumar, 2020)

The term "Maintenance" was first defined by the British Standard (1964) in their effort to standardise "Glossary of General Terms used in Maintenance Organisation" or "Glossary of Maintenance Terminology," whereby "Maintenance" was defined as "work undertaken in order to keep or restore every facility to an acceptable standard." The maintenance definition has been modified to "the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function" as a result of monitoring the changes in maintenance discipline (British Standard BS 3811: 1964, 1993). The majority of academics who study maintenance management generally concur that maintenance is a "set of activities necessary to maintain physical assets in the desired operating conditions." (Pintelon & Parodi-Herz, 2008; Karki & Porras, 2021). The evolution of maintenance definition detailed in the Figure 2.1.

Figure 2.1:
History of maintenance.



Note: The evolution of maintenance definition. From Pre-World War II until recently. From Maintenance Resources Management: Adapting Materials Requirements Planning by Dinesh Shenoy and Bikash Bhadury (1998) published by Taylor & Francis Ltd., London, UK. Copyright 1998 by Taylor & Francis Ltd

Technical expertise, procedures, and techniques are needed to properly employ assets including buildings, structures, machinery, tools, and systems during maintenance activities (Velmurugan & Dhingra, 2015; Mong, Mohamed, Misnan, & Palis, 2021). Ensuring of system function, the system life as well as the system safety was regarded as the main objectives for maintenance (Khaira & Jain, 2012; Velmurugan & Dhingra, 2015; Mong, Mohamed, Misnan, & Palis, 2021). Further, according to Moubray, 2003 and Sidhu, Singh, and Ahuja (2021) "rapidly restore the equipment to its operational readiness state using available resources" is the maintenance's main goal. Inadequately maintained equipment may experience sporadic failure that could have an impact on service or production (Khaira & Jain, 2012; Velmurugan & Dhingra, 2015; Mong, Mohamed, Misnan, & Palis, 2021). Realising this, Simeu-Abazi and Sassine (2001) and Retolazaa, Ezpeletab, Santosa, Diaza, and Martine (2021) emphasised the need for effective maintenance practises in order to improve performance and production levels and prevent the negative effects of breakdowns. The essential component in attaining this goal is maintenance management.

The maintenance management central aim is "*total asset life cycle optimization*" i.e., maximize availability and reliability of assets to achieve business or operational objectives.

According to Schokry (2010) and Lentzsch and Herrmann (2021), maintenance objective is to maximize the productivity at the lowest possible cost and at the same time produces the highest quality products or service and comply with the best safety standards. On that note, maintenance is not solely engaged with technology matters as the maintenance activities are a mix of management, operations, technology and business strategies (Pintelon & Parodi-Herz, 2008; Karki & Porras, 2021). The optimal maintenance strategy is to maximize quality and safety of goods, services, systems, or infrastructure while minimizing costs and maximizing production..

2.3 Maintenance Management

Many researchers frequently use the term "maintenance management" to describe the concept of maintenance, along with other terms like "maintenance systems," "maintenance strategies," "maintenance methods," "maintenance models," "maintenance techniques," and "maintenance practice" (Fraser, Hvolby, & Tseng, 2015; Ingemarsdotter, Kambanou, Jamsin, Sakao, & Balkenende, 2021). In this sense, maintenance systems, maintenance strategies, maintenance procedures, maintenance patterns, maintenance techniques, and maintenance philosophies will all be referred to as "practice" in the current study..

The British standard 3811 presented in Essays UK (2013) categorized maintenance into five parts, as described below:

a. Preventive Maintenance (PM) – while the machinery is still operating, standard maintenance is carried out with the goal of lowering the likelihood of a failure or breakdown.;

b. Corrective maintenance (CM) – when preventing failure is either not feasible or not cost-effective, maintenance work is done to restore an item's functionality after it has been permitted to fail.;
c. Emergency Maintenance (EM) - Maintenance is carried out when the property or equipment is damaged due to unforeseen circumstances that immediately endanger well-being and safety.
d. Condition-Based Maintenance (CBM) - a method of maintenance that filters the real state of the asset or piece of machinery to decide what repair is required. According to CBM, maintenance may be necessary if certain indicators point to a decline in performance or impending failure; and
e. Schedule maintenance (SM) - any repair and maintenance work that was done within the stipulated time. The schedule also stated what kind of maintenance work completed and by whom. This method of maintenance may occur during recovery or due to work demands.

In addition, maintenance management techniques experience many major processes of transformation in recent years. Nowadays, the development in maintenance practice has been aggravated by the development of complex manufacturing process, variety of product demanded, increased awareness of maintenance influence on environment issue, safety of operators, business profitability and product quality (Khan & Haddara, 2003; Leonia, et al., 2021). Hence, the maintenance concept forced into production operation to enhance the sustainability of a company. Table 2.0 showcases the advancement in maintenance policies that has been categorized as first, second, third and recent generation (Cooke, 2003; Moubray, 2003; Sidhu, Singh, & Ahuja, 2021).

Table 2.0

Development of maintenance philosophies

Generation	Maintenance Philosophies
First Generation	▪ Fix it when it broke ▪ Basic and Routine maintenance ▪ Corrective maintenance
Second Generation	▪ Planned Preventive maintenance ▪ Time based maintenance ▪ System for planning and controlling work

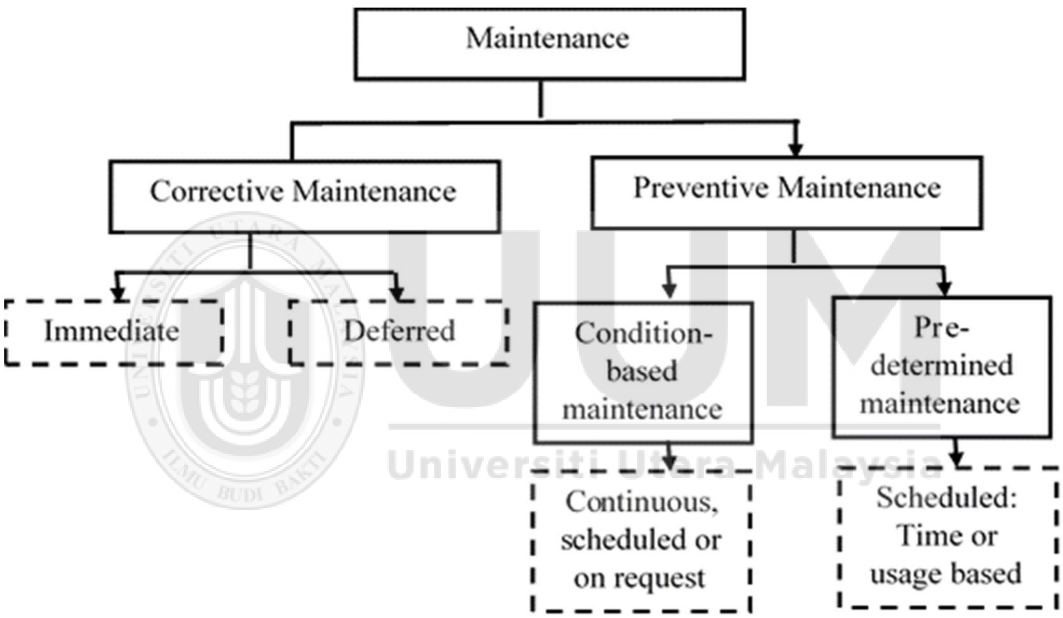
Development of maintenance philosophies (continue)

Third Generation	▪ Condition based maintenance ▪ Reliability centered maintenance ▪ Computer aided maintenance management and information system ▪ Workforce multi-Skilling and teamworking ▪ Proactive and strategies
Recent Generation	▪ Risk based inspection ▪ Risk based maintenance ▪ Risk based life assessment ▪ Reliability centered maintenance ▪ Condition based monitoring ▪ Computer aided maintenance management and information system

Note: The evolution of maintenance policies. From the first generation until recent. From Plant maintenance strategy: evidence from four British manufacturing firms by Fang Lee Cooke (2003), Twenty-first century maintenance organization: part 1 - the asset management model by John Moubray (2003) and An empirical investigation of maintenance practices for enhancing manufacturing performance in small and medium enterprises of northern India by Simranjit Singh Sidhu, Kanwarpreet Singh and Inderpreet Singh Ahuja (2021) published in Journal of Quality in Maintenance Engineering, 9 (3), Twenty-first century maintenance organization: part 1 - the asset management model and Journal of Science and Technology Policy Management respectively. Copyright 2003 by Emerald Publishing Limited, 2003 by Applied Technology Publications and 2021 by Emerald Publishing Limited

According to ISO/SS 13306 standards, maintenance practice can be categorized into two main types, Corrective Maintenance and Preventive Maintenance (BSI Standards Publication, 2017). The Corrective Maintenance (CM) can further divided into deferred maintenance and immediate maintenance whereas Preventive Maintenance (PM) can be subdivided into condition-based maintenance and pre-determined maintenance (Manickam, 2012; Tortorella, Fogliatto, A.Cauchick-Miguel, Kurnia, & Jurburg, 2021) (refer to Figure 2.2).

Figure 2.2:
Maintenance overview according to ISO/SS 13306 standard

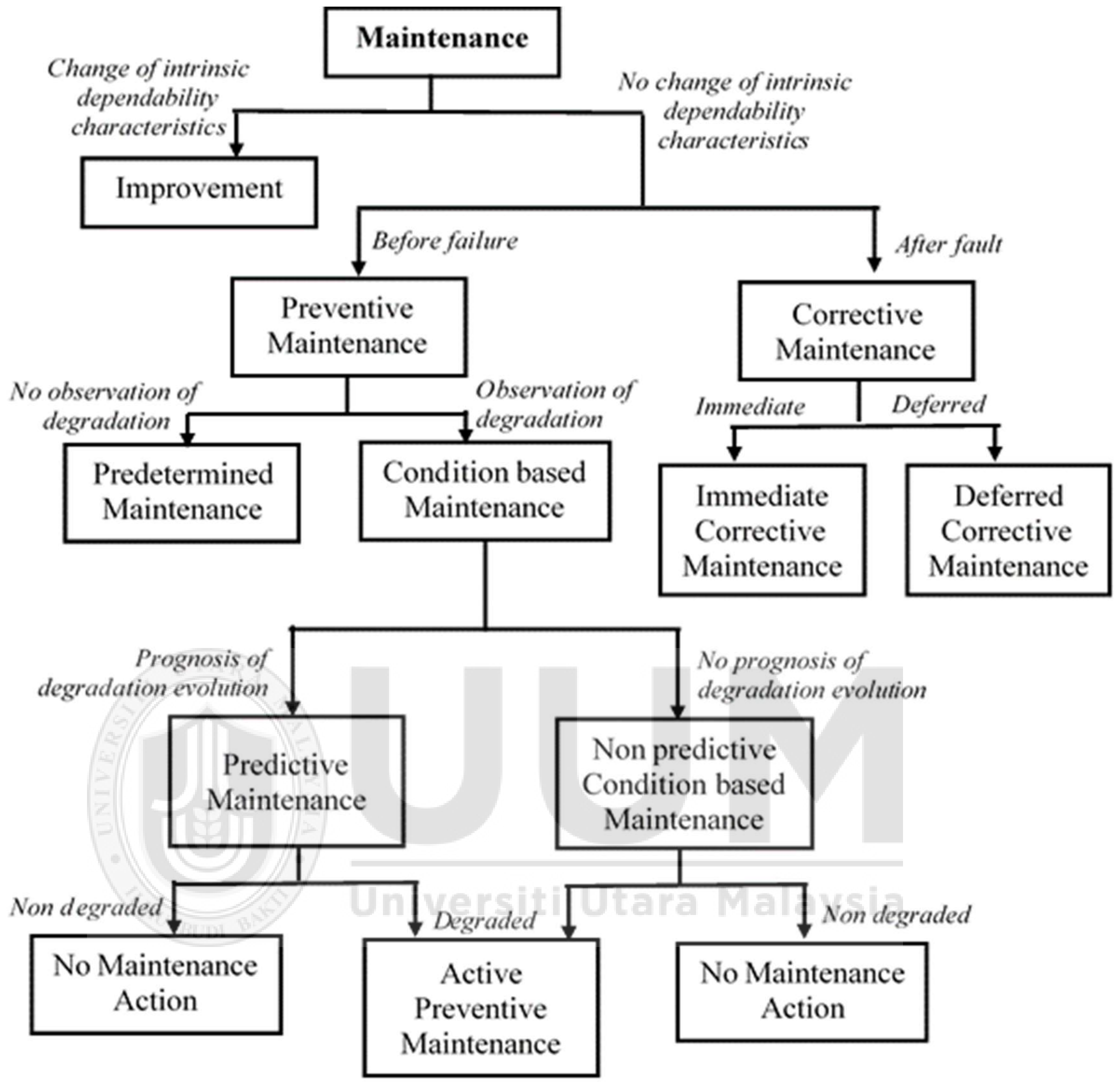


Note: The ISO/SS 13306 Standard for maintenance. From Proposal for fourth generation of Maintenance and the future trends a challenge in Production by Louis Manickam (2012). Copyright 2012 by Mälardalen University, Västerås, Sweden

Maintenance has become an integrated part of the production process from the support or peripheral activities. Therefore, developing effective and optimal maintenance strategies and models have been the subject of study in both academic and industrial fields. On that note, to further enhance the understanding of maintenance field, ISO/SS 13306 standard added the following diagram (figure 2.3).

Figure 2.3:

Maintenance Types Overall Overview ISO/SS 13306 standard



Note: BSI Standard for the overall overview of maintenance types. From BSI Standards Publication - Maintenance — Maintenance terminology by European Standard (2017). Copyright 2017 by European Standard.

Maintenance can be categorized into different classifications according to its actions (Mohamed, 2016). Many researchers have examined maintenance practises to understand how they affect a company's competitive advantage. Ten previous reviews by Noble (1984), Stoneham (1998), Sherwin (2000), Mostafa (2004), Garg and Deshmukh (2006), Schokry (2010), Fernández and Márquez (2012), UK Essay (2013), Galán and Gómez

(2018), and Lundgren, Skoogh, and Bokrantz (2018) covered a total of 135 different maintenance models. These 10 significant reviews of this maintenance model were chosen in order to determine which maintenance model was preferred by academics and practitioners. (refer to table 2.1).

Table 2.1
Maintenance management summary of literature review

Author (s)	Maintenance Models
William P. Pierskalla and John A. Voelker, *"A Survey of Maintenance Models: The Control and Surveillance of Deteriorating Systems"* (1976)	▪ Maintenance and Inventory Models; ▪ Control Theory Models; ▪ Age Dependent Replacement Model; ▪ Shock Models; and ▪ Interacting Repair Activities Models.
David F. Noble, *"Forces of Production: A Social History of Industrial Automation"* (1984)	▪ Routine of Cyclic Maintenance; ▪ Planned Maintenance; ▪ Planned Inspection; ▪ Emergency of Breakdown Maintenance; and ▪ Minimum Maintenance.
Rommert Dekker, *"Applications of maintenance optimization models: a review and analysis"* (1996)	▪ PM; ▪ Time-based preventive maintenance; ▪ Reliability Centered Maintenance (RCM); and ▪ Total Productive Maintenance.
Derek Stoneham, *Maintenance "Management and Technology Handbook (1st Edition"* (1998)	▪ Breakdown Maintenance; ▪ Total Productive Maintenance (TPM); ▪ Condition-Based Maintenance (CBM) ▪ Reliability-Centered Maintenance (RCM); ▪ Run-To-Destruction;

	▪ Pre-Planned Maintenance; and ▪ Campaign maintenance.
Maintenance management summary of literature review (continue)	
David Sherwin, *"A review of overall models for maintenance management"* (2000)	▪ Basic Terotechnology Model; ▪ Advanced Terotechnological Model; ▪ Total Quality Maintenance (TQMain); ▪ The Eindhoven University of Technology (EUT) Model; ▪ RCM; ▪ TPM; and ▪ Kelly's philosophy
Ismail Samir Mostafa, *"Implementation of proactive maintenance in the. Egyptian Glass Company"* (2004)	▪ Scheduled Maintenance; ▪ CBM; ▪ Predictive Condition Monitoring; ▪ RCM; ▪ TPM; ▪ IJQRM; ▪ TQMain; ▪ Maintenance Management Metric; ▪ Maintenance Management Training and Administration; ▪ Run-To-Failure (RTF); ▪ Corrective Maintenance (CM); ▪ Planned Maintenance; Preventive Maintenance ▪ Equipment Asset Management; ▪ Preactive Maintenance; ▪ Productive Reliability; ▪ Proactive Maintenance; and ▪ Profit centre maintenance.

Maintenance management summary of literature review (continue)

Amik Garg and S.G. Deshmukh, *"Maintenance management: Literature review and directions"* (2006)	▪ PM; ▪ CBM; ▪ TPM; ▪ RCM; ▪ Computerized Maintenance Management System; ▪ Predictive Maintenance (PDM); ▪ Outsourcing; ▪ Effectiveness-centered Maintenance; ▪ Strategic maintenance management; and ▪ Risk based maintenance
Kym Fraser, Hans Henrik Hvolby and Tzu Liang Tseng, *"Maintenance management models: a study of the published literature to identify empirical evidence. A greater practical focus is needed"* (2015)	▪ Age-based maintenance; ▪ Availability-based maintenance; ▪ E-maintenance; ▪ Time-based maintenance ▪ Value-driven maintenance planning; ▪ Condition monitoring; ▪ Predictive condition monitoring; ▪ Run-to-destruction; and ▪ Run-to-failure
Abed Schokry, *"Introduction to Maintenance"* (2010)	▪ RTF; ▪ PM; ▪ CM; ▪ Improvement Maintenance (IM); and ▪ PDM.

Maintenance management summary of literature review (continue)

J. F. Gómez Fernández and A. Crespo Márquez, *"Maintenance Management in Network Utilities"* (2012)	▪ Techniques dealing with economic or financial aspects of maintenance; ▪ CMMS; ▪ Techniques about human resources management; ▪ Application of operations research or management sciences; ▪ Life cycle analysis; ▪ TPM; ▪ RCM; ▪ Simulation, inventories models; ▪ Reliability theory; and ▪ Expert system.
Essay UK, *"The British Standard 3811"* (2013)	▪ CM; ▪ PM; ▪ Schedule Maintenance; ▪ Emergency Maintenance; and ▪ CBM.
Zahra Yousefli, Fuzhan Nasiri and Osama Moselhi, *"Healthcare facilities maintenance management: a literature review"* (2017)	▪ Total preventive maintenance; ▪ Reliability Centered Maintenance (RCM); ▪ Reliability Centered Failure Analysis (RCFA); ▪ Computerized Maintenance Management System (CMMS); ▪ Electronic Document Management System (EDMS); ▪ Energy Management Systems (EMS); ▪ Building Automation Systems (BAS); and

	▪ Analytic Hierarchy Process

Maintenance management summary of literature review (continue)

Michael Herrera Galán and Erwin Adan Martínez Gómez, *"A Review of Maintenance Management Models: Application for The Clinic and Hospital Environment"* (2018)	▪ Corrective Maintenance; ▪ Breakdown, Reactive maintenance / Failure-Based Maintenance (FBM); ▪ Campaign maintenance; ▪ Run-to-failure model / Run-to-destruction model; ▪ Proactive maintenance; ▪ Preventive maintenance (PM) / Scheduled maintenance; ▪ Predictive maintenance (PdM); ▪ Reliability-Centered Maintenance (RCM); ▪ Total productive maintenance (TPM); ▪ Total quality maintenance (TQMain); ▪ Evidence-based asset management (EBAM); ▪ Time-based maintenance (TBM); ▪ Computerized maintenance management system (CMMS); ▪ Outsourcing model; ▪ Virtual maintenance model; ▪ Condition monitoring; ▪ Risk-based maintenance (RBM); ▪ Value-driven maintenance planning (VDM); ▪ Effectiveness-centred maintenance; ▪ Age-based maintenance; ▪ Availability-based maintenance (ABM); ▪ Prognosis Help Management (PHM); ▪ E-maintenance ▪ Terotechnology model; ▪ Strategic maintenance management; and

	▪ Maintenance training model

Maintenance management summary of literature review (continue)

Camilla Lundgren, Anders Skoogh and Jon Bokrantz, *"Quantifying the Effects of Maintenance – a Literature Review of Maintenance Models"* (2018)	▪ Value Driven Maintenance (VDM); ▪ Life Cycle Cost analysis (LCC); ▪ Life Cycle Profit (LCP); ▪ Total Productive Maintenance (TPM); ▪ Reliability Centered Maintenance (RCM); ▪ Total Quality Maintenance (TQMain); ▪ Vibration-based Maintenance; ▪ Condition Based Maintenance (CBM); ▪ Maintenance Function Deployment (MFD); ▪ Fuzzy Multiple Criteria Decision-Making Model; ▪ Degradation-based Maintenance; ▪ Terotechnology Model; ▪ Kelly´s Philosophy; ▪ Risk-Based Maintenance; and ▪ The Eindhoven University of Technology (EUT) Model

Note: The compilation of types of maintenance models cited in articles/publication by Noble (1984), Stoneham (1998), Sherwin (2000), Mostafa (2004), Garg and Deshmukh (2006), Schokry (2010), Fernández and Márquez (2012), UK Essay (2013), Galán and Gómez (2018) and Lundgren, Skoogh and Bokrantz (2018). Copyright 2022 by author.

According to Table 2.1, Preventive Maintenance (PM), Corrective Maintenance (CM), Condition-Based Maintenance (CBM), Total Productive Maintenance (TPM), and Reliability-Centred Maintenance (RCM) were the most often discussed maintenance models. This is because maintenance research has broadly embraced these maintenance practices (Gandhare & Akarte, 2012; Bukowski & Werbińska-Wojciechowska, 2021). Therefore, researchers in the field of maintenance management came to the conclusion that the two main maintenance techniques used in the industrial sector are preventive maintenance (PM) and corrective maintenance (CM) (Velmurugan & Dhingra, 2015; Gandhare & Akarte, 2012; Al-Mansour, Sinha, & Thomas, 1993; Mong, Mohamed, Misnan, & Palis, 2021).

Planned maintenance includes both the PM and CM, but unscheduled maintenance is simply stated as emergency maintenance (Institute of Maintenance Management Education, 2013). CM is sometimes referred to as breakdown maintenance, which is regarded by the academics as being the oldest maintenance model in the industrial sector, according to Zaim, Turkylmaz, Acar, Al-Turki, and Demirel (2013) and Ghani (2018). where repairs are made if a system malfunctions. Predictive maintenance and periodic maintenance are the two divisions of PM practice (Wang, Chu, & Wu, 2007; Lundgren, Bokrantz, & Skoogh, 2021).

Planned maintenance, which referred to the CM and PM could also be time-based maintenance (TBM) or condition-based maintenance (CBM) (Drent, Kapodistria, & Resing, 2019). According to Perrons and Richards (2013), Doostparast, Kolahan and Doostparast (2014) and Mena, Viveros, Zio and Campos (2021), the maintenance management practices for onshore and offshore oil field equipment, currently are CM, TBM and CBM.

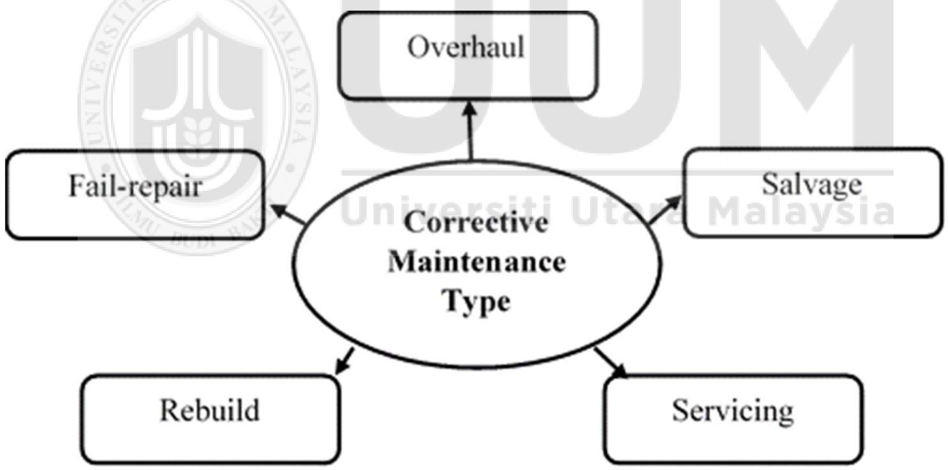
2.3.1 Corrective Maintenance

The corrective maintenance strategy includes replacing or repairing the equipment after it breaks down (Deighton , 2016; Mottahedi, Sereshki, Ataei, Qarahasanlou, & Barabadi, 2021). Once an equipment fails or a machine breaks down, the CM must correct the failure so that the equipment can be restored and the production facility can resume operation (Mital, Desai, Subramanian, & Mital, 2014; Pinzón-Castro, Maldonado-GuzmánN, Mojica-Carrillo, & RodrÍguez-González, 2021). For this reason, CM is reactive in nature. Maintenance tasks performed are prioritized so that the high-priority tasks will be addressed first (Xu & Xu, 2017; Hu, Miao, Si, Pan, & Zio, 2022). According to Mohamed (2016) and Aldaher (2021), CM is also signified to as, breakdown maintenance, failure based maintenance, or run to failure strategy.

CM will be performed once the operation or the manufacturing process cease its activity (Galar & Kumar, 2017; Abbasinejad, Hourfar, & Elkamel, 2021). In relation to that, the productivity will decrease in addition to the increase in the cost of production. Therefore, CM normally will be applied to non-critical assets which do not involve significant economic problem with the firm (Dhillon, 2002 (Daniel, Costinel, Krzysztof, & Carla, 2021)). Generally, certain equipment, machine or system already been identified in CM practice as the other maintenance approach will involve more cost (Deighton , 2016; Mottahedi, Sereshki, Ataei, Qarahasanlou, & Barabadi, 2021).

Types of corrective maintenance as listed in the U.S. Army's Engineering Design Handbook: Maintenance Engineering Techniques can be categorized into; 1) fail repair; 2) overhaul; 3) salvage; 4) servicing; and 5) rebuild. (Igor Bazovsky, Igor Bazovsky, Dauncey, Melvin B. Kline, & Sternlight, 1976; Lerch, De-Prada-Gil, & Molins, 2021). CM also includes the tasks of identification, detection, diagnosis, repair or replacement of a part or equipment and the verification of a failure or sudden failure of the production process or system. (Dhillon, 2002; Mezher & Ali, 2020) (refer to Figure 2.4). In oil and gas operation, equipment availability plays a vital role in plant operation, therefore maintenance planning concerning the CM need to ensure equipments are able to carry out continued operation and generate the optimum productivity (Mohamed, 2016; Aldaher, 2021).

Figure 2.4:
Corrective Maintenance Type



Note: The types of corrective maitenance. From Engineering maintenance: a modern approach by Balbir S. Dhillon (2002). Copyright 2002 by CRC Press

2.3.2 Preventive Maintenance

Preventive Maintenance (PM) approach is the periodic task performed on the equipment/system to prevent failure (Li & Zhang, 2020). Wakjira and Ajit (2012) and

Gwangwava, Baile, Dikgale and Kefhilwe (2021) stated that PM regarded as planned or scheduled maintenance activity that is fundamental in maintenance policy of any firm. PM strategies were proposed in the 1940s that requires engineers to perform certain maintenance action to reduce the probability of system failure or avoided any operation shutdown totally (Gillespie, 2015; Kablan & Serin, 2020). PM revolutionize the maintenance landscape from reactive practice to proactive method.

Gunckel, Kristjanpoller and Peñaloza (2020) highlighted that PM primarily performed to avoid unplanned maintenance, which normally not only trigger higher downtime, costly repair, interruption to business operation, but also will cause catastrophic events related to the safety of the personnel and also the environment. Therefore, the PM should be properly planned based on time, usage, age or condition information (Jonge & Scarf, 2020).

Prerequisite process and system that are required in ensuring PM strategies to be effective as proposed by Deighton (2016) and Mottahedi, Sereshki, Ataei, Qarahasanlou and Barabadi (2021) are as follows;

1) Proper maintenance management system;
2) Maintenance personnel discipline; and
3) Updated records pertaining to equipment failure and repair history.

The health of the equipment/system will be assessed using related parameters, which is equivalent to the baseline performance profile. Subsequently, plan the future state of the equipment or system for an effective maintenance program and actions (Eyoh & Kalawsky, 2018). This type of maintenance is the one that will be covered in this study to understand the effectiveness of the preventive maintenance practice in oil and gas company.

In general, the total cases of equipment/parts failure can be reduced if the proper PM approach is selected as it is maintenance activities that are performed based on predefined maintenance schedule (Mohamed, 2016; Deighton , 2016; Mottahedi, Sereshki, Ataei, Qarahasanlou, & Barabadi, 2021). Prognostic, predictive and conditional terms are the terminologies related to PM (Gunckel, Kristjanpoller, & Peñaloza, 2020). Hence, the most common PM strategies are time-based maintenance (TBM) and condition-based maintenance (CBM).

2.3.2.1 Time-Based Maintenance (TBM)

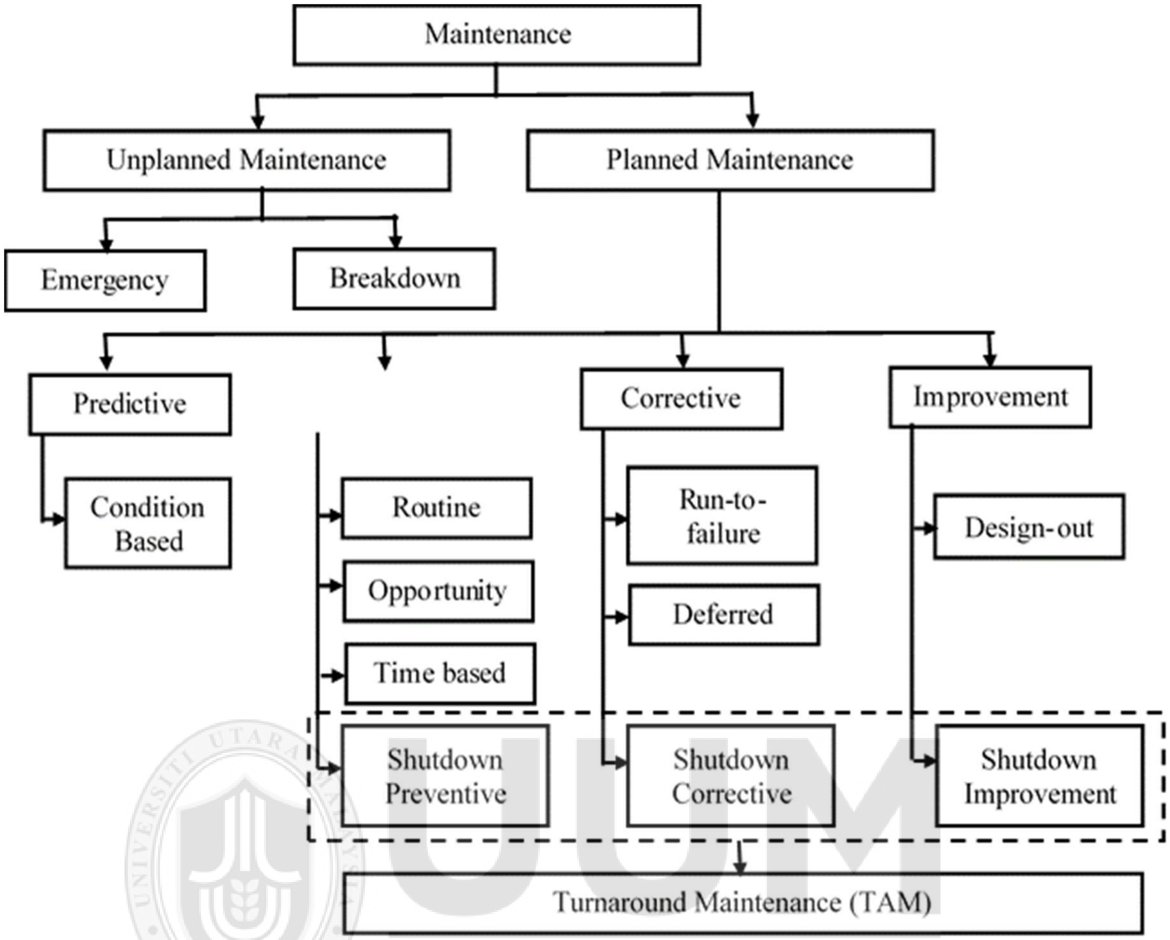
TBM refers to maintenance activities performed at certain fixed intervals, independent of the condition of the equipment/parts (Bazovsky & Associates, 1976; Wu & Zhou, 2021). Failures can be avoided by replacing parts/components in the equipment or system at the designated time, hence it's also known as scheduled maintenance (Mohamed, 2016). The primary purpose of TBM is to protect business operation against assets' wearing components. One of the maintenance activities in the MTB is the Turnaround Maintenance (TAM) - defined as the largest and most important O&G maintenance activity in terms of cost and time (Elfeituri & Elemnifi, 2007; Iheukwumere-Esotu & Kaltungo, 2020).

The TAM is completed at a time interval to ensure the safety of critical equipment. This equipment is generally not capable of being inspected and maintained during normal plant operation unless the plant facilities are completely shut down (Duffuaa & Daya, 2004; Elwerfalli, Khan, & Munive-Hernandez, 2019). Consequently, "*the TAM is considered to be a determining factor in the performance of oil and gas companies and has become* *necessary for any processing plant operating continuously under rigorous operating conditions to mitigate risks between periods of TAM*" (Al-Marri, Nechi, Ben-Ayed, & Charfeddine, 2020).

The TAM Project is considered necessary maintenance to ensure the operating conditions and residual life of the equipment critical to oil and gas operations (Elwerfalli, Khan, & Munive-Hernandez, 2019). Preventive maintenance (PM), corrective maintenance (CM), and predictive maintenance (PdM) are examples of maintenance practises that, according to Al-Marri, Nechi, Ben-Ayed, and Charfeddine (2020), do not completely address the inspection, repair, replacement, development, and renewal of oil and gas facilities. Figure 2.5 illustrates that the CM is a step backward in the PM while the PdM is a step forward.

However, with only 11% of components, showing ageing attributes in the study of Boeing 747 that suitable for TBM approach (Nowlan & Heap, 1978; Singh, Ganguly, & Samad, 2021), therefore the new maintenance policy has been introduced that will overcome the limitation of TBM known as Condition-Based Maintenance (CBM) (Baglee, Jantunen, Campos, & Sharma, 2016; Gugaliya & Naikan, 2020).

Figure 2.5
Turnaround Maintenance (TAM) Initiation



Note: The Turnaround Maintenance (TAM) roots. From Developing Turn Around Maintenance (TAM) Model to Optimize TAM Performance Based on the Critical Static Equipment (CSE) of GAS Plants by Abdelnaser Elwerfalli, Mohammed Khurshid Khan and Jose Eduardo Munive Hernandez. (2019). Copyright 2019 by ResearchGate GmbH.

2.3.2.2 Condition-Based Maintenance (CBM)

CBM involves examining the function of equipment or system with visual assessment, programmed testing, and sensor equipment to determine the most cost-effective maintenance method (Rastegari, 2017; Carnero & Cárcel-Carrasco, 2021). BSI Standards Publication (2010), defines CBM as *"preventive maintenance which include a combination of condition monitoring and/or inspection and/or testing, analysis and the ensuing maintenance actions"*. CBM is regarded as an attempt to evade unnecessary maintenance activities unless the asset showing abnormal behaviour (Baglee, Jantunen, Campos, & Sharma, 2016; Gugaliya & Naikan, 2020). The purpose of CBM also is to monitor asset's condition and if malformation of the equipment/system persists, the next issue will be how long the equipment/system can continue running before failure/shutdown (Fridholm, 2018). *"Condition based maintenance carried out following a forecast derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item"* (BSI Standards Publication, 2010)

2.3.2.3 Innovation in Preventive Maintenance

Many businesses, from manufacturers to construction firms to mining and drilling firms, place the highest priority on safeguarding sophisticated equipment and keeping expensive assets operating at peak efficiency (Görner, Kudar, Mori, & Samek, 2020). O&G companies included, on the grounds that the viability of their businesses depends in part on their capacity to carry out their current activities. For this reason, substantial resources, including research and development on a few cutting-edge applications of the technologies, have been devoted to preventative maintenance and after-sales support. All sizes of Manufacturing and Industrial Equipment (IM&E) businesses can now benefit from these innovative applications and implement the ideas in their operations (Sapot, 2021).

Although after-sales support and preventive maintenance have long been regarded as crucial elements of the O&G sector, they are now more crucial than ever. Mission-critical devices, such as generators, are just too expensive and high priority in the case of a failure, as are manufacturing and mining machines, bulk equipment for road and building work, and these types of devices (Çınar, et al., 2020). From the proper integration of high-tech components to the compatibility of platforms and version versions of electrical components, they are also complicated and run the danger of malfunction (Görner et. al., 2020). Unexpected downtimes can be disastrous for both extending the lifespan of expensive gear and keeping multinational corporations working as required. Because of this, businesses have been able to justify spending a lot of money on R&D to improve the efficiency of maintenance and service operations (Akinlabi, Agarana, & Akinlabi, 2021). A variety of devices have been introduced using assistive technology such as but not limited to;

- Intelligent Sensor Reading - The equipment's embedded sensors can offer a wealth of data about the condition and operation of the unit. Physical conditions that can be measured and monitored include temperature, vibration, volume, and weight. The information could be utilised to spot early signs of decline. Early detection of possible issues and prompt response could stop the cascade (Pech, Vrchota, & Bednáˇr, 2021);
- Predictive forecasting - Advanced analytics can also be used to anticipate typical life cycle stages so that maintenance can plan ahead. and schedule during downtime any necessary calibrations, replacing consumables such as filters, and replacing eroded parts before they fail (Çınar, et al., 2020);
- Holographic simulation and virtual reality - As the present work force ages and enters retirement, businesses must increase the hiring and training of new technicians. Companies are resorting to virtual reality and simulation settings to help with training recruits, allowing them to "train and fail" in safe conditions,

rather than damage the real machine, to quicken the process and the huge transfer of knowledge about hardware;

- Video transmissions and wearable technology - Another innovation brought on by the lack of trained specialists is the use of video communications. Junior technicians can be dispatched to the task site with portable technology rather than sending one or two senior technicians and wasting valuable time travelling there. The wearable might be a helmet with a built-in camera that sends the primary technician a view of the damaged equipment. To assist the learner in visualising the proper task, the senior technician can communicate via audio or pictures supplied to glasses or wrist devices, such as diagrams.;
- Robotics operated remotely - When carrying out specific repairs or maintenance tasks, robots can frequently be both more accurate and economical. This is especially true for equipment utilised in molten metals, toxic vapours, strong fuel gases, or dangerous heights that is situated in a remote place or at a site that is dangerous to people. Robotics can be utilised in these situations to replace conventional parts like belts or bearings or to perform simple calibration tweaks, repairs, and replacements.; and
- Drones - Small, remote-controlled aerial drones are also utilised to access machinery or equipment where sending a specialist could be risky or impractical. Drones can perform X-rays, take ultrasound scans, or record videos of the apparatus, giving technicians incredibly helpful diagnostic tools..

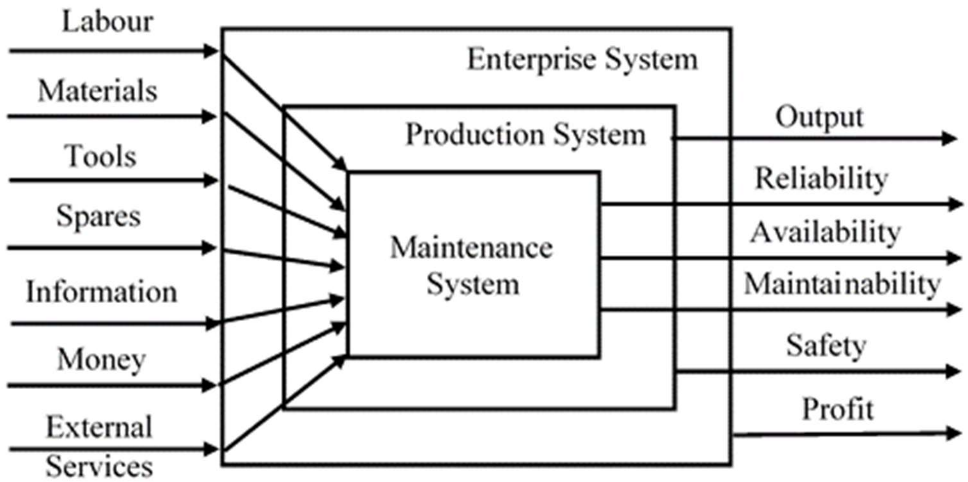
These innovation in PM have been earmarked to be the future of effective and efficient maintenance practice in manufacturing and O&G industry. Hence the current study also attempts to identify whether it is available in the operation of PIC.

2.4 The Function of Maintenance

Proactive (CM) or preventive maintenance (PM) strategies are an essential component of an effective maintenance program for any organization. The purpose of maintenance as cited by Dekker (1996) from "BS3811: Glossary of maintenance terms in Terotechnology" (1984) is "*the combination of all technical and associated administrative actions intended to retain an item or system in, or restore it to, a state in which it can perform its required function"*. As a result, a company's survival depends on its chosen maintenance strategy (see Figure 2.6).

Maintenance field will always be associated with the concept of Reliability, Availability and Maintainability (RAM) (Corvaro, Giacchetta, Marchetti, & Recanati, 2017). RAM parameters are often used in maintenance planning to improve productivity, efficiency and quality of the product or service (Tsarouhas, 2020). According to Zhang, Haskins, Liu and Lundteigen (2018), RAM is critical to creating competitive advantages in order to reduce capital investment (CAPEX) and operational costs (OPEX), limit restructuring risk and mitigate potential future operational disruptions.

Figure 2.6:
The relationship between maintenance and enterprise



Note: The diagram of maintenance and enterprise relation. From Modeling maintenance performance: a practical approach by Jacobus Krige Visser (1998). Copyright 1998 by IMA Conference, Edinburgh, United Kingdom

Effective maintenance strategies depends on acquiring proper knowledge regarding the principles and practices of the maintenance management as well as the information which relates to the performance of specific facility/equipment/system (Deighton , 2016; Mottahedi, Sereshki, Ataei, Qarahasanlou, & Barabadi, 2021). Rastegari (2015) and Carnero and Cárcel-Carrasco (2021) further stated that no one-size-fit-all maintenance strategy exists today to accommodate the ever-changing facility performance and conditions. Therefore, the maintenance strategy and practice need to be specifically designed to satisfy the unique requirements of a facility/system/asset. An effective strategy essentially needs to be dynamic and periodically updated to address the change in environment and circumstances (Deighton , 2016; Mottahedi, Sereshki, Ataei, Qarahasanlou, & Barabadi, 2021). Fail to do so will result in catastrophic events not only for the company, the personnel involved as well as the environment.

2.5 Maintenance Management Problem in Oil and Gas Industry

Preliminary research has shown that the major causes for increased spending on oil and gas facilities and processing plants are planned and unplanned shutdowns, i.e. repairs, overhauls and replacements of parts/components (Utne, Brurok, & Rødseth, 2012; Negri, et al., 2021). The occurrences happen due to unreasonable and insufficient maintenance policy which leads to disastrous occurrence to the security of production and the economic cost of the petroleum and gas exploration process (Tang, Yu, Chen, & Makis, 2015; Mohamed, 2016; Aldaher, 2021). The next section will explain the problems associated with maintenance management in O&G industry.

O&G industry is a capital intensive business with state-of-the-art production system, advanced technology, custom facilities, heavy machineries, top-talent manpower, multiple assets and proper supply chain management (Ratendra & Virender, 2020). The industry also highly competitive, therefore, to stay relevant in the business, the management need to decide on the best method for their company to be operating in and avoiding unnecessary shutdown is one of the best approaches. According to an article on Offshore Technology (2020), the company that's able to manage their operating expenditure had better chances to survive in this unpredictable economic condition.

The O&G industry is always volatile and with the current low price, condition extended, intensified by the decrease in operating efficiency due to higher extraction cost faced by many oil and gas operators, a new mechanism to reduce the operation cost need to be identified soon. The key element in reducing costs in the O&G industry is maintaining the equipment (machine/system/asset) (Cristofari, Familusi, Perrin, & Sevin, 2016; Amin, Liu, Abbas, Hanif, & Vo, 2021). A study by Ratendra and Virender (2020) regarding O&G industry in India discovered that the main reasons cited for equipment failures were 1) poor maintenance; 2) human error; 3) unsafe maintenance practices; 4) incompetent maintenance personnel; and 5) poor communication between operators and maintenance personnel. Maintenance is the heart of business operation as its enables appropriate quality of work and at the same time enhance the productivity of the company.

The second factor related to the maintenance management issue in the O&G industry is aging infrastructure. The equipment and infrastructure used in the O&G industry was developed and built decades ago (Offshore Technology, 2020). This leads to obsolete technology and irreplaceable materials for parts and equipments which may result in constant monitoring and inspection but still with a lack of assurance that the equipment will not fail or breakdown. Ageing is the condition whereby the facility or component experiences some kind of material deterioration that will increase the probability of failure over the lifetime (Akashraj & Maleith, 2020).

Oil and gas facilities include oil rigging structures, oil gathering poles, service rigs, pipelines, engines and power stations are destined to undergo a certain level of equipment obsolescence, deterioration, corrosion, erosion and fatigue (Akashraj & Maleith, 2020). Groysman (2017) and Lozinskii, Kuchin, Efimov and Pakhomova (2021) mentioned that in a condition of pressures from vacuum to 1,000 bar and temperatures between -196°C to +400°C which occurring in metallic equipment, various hazards are inevitable due to erosion or corrosion that can lead to catastrophic events. In relation to this issue, a proper maintenance technique should be applied to anticipate such corrosion phenomena.

The lack of competent staff is the third issue with maintenance management in the oil and gas sector. The decline in employment in the oil and gas industry is a global issue, according to IBM Corporation's 2020 study on "The chemicals and petroleum industry guide to closing the skills gap," which noted that the oil and gas industry. Nearly 90% of study respondents stated that a skills shortage has a negative impact on productivity and that gaps are widening in every sector of the industry. The shortage of qualified workers will be up to 40,000 workers by 2025 (Andrews, Datta, Newnam, & Rousset, 2019). Technological advancement, innovation in business operation model, the exodus of retirees, and loss of interest in young talents for the "out-of-favour" industry were cited as reasons why the industry is in this situation (Dickson, Tilghman, Bonny, Hardin, & Mittal, 2020).

Offshore Technology (2020) highlighted another issue pertaining to the workforce that operating oil and gas equipments or related devices require years of training and field experience that can lead to the shortage of trained workforce. In addition, many talents are evolving quickly as a result of the development of digital technology, making it challenging to meet their most recent requirements (Ballaert, Lin, & Womack, 2020). The engineering function will be severely affected as a lot of these graduates are more attracted to the "technology" sector rather than the oil and gas field (Keane, 2019).

The final major maintenance management issue facing the O&G industry is to streamline maintenance activities. The maintenance strategy in the O&G industry has shifted from reactive to preventative to be more effective (Offshore Technology, 2020). In addition, according to Mohamed (2016) and Mottahedi, Sereshki, Ataei, Qarahasanlou and Barabadi (2021), deciding on the best maintenance practice is a hard and complex task due to the requirement of knowledge regarding cost and budget, mainpower, technology, system, enviroment and safety aspects.

Furthermore, the oil and gas players currently are more incline to optimize the maintenance management to minimize the cost of operating the available equipment in an environmentally and safety-conscious manner. In relation to this, oil and gas industry in dire needs for an effective maintenance program for the business to be sustainable and at the same time do not effect the surrounding negatives.

2.6 Maintenance Strategy Selection and Optimization

Maintenance is usually only an inevitable part of production, where it has been regarded as a necessary evil (Pintelon & Parodi-Herz, 2008; Karki & Porras, 2021). Restoration, repairs and replacements were completed as required and no questions related to optimization were raised (Burde, 2008; Ghani, 2018). After that, the maintenance been discussed at management level as it was related to technological issue (Roy, Stark, Tracht, Takata, & Mori, 2016; Zheng, Ardolino, Bacchetti, & Perona, 2021). The new implementation of maintenance practices included not only the optimization of technical maintenance solutions, but also a greater concentration of the organization on maintenance activities (Kobbacy & Murthy, 2008; Tortorella, Fogliatto, A.Cauchick-Miguel, Kurnia, & Jurburg, 2021). Later, the maintenance practice became a full-scale function, as an alternative to sub-function for production. (Mostafa, Lee, Dumrak, Chileshe, & Soltan, 2015; Shou, Wang, Wu, & Wang, 2021). Nowadays, maintenance management has become a complex enterprise, covering technical and management sciences, while requiring flexibility to manage the dynamic business environment (Mufudza, 2018). Companies' senior management now recognize that a carefully designed and synchronized maintenance strategy with prudent implementation of this strategy could have a substantial financial impact (Pintelon, 2010; Farhoomand, Markus, Gable, & Khan, 2021)

The best maintenance procedure to select depends on a number of factors, such as the selected maintenance method that should determine the problem, implemented within the limits of a budget and finally minimal disturbance for the public (Ansell, Holmes, Evans, Pasquire, & Price, 2009; Kissi, Adjei-Kumi, Twum-Ampofo, & Debrah, 2020). In addressing the maintenance model selection and optimization approach, many scholar already proposed the Decision Support System (DSS) models that will assist in the implementation of an appropriate maintenance methodology that will help improve maintenance performance and optimize operations, or/and maintenance costs, such as the maintenance decision-making system (Lin, Ambani, & Jun, 2009; Mahdi, Hossein, & Taha, 2010; Parvizsedghy, Senouci, Zayed, Mirahadi, & El-Abbasy, 2015; Khan, Yarveisy, & Abbassi, 2021).

Mathematical discipline has been utilized as an effective maintenance optimization approach by operation and maintenance manager (Garg & Deshmukh, 2006; Gharoun, Hamid, & Torabi, 2021). However, the impact of this method in assisting the maintenance activities are not being proved yet as a lots of reasearch stated many flaws associated with this approach such as the lack of knowledge (Moubray, 2001; Tinga, 2010; Broek, H.Teunter, Jonge, & Veldman, 2021), lack of data creadibility (Mann, Saxena, & Knapp, 1995; Dekker & Scarf., 1998; Braaksma, Klingenberg, & Veldman, 2013; Wang, Jia, Jia, & Song, 2021) and insufficient amount of data determine the accuracy of the model parameters (Bram, 2017; Antosz, Mazurkiewicz, Kozłowski, Sęp, & Żabiński, 2021). Typically, maintenance optimization is a combinatorial optimization issue because the maintenance plan consists of various maintenance metrics (Miyamoto, Kawamura, & Nakamura, 2000; Nili, Taghaddos, & Zahraie, 2021).

The oil and gas industry also has to overcome the loss of efficiency in its operations over the past 100 years as stated by McKinsey in comparison with most other asset-intensive industries (Handscomb, Sharabura, & Woxholth, 2016; Candina, Fernández, Hall, & Verre, 2020). Companies involved in oil and gas activities are exposed to a scenario in which production performance is strongly influenced by maintenance efficiency (Parida & Kumar, 2009; Shou, Wang, Wu, & Wang, 2021). This has put significant pressure on many oil and gas operators to accelerate further efforts to reduce oil and gas price volatility, by increasing the level of output, maximizing profit and reducing costs (Lu, Guo, Azimi, & Huang, 2019).

Various maintenance management approaches have been introduced to assist oil and gas companies and maintenance manager to accomplish maintenance effectiveness such as decision support system (Akram, Isaa, Rajkumar, & Lee, 2014; Hassan, M., Soomro, & Sherwani, 2017; Asad M. , Hassan, Soomro, & Sherwani, 2017; Asad, Sherwani, Hassan, Sahito, & Khan, 2021), expert system (Ning, et al., 2019; Buccieri, Muniz Jr., Balestieri,

& Matelli, 2020), system dynamic (Handani, Ishida, Nishimura, & Hariyanto, 2011; Leon, Osman, Georgy, & Elsaid, 2018; García & García, 2018) and computerized maintenance management system (CMMS) (Mahmood, Rahman, Mazli, & Deros, 2009; Mahmood, Rahman, & Deros, 2011; Alburaiesi, 2020).

The decision support system (DSS) aids the maintenance management managers' decision making process using the combination of sophisticated model and tool, data and comprehensible application in a unique and powerful system that supports both semi-structured and unstructured decision-making (Dey, 2004; Parvizsedghy, Senouci, Zayed, Mirahadi, & El-Abbasy, 2015; Khan, Yarveisy, & Abbassi, 2021). Korovin and Kalyaev (2015) and Kaljic, Maric, Njemcevic and Hadzialic (2019) highlighted that DSS is the simplest in terms of architecture as it is created to solve specific problems and focused on a single circle of users which also indicates that it has limitation on the range of issues that can be resolved. Due to this feature, DSS generally utilised in managing the pipelines in oil and gas sector (Dey, 2004; Azwar, Migas, & Agus, 2015; Khan, Yarveisy, & Abbassi, 2021).

Expert System (ES) applications are being developed in the mainenance management field as larger software bundles rather than standalone components (Lokko, Raza, & Liyanage, 2015; Temizel, et al., 2021). According to Badiru and Cheung (2002) and Badiru (2021), ES assist the non-expert with some of the skills and knowledge of expert in solving problems pertaining maintenance area. An advantage of expert systems is *"their ability to involve expert knowledge and subjective human reasoning"* (Chang Albitres, Krugler, & Smith, 2005).

ES requires strong knowledge processing ability and maintenance cost (Li, Yu, Cao, Tian, & Cheng, 2020). In relation to this, ES is further developed to include machine and computer in making suggestions and act like an expert in a particular field (Ong, 2018). This leads to the further establishment of machine aided method of decision making in maintenance management or also known as artificial intelligent (AI) (Li, Yu, Cao, Tian, & Cheng, 2020).

System Dynamic (SD) appreciates that individual component has a significant influence on the overall system reliability (Handani, Ishida, Nishimura, & Hariyanto, 2011; Shaker, Shahin, & Jahanyan, 2021). SD considers as a useful method to model the interaction between system entities (Daneshzand, Amin-Naseri, Elkamel, & Fowler, 2018). Casey and Töyli (2012) and Cenamora and Frishammar (2021) stated that this method focuses on the modeling of endogenous interactions between variables to regulate the dynamic behaviour of the system. Acquiring this knowledge will allow the maintenance manager to understand the structure of the problem by the cause and effect of the variables that exist within the system.

Computerized maintenance management system (CMMS) is now a key component of the maintenance department for many companies, and it provides support at various levels in the organizational hierarchy. Indeed, the CMMS is a world-class maintenance method, as it provides a platform for decision analysis and therefore acts as a management guide (Labib, 1998; Mahmood, Rahman, Mazli, & Deros, 2009; Kumar & Narula, 2020). CMMS is computer software that is commonly used to control and report on work activities and resources.

CMMS application for Petronas is known as Petronas Maintenance Management System (PMMS) (Mahmood, Rahman, Deros, & Mazli, 2011; Kumar & Narula, 2020). Karim, Candell and Söderholm (2009) and Zaibi, Riahi and Moussa (2020) stated that maintenance management is performed efficiently with computers. This method currently being expanded with the introduction with Indusrial Revolution 4.0 (IR 4.0) that utilized the deep integration of industrialization and computerization, which can bring significant benefits by accelerating the digitalization and intelligence of the O&G industry (Lu, Guo, Azimi, & Huang, 2019). The breakthrough in the knowledge and technology via this IR 4.0, will enable O&G industry to greatly improve in terms of efficiency and cost saving (Yang, Qiu, Hao, Zhao, & Guo, 2016; Lu, Guo, Azimi, & Huang, 2019) (refer Figure 2.7).

Figure 2.7:
Development course of world oil and gas technology

1980-1990	1990-2000	2000-2010	2010-2020	2020-2030
▪ Electric drive rig ▪ Top drive ▪ Measurement while drilling ▪ Directional drilling ▪ Downhole flowmeter ▪ Airtight transportation ▪ Mechanized welding	▪ Automated drilling ▪ Logging while drilling ▪ Automatic vertical drilling ▪ Rotary steerable drilling ▪ Numerical reservoir simulation ▪ Supervisory Control and Data Acquisition ▪ Pipeline automation	▪ 3D imaging ▪ Intelligent completion ▪ Digital oilfield ▪ Automate managed pressure drilling ▪ Fiber monitoring ▪ Dynamic optimization of the production ▪ Pipeline simulation ▪ Automatic welding ▪ Nondestructive testing ▪ Underwater robot	▪ Virtual reality ▪ High build-up rate rotary steerable drilling ▪ Drone inspection ▪ Big data analysis ▪ Pipe robot ▪ Intelligent sensor ▪ Geographic Information System	▪ Intelligent oilfield ▪ Intelligent pipeline ▪ Intelligent refinery ▪ Drilling robot ▪ Remote-controlled drilling ▪ Nanorobot ▪ Artificial intelligent assisted decision making

Note: The evolution of the world's oil and gas technology. From Intelligence – Oil and gas industrial development trend by Yang Jinhua, Qiu Maoxin, Hao Hongna, Zhao Xu and Guo Xiaoxia (2016). Copyright 2016 by Petroleum Science and Technology Forum

Key indicators for maintenance efficiency are reliability, availability, maintainability and safety, which are critical to optimize the maintenance model (Qingfeng, Wenbin, Xin, Jianfeng, & Quingbin, 2011; Hajipour, Amouzegar, Gharaei, Abarghoei, & Ghajari, 2021). According to Pintelon and Parodi-Herz (2008) and Karki and Porras (2021), the concept of an "optimized" maintenance program proposed a combination of maintenance engagements and policies. New optimization models being developed and practiced all over the world to help production-related industry managers and practitioners, hence further research needed to cover this field and identify the best method in Malaysia's oil and gas context.

2.7 Effectiveness in Maintenance Management

In general, maintenance is associated to unpredictable, irregular events. The process relies more on human skill and ability than on technology, and it is heavily reliant on human competency. (Simeu-Abazi & Sassine, 2001; Retolazaa, Ezpeletab, Santosa, Diaza, & Martinez, 2021). Without a proper and systematic framework, maintenance functions will be difficult to carry out effectively (Agbejule & Jokipii, 2009; Scheetz, Smalls, Wall, & Wilson, 2021).

The effectiveness of the maintenance system can be derived from optimization of maintenance planning and scheduling (Ma´rquez, Leo´n, Ferna´ndez, Ma´rquez, &

Campos, 2009; Silva R. F., 2022). According to Jonsson (1997) and Liedberg (2021), maintenance management was a combination of elements including strategy, the human factor, organisation, a support system, tools, and procedures. The five elements should be linked together to establish an effective maintenance management strategy (Sharma, 2013; Kurian, Shalij, Pramod, & Sunilkumar, 2021).

Additionally, the cause-and-effect diagram relating to the factors such as manpower, material, method, and machine was correlated with the effective maintenance system. (Williams, 2004; Temizel, et al., 2021) as well as considerations, data, policies, techniques and tools (Ma´rquez, 2007; Silva R. F., 2022). The efficiency of the maintenance management system may also be associated with the incorporation of AI techniques in the form of fuzzy games, neural networks, etc. In the maintenance modeling and decision making (Ogaji & Singh, 2003; Wang, Golnaraghi, & Ismail, 2004; Chang, 2005; Edwin & Chaturvedi, 2011; Boral, Howard, K.Chaturvedi, McKee, & Naikan, 2020) in addition to the involvement of high human expertise (Sinha, 2015; Ismail, Razelan, Yusof, Zulkiple, & K.A., 2021).

The effective maintenance of equipment or system is well noted to be very vital in today's economic downturn due to the spreading of the pandemic Covid-19 particularly in capital-intensive industry such as oil and gas. Organizations should develop quality benchmarks to measure the current effectiveness of the maintenance management system and forecast future performance and use the data to understand improvements that can be made (Christiansen, 2018). The maintenance metric identified to give qualitative and quantitative insight in tracking, improving and optimizing the maintenance operation are, 1) Planned maintenance percentage (PMP); 2) Overall Equipment Effectiveness (OEE);

3) Mean time to repair (MTTR); 4) Mean time between failure (MTBF); and 5) Preventive maintenance compliance (PMC) (Kumar, Galar, Parida, Stenstro¨m, & Berges, 2013; Christiansen, 2018).

1) The Planned Maintenance Percentage (PMP) metric represents the calculation of the percentage of scheduled maintenance versus planned maintenance, plus any emergency maintenance required to resolve failures (Andrews, 2019). In other words, it informs the maintenance manager of the amount of maintenance done on a particular asset that is part of their preventive maintenance plan compared with the time spent repairing it because it crashed unexpectedly. Therefore, the formula for this metric is PMP = (scheduled maintenance time/total maintenance hours) x 100 whereby the excellent maintenance practice should state more than 90% of the maintenance work should be categorized as planned maintenance (Christiansen, 2018).
2) Overall Equipment Effectiveness (OEE) is the maintenance performance measurement of the effectiveness of machine/equipment (Siregar, Syahputri, Anizar, Rizkya, & Tambunan, 2018). The data provided by OEE give information on the effectiveness of maintenance processes in terms of quality, performance and availability (Christiansen, 2018). In other words, the effectiveness of the equipment as a whole helps organization recognize the problems in the company's operation, identify the percentage of truly productive manufacturing time and improve it while providing the standard benchmarks for tracking progress (Trout, 2020). The goal of OEE is continuous improvement, therefore OEE = availability x performance x

quality which the aim to achieve 100% (zero defect) (Corrales, Lambán, Korner, & Royo, 2020).

3) Mean Time to Repair (MTTR) "*is mean time to do maintenance on the component or equipment in order to restore its function into initial state*" (Dhillon B. , 2002; Kurian, Shalij, Pramod, & Sunilkumar, 2021)Timing for MTTR begins once the restoration work start and will continue until the system operation are restored or the equipment is fixed and this MTTR activities already take into account the repair time, period for testing and back to normal operating state (Christiansen, 2018). Generally, companies involved in oil and gas activities will try their level best to reduce the MTTR as it would inflict huge lost for an operator if additional hours required to reinstate the machinery/equipment. MTTR can be calculated by dividing the downtime period by the total number of downtimes, MTTR = (SUM of downtime periods/ total number of repairs) (Siswanto & Kurniati, 2017).

4) Mean Time between Failure (MTBF) measurement of the estimated time from one failure to the next in normal operation and normally applicable for non-repairable items (Ake, Ukpaka, & Nkoi, 2019). According to Kumar, Bansal and Mehta (2021), MTBF calculations can assess the anticipated operating life of equipment. Hence, MTBF notifies the maintenance manager about the lifespan for a particular equipment which indicate that the higher MTBF means the part (or component) acquired will be in operation longer before it crashes/fail. (Christiansen, 2018). As a result, to calculate the MTBF, the total operating time must be divided by the number of failures. MTBF = (SUM of operational time/total number of failures).

5) Preventive Maintenance Compliance (PMC). The main idea of preventive maintenance is the implementation of proactive actions against unplanned stop times to identify potential defects before they turn into something more serious. Therefore, timely schedules and interventions are very important (Peycheva, 2018). Preventive maintenance compliance scores represent the percentage of planned preventive tasks performed within a specified time interval (Christiansen, 2018). Thus, the maintenance management system is considered as effective once the proper practice was put in place to assist the maintenance manager and companies in making a right decision with regards to a company's survival.

The principles underlying preventive maintenance remain the foundation of an effective and cost-effective maintenance strategy. Such a maintenance strategy has the inherent advantages of better equipment availability and reduced operational failures that result in cost savings related to asset management and asset lifecycle.

In managing the life of industrial assets and utilities such as the O&G industry, innovation and technology have changed significantly over time. Therefore, the study of maintenance practice for PICs was conducted in order to understand the relevancy of the strategy in keeping pace with the new landscape of O&G industry.

2.8 Policy and Regulation in Maintenance Management

Maintenance management is relying on the proper implementation of policy and regulation as the key element to be successful (Choudhury & Sharan, 2011; Saha, Azeem, Hasan, Ali,

& Paul, 2021). Preventive maintenance in the framework of oil and gas, electricity and utility supply companies are very unique as such companies cannot afford to experience any ceased or halt in their operation due to long-term supply arrangements with buyers of their services and products (Elavarasan, et al., 2020). Their contract requires heavy restrictions in short or inappropriate circumstances (Hamel, 2020). Furthermore, regulators implement strict adherence to system effectiveness and environmental protection against exhaust and effluent gases (Yang, 2019). Only a formidable preventive maintenance strategy based on timed inspections and also triggered by Key Performance Indicators (KPIs) for equipment, fittings, pipelines and piping systems can help prevent unauthorized leaks, oil spills, equipment or appropriate stop times and, in extreme cases, catastrophic accidents resulting in complete system shutdown (Industrial SkyWorks, 2017; Ratendra & Virender, 2020).

"A formalised set of rules and guidelines to achieve good maintenance practise" is referred to as a "maintenance policy." (Choka, 2013; Rebaiaia & Ait-kadi, 2020). The maintenance policy is viewed as the guiding principle for allocating resources to the many maintenance options available to management. (Choudhury & Sharan, 2011; Saha, Azeem, Hasan, Ali, & Paul, 2021). According to Ghani (2018), tasks for appropriate maintenance Without an appropriate maintenance policy and plan in place, proper maintenance activity will not be feasible because the maintenance policy handles the following maintenance issues;

1) The maintenance, workflow function;
2) To ensure the calibre of the maintenance work, the maintenance standard is given to the maintenance staff;

3) Maintenance staff members gaining the abilities and knowledge necessary to perform maintenance tasks;
4) Records management is effective and systematic to make it easier to find and fix maintenance issues.;
5) Sufficient funding to send out repair workers to carry out maintenance tasks;
6) Whether to tackle the maintenance issue internally or externally; and
7) The issue of whether maintenance procedures adhere to the act's criteria.

Maintenance scholars Lee and Scott (2008) and Harris (2021) highlighted that The selection of the maintenance strategy, the definition of the maintenance standard, and the allocation of maintenance resources are three crucial factors in the development of the maintenance policy, and maintenance activities would not be planned and successfully implemented without an understanding of these elements. A specific maintenance strategy always addresses the efficiency of maintenance in terms of making the best use of resources for maintenance, including money, employees, equipment, installations, tools, and procedures (Choka, 2013; ElKhouly & Fadil, 2019). Since the long-term maintenance strategy addresses all facets of maintenance management and outlines the systems and procedures to be used for the planning and management of maintenance activities, the maintenance policy gives management the ability to plan the long-term maintenance strategy and budget projections (Ghani, 2018).

In relation to this aspect, this study was conducted to obtain a proper understanding of maintenance management practice in Petronas and its integration with maintenance policies and regulations enforced.

2.9 Communication in Maintenance Management

Communication is very vital in every facet of human lives, even more so in the business field. In the oil and gas production and processing sectors, effective communication is an essential element and is often neglected by industry leaders (Nwabueze & Mileski, 2018). The Deepwater Horizon disaster provides a relevant case study on how global businesses can suffer performance losses from ineffective communication as the White House Oil Spill Commission said that the communications failure of BP and its Macondo well partners caused the oil catastrophe in the Gulf of Mexico (Goldenberg, 2010).

In the current global business context, effective internal and external communication has a significant impact on the success of the organization (Stacho, Stachová, Papula, Papulová, & Kohnová, 2019). Some studies have highlighted the importance of effective communication to gain and sustain a competitive advantage (Shonubi & Akintaro, 2016; Chepkemoi, 2021). Nwabueze and Mileski (2018) mentioned that at present, computers and information technologies are as much about communication as they are about calculation. Most researchers see ICT as inclusive of people, software applications, systems and networks. Communications increase the amount of data shared among all field staff, fostering critical time and cost reduction through streamlined processes, maintenance and operations, while linking distant oil and gas sites to the outside world (Alcatel-Lucent, 2013; Arif, Rehman-Shaikh, & Evangelou, 2022).

Improvements in employee safety, plant safety and operational productivity are key priorities for the oil and gas industries. Low-power, reliable and robust communication devices, designed specifically for the oil and gas (upstream and downstream) environment—and secure networks—make these enhancements possible (USAT, 2020). However, the lack of fluency in communication and information has dissuaded maintenance personnel from providing ideas and suggestions for improvement of the maintenance function (Hansson & Backlund, 2003; Colazo, 2021).

The lack of centralized information repository has prohibited the flowing of information between the maintenance personnel resulting in poor teamwork effort and decrease of the organization's growth rate (Singh, Gupta, Kumar, & Khan, 2016; Karuppiah, Sankaranarayanan, & Ali, 2021). In relation to that, the companies that realize that communication is an integral part of their strategic success will not only gain a competitive advantage, but will continue to do so under adverse conditions (Nwabueze & Mileski, 2018). Ghani (2018) expressed that sound communications management, when carefully implemented, will increase integrity, reliability and cost savings. Based on this understanding, the researcher uncovered the communication approach of PIC in their maintenance management system not only with regards to the internal parties as well as the third party vendors in view to understand the influence of preventive management strategy in the company operation.

2.10 Third Party Vendor Roles in Oil and Gas Companies

Outsourcing of maintenance activities to the third parties vendors is now an integral part of an organization's operation process. This involves transferring operation-related activities, in whole or in part, to external parties to implement them. The benefits of using outsource vendors includes reduction of operation cost, improvement in scalability and flexibility, saving in capital investment, improvement of business growth and market expansion plus enhancing customer satisfaction has make this practice became more popular in recent times (Giri & Sarker, 2017; Mahmoudi, Govindan, Shishebori, & Mahmoudi, 2021). According to Chen, Goan and Huang (2011) and Liu, Hou, Yan and Tang (2021) the practice of employing a third-party vendor also will enhance the company's competitiveness. Oil and gas companies will always be confronted with the challenges of providing the appropriate requirements for maintenance solutions. Limited internal capacity to provide specialized maintenance solutions and inefficient internal resources has a resulted to the practice of using external resources for their core business (Etokudoh, Boolaky, & Gungaphul, 2017; Okeke, Warnock-Smith, & Hamzat, 2021).

Maintenance is not considered as the essential activity in oil and gas business operation as it's not related to the functions of exploration, production or refining. Hence, the third-party vendors would be required to fill-in in providing professional maintenance services to the oil industry ((Etokudoh, Boolaky, & Gungaphul, 2017; Okeke, Warnock-Smith, & Hamzat, 2021). There are a number of strengths and weaknesses that need to be carefully evaluated by organizations (Nguyen & Chinh, 2019). Historically, the traditional method of selecting vendors/suppliers has been price-driven. (Asamoah, Annan, & Nyarko, 2012; Kaya & Aycin, 2021), however, recent practice had several criteria such as safety, environments, social, political, client satisfaction, etc.in addition to the basic traditional criteria such as cost, quality, performance in the criteria that need to be consider to rank third-party vendors (Thiruchelvam & Tookey, 2011; Tahriri, Osman, Ali, Yusuff, & Esfandiary, 2008; Haleem, et al., 2021). Based on this argument, it is very important for the company to select the appropriate vendors to complement their commercial operation. As such, multi-criteria decision-making (MCDM) is used to determine the right vendor that meets the multi-criteria requirements set by companies (Nguyen & Chinh, 2019).

Scholars divided MCDM into two categories namely Multi-objective decision making (MODM) and Multi-attribute decision making (MADM) (Kumar, et al., 2017; Abdel-Basset, Gamal, K.Chakrabortty, & Ryan, 2021). MODM methods or tools are used to find multiple trade-off solutions (Penadés-Plà, García-Segura, Martí, & Yepes, 2016; Harirchian, et al., 2021) or can also be associated with problems in which the alternatives have been non-predetermined (Zavadskas, Antucheviciene, & Kar, 2019). MODM uses heuristic algorithms such as Particle Swarm Optimization (PSO); Genetic Algorithm (GA), Simulated Annealing (SA); Ant Colony Optimization (ACO); and Harmony Search (HS) to assist managers in decision making task (Zavala, Nebro, Luna, & Coello Coello, 2013; Kashani, Camp, Rostamian, Azizi, & Gandomi, 2021). Meanwhile, in MADM, the decision making is based on the scoring method that consists of assessing the alternatives using basic arithmetical operations (Penadés-Plà, et al., 2016; Harirchian, et al., 2021). MADM consists of methods such as Analytic Hierarchy Process (AHP), Data Envelopment, Analysis (DEA), Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS), Elimination and Choice Expressing Reality (ELECTRE) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) (Kumar, et al., 2017; Abdel-Basset, Gamal, K.Chakrabortty, & Ryan, 2021).

Gaps exist in literature pertaining to the evaluation of vendors evaluation (Zhang, Li, & Wang, 2020). It is often said that the only certainty about the data involved in real-world decision-making issues is uncertainty for a number of reasons, such as 1) the available data are not always accurate or precise; 2) inadequate linguistic data and information; 3) lack of evidence, subjective and vague assessments of decision makers; and 4) imperfect statistical analysis, etc. (Zavadskas, Antucheviciene, & Kar, 2019). The fundamental issue concerning the sustainability of oil and gas companies lays on the right decision made by the top management relating to the appointment of third-party vendor. Therefore, the study was performed to understand the scenario in maintenance vendors selection for PIC in their refining operation.

2.11 Conclusion of Literature Review

Stakeholders, oil and gas organizations', businesses, and personnel all have a solid understanding of preventive maintenance. However, due to the roles played by the oil and gas sector in accommodating almost all aspects of Malaysian citizen life in terms of business and wellbeing, their awareness of the level of effectiveness and also the best practices of oil and gas maintenance activities still needs to be discovered.

The methods utilized to look for fresh, useful information regarding this study was covered in the following section of the essay. The precise procedures or strategies used to locate, pick, process, and analyze data on preventative maintenance practices in Malaysia's O&G industry are known as the study methodology.

CHAPTER 3

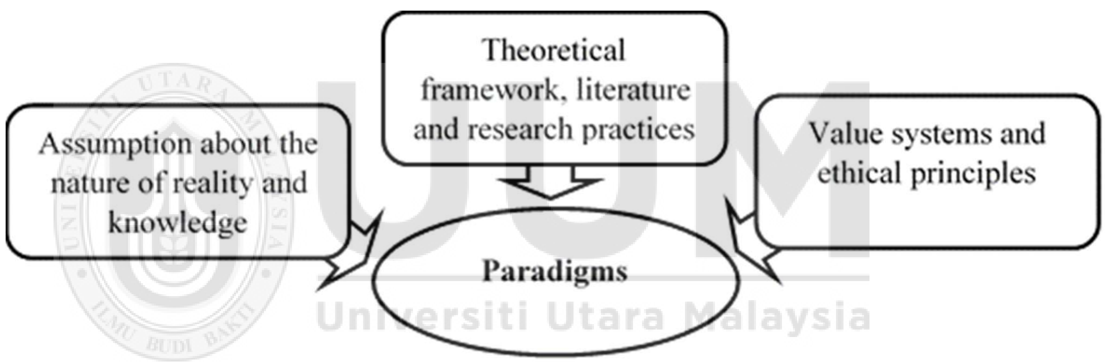
METHODOLOGY

3.0 Introduction

Examining the performance of PIC's preventive maintenance management system is the goal of this study. As a result, this chapter outlines the research design methodology as the study's guiding principles. It does so by discussing research design, data collecting, participant selection, and data management techniques, reliability and validity issues, critical thinking, and data analysis procedures.

The methodology was defined as *"the method used to conduct the study"* (Antwi & Hamza, 2015). In addition, the methodology also referred to *"How should we study the world"* (Chilisa & Kawulich, 2012; Jones, Meckel, & Taylor, 2021). The fundamental methodological question is “How to acquire knowledge?” (Martin, 2017). The research process, or the path of the research, is summarised by the methodology. The research paradigm that will serve as the study's compass is chosen before choosing the methodology. Therefore, philosophical assumptions about the nature of reality, knowledge, and values serve as the foundation for the methodological process. and the theoretical framework that guides how a research subject is understood, interpreted, represented in literature, and studied. (Chilisa & Kawulich, 2012; Jones, Meckel, & Taylor, 2021) refer to the Figure 3.0

Figure 3.0
Factors influencing the choice of paradigm



Note: The factors that will influence the choice of research paradigm. From Selecting a research approach: Paradigm, methodology and methods by Bagele Chilisa and Barbara Kawulich, (2012) and Research Methods by Oswald Jones, Ping Meckel and David Taylor 2021). Copyright 2012 by McGraw Hill and 2021 by Springer.

The qualitative approach used for the study because of the need to understand the phenomenon in the oil and gas industry related to the PM system whereby the data will be collected and analyzed from the related parties such as from the understudy oil and gas employees. Qualitative research has undertaken to explore important issues and disclose key research claims regarding preventative maintenance management practice.

The current study's qualitative methodology explains several facets of the academic tradition in important disciplines like psychology, sociology, anthropology, and history and their procedures, which produce words rather than numerical data as analytical input. The goal for "more insight or a deeper understanding about the phenomenon under investigation," "exploration of experience," and "development of meaning" are cited as the foundation for using qualitative research (Kapoulas & Mitic, 2012; Bednář, Lukáš, & Smékalová, 2021). In summary, the social sciences have long used qualitative research to examine people's experiences, viewpoints, and perceptions. (Jameel, Shaheen, & Majid, 2018).

3.1 Qualitative Research

The qualitative study was developed with some significant contributions, namely. Barney Glaser and Anselm Strauss who published "*The Discovery of Grounded Theory: Strategies for Qualitative Research"* in 1967 and Egon Guba who published "*Toward a Methodology of Naturalistic Inquiry in Educational Evaluation"* in 1978 (Kamal, 2019). According to Glaser and Strauss (1967), the social phenomenon investigation can be used to generate a theory (inductive method) instead of just testing or refining the theory (deductive method) (Tie, Birks, & Francis, 2019). Meanwhile, the work of Guba (1978) insisted on what is going on and what is in a real context with no control and manipulation of what is being explored (Guba, 1981; Kamal, 2019).

The study by Guba also discussed about one of the main characteristics of qualitative study setting which is naturalistic inquiry (McInnes, Peters, Bonney, & Halcomb, 2017). *The term "'naturalistic" describes a paradigm for inquiry, not a method* (Guba, 1981; Kamal, 2019). This study provided an explanation for how naturalistic inquiry can be successfully utilized to understand the issue pertaining to preventive maintenance management in oil and gas companies in Malaysia.

The qualitative paradigm engaged in this study with the aimed to understand the experiences, perspectives, and thoughts of participants in the study (Harwell, 2011). Denzin and Lincoln (1994) defined qualitative research.

"Qualitative research focuses on many methodologies and takes an interpretative, naturalistic approach to the topic at hand. As a result, qualitative researchers focus on studying phenomena in their natural environments while attempting to understand or interpret them in terms of the meanings that individuals assign to them. In order to describe routine and problematic moments and meaning in people's lives, qualitative research examines the use and collection of a variety of empirical materials, including case studies, personal experiences, introspective, life story interviews, observational, historical, interactive, and visual texts."

According to Merriam and Tisdell (2016), a qualitative study approach includes a number of important traits. The study's first goal is to comprehend people's experiences. Second, the researcher is the principal tool for gathering and analyzing data. Thirdly, induction is used to analyze the study data. This means that the researcher will offer explanations in terms of concepts, hypotheses, or theories based on the evidence. Last but not least, a thorough description will be created using a variety of data sources, including documentation, field notes, and interviews.

Qualitative paradigm for the study started off by the researcher by conducting interviews with selected oil and gas maintenance personnel that were identified from PIC as well as the direct observation of maintenance management activities and reporting mechanism. Each sitting in the interview session will consist of only one person. The triangulation for the study achieved by re-measuring of important subject and general documents concerning the maintenance management record activities and function description.

The research is exploratory in nature given that the study on preventive maintenance is a comparatively new phenomenon (Cavana, Delahaye, & Sekaran, 2001; Zikmund, 2003; Kelly, 2008; Sekaran & Bougie, 2019) in oil and gas industry in Malaysia. The study also complied with the ontological research model as "*reality is subjective and multiple as seen by participants in a study*" (Clarke, 2005; Khanam & Daim, 2021). The engagements with personnel from the oil and gas industry gave a proper picture of how people from the supervisory roles such as top management value the maintenance practice against the view of operators regarding the maintenance management system employed in their operation.

3.2 Research Philosophy

The basis of the research relates to the choice of research strategy, formulation of the problem statement, data collection tools, data processing and analysis procedures or also known as the research philosophy – "*a system of the researcher's thought, following which new, reliable knowledge about the research object is obtained"* (Žukauskas, Vveinhardt, & Andriukaitienė, 2018). Chege and Otieno (2020) further stated that the philosophy of research may be defined as a set of beliefs about the nature of the reality being studied and the chosen philosophy depends on the area of study as well as the knowledge under investigation. In the context of business studies in particular, four major research philosophies exist, namely 1) Pragmatism; 2) Positivism; 3) Realism; and 4) Interpretivism (Interpretivist) (Dudovskiy, 2018).

Pragmatism was introduced in the United States in the late 19th century (Maxcy, 2003) from works by philosophers Charles Pierce, William James and John Dewey (Muhaise, Ejiri, Muwanga-Zake, & Kareyo, 2020). The concept of pragmatism was referred to *"Reality is the practical consequences of ideas"* and *"Flux of processes, experiences and practices"*. (Saunders, Lewis, & Thornhill, 2019). Hence, the theories, concepts and ideas only relevant only in support of the action (Elkjaer & Simpson, 2011; Brierley, 2017).

Pragmatists value reality as the practical effects of ideas, and knowledge is valued to enable actions to be achieved successfully (Muhaise, Ejiri, Muwanga-Zake, & Kareyo, 2020). In addition, the central conception of pragmatism can be traced back to its origin Greek word "pragma" which mean "action" (Pansiri, 2005; Xu, Chen, Pearce, Mohammadi, & Pearce, 2021) or "works or deeds (Steyn, Behr, Bisschoff, & Vos, 1986; Landman, Van der Merwe, Pitout, Smith, & Windell, 1990; Hafsa, 2019). Pragmatism was therefore considered to be the philosophical foundation of mixed methods research (Morgan, 2007; Creswell, 2014).

Positivism philosophy emphasized on knowledge creation via research with the natural science setting, collection of data from varied samples of wider perspective and typically using more structured research tools, such as questionnaires containing closed questions (Charumbira, 2013). Its objective is to generate data that can be analysed statistically and whose results can be expressed digitally (Dibb, Simkin, Pride, & Ferrell, 1997; Silva P. M., 2021). Therefore, the results of positivism philosophy are typically objective and reliable because they are based on large representative samples (Chirkov & Anderson, 2018). In other words, a positivist approach emphasizes experimentation, observation, monitoring, measurement, reliability and validity of research processes that imply a quantitative research methodology (Dudovskiy, 2018).

The philosophy of realism research lies in the idea of the independence of reality from the human mind. Thus, the concept of realism can be defined as the hypothesis that reality exists independent of a mind that perceives it (Khanna, 2018). "Reality" in realism refers to what it is in the universe, such as structures, forces, entities, objects, etc. (Maxwell, 2012; Saldana, 2021).

The idea that entities exist no matter how they are perceived or related theories." Realism is most often associated with everything and any position in philosophy when philosophers believe the truth of something (Manee, 2018). This causal situation or also known as "causal tendencies" showcased a different attribute of realism philosophy which appropriate for "cause and effect" research problem (Sobh & Perry, 2006; Pandey, et al., 2021).

Interpretivism philosophy tends to view the world from a much different angle, requiring a different response from researchers (Muhaise, Ejiri, Muwanga-Zake, & Kareyo, 2020). Interpretivist seeks to explore the intricacies of social phenomena through an empathetic understanding of how research subjects perceive the world (Bryman & Bell, 2011; Saunders, Lewis, & Thornhill, 2012; Ramsberg, 2018) based on results from a comparatively small sample (Collis & Hussey, 2014).

Interpretive research enables the deliberate selection of study participants (Moser & Korstjens, 2018) and using open-ended interview method of exploration of complex and subtle phenomena like opinions, feelings and experiences, complex issues that require a detailed understanding of how things work or the production of specific information based on a person's experience or job (Denscombe, 2014; Ramsberg, 2018). The features of the interpretivism philosophy are the most appropriate approach to meet the objectives of existing research.

3.3 Research Design

The purpose of research design is to give a study a suitable structure. Making a selection on the research approach, which specifies how pertinent data will be acquired for a study, is a crucial step in the research design process (Kumar, Leone, Aaker, & Day, 2018). This search will be conducted using a descriptive search methodology. According to Loeb, et al., (2017), the definition of descriptive research methodology better describes situations. For example, this method is intended to address the statement of the research problem ‘what' research topics rather than ‘why'.

The descriptive research approach is different than the analytic approach (McCombes, 2020). It is because a descriptive search method describes what it is when the analytical search method determines the cause and effect of a particular subject. As such, a descriptive research method was the most appropriate method for this research design as this basically involves analyzing the data collected, in terms of sharing demographic data and descriptions, approving and explaining the results of the research. (Formplus blog, 2020).

3.3.1 Population

The right sample size also affects the credibility of qualitative research (Marshall, Cardon, Poddar, & Fontenot, 2013; Lakens, 2021). According to Patton (2002) and Skinner, Edwards, and Smith (2020), there are no restrictions on sample size for qualitative research. Because the pertinent respondents rather than statistical samples were chosen for the study, generalising logic enables the study to be a credential search.(Yin, 1989; 2018). Only qualified respondents, according to Cresswell (2007), will offer reliable data for the study. Given that the focus of qualitative research is to understand a phenomenon from the viewpoint of participants. As a result, it is crucial to choose respondents in areas where the most pertinent data may be gathered (Merriam S. B., 2002; Merriam & Grenier, 2019).

The study population will be based on occupational characteristics that are likely to have related experience, thinking or understanding of the research topic (Mack, Woodsong, MacQueen, Guest, & Namey, 2005). Dodge (2011) and Tabuena, Hilario, and Buenaflor (2021) emphasised the significance of choosing the appropriate "guardian" of knowledge in order to obtain the most accurate information. Because they are the ones who directly engage in maintenance management activities and who prepare reports and data regarding the oil and gas companies' maintenance management system used for the study, the present study identified oil and gas maintenance management personnels such as Managers, Supervisors, and Staff who are attached to Maintenance Department as the "gatekeepers."

3.3.2 Sampling Procedures

Sampling strategies for qualitative methods are generally assumed to be selected in such a way as to produce "*information-rich*" cases (Patton, 2002; Skinner, Edwards, & Smith, 2020). An extensive examination of a person's professional history is regarded as a crucial component of the data for a qualitative inquiry. This method of sampling strategies is known as purposeful sampling strategies (Palinkas, et al., 2015). It is beneficial to comprehend how participants view their involvement in maintenance management process (Ghani, 2018).

Purposeful sampling involves "*identifying and selecting individuals or groups of individuals who are particularly familiar with or have experience with a phenomenon of interest*" (Cresswell & Plano Clark, 2011). Besides bringing knowledge and experience, Bernard (2002) and Andrade (2020) stated that purposeful sampling strategies also stressed the importance of availability and willingness to participate in the study, as well as the capacity to convey experiences and opinions in an articulated, expressive and thoughtful manner.

The study's intended sample participants, who complied with the requirements, are those who work in the maintenance department.. These are the personnel identified that should be able to provide saturation of information/data required (i.e., obtain a full understanding by continuing to sample until new background information is available) for the study.

3.3.3 Data Collection Strategies

In the current qualitative research, data and information were gathered in many ways such as from interviews, case studies, observation, and so on to explore many perspectives of a topic of interest (Kaplan & Maxwell, 2006; Harwell, 2011). According to Cresswell (2007), qualitative methods can more effectively measure a complicated feature like maintenance than quantitative models. Merriam (2002) asserts that the types of questions addressed are crucial in qualitative research. When researching what is happening, as opposed to the subject, the questions "what," "why," and "how" are frequently used (Kaplan & Maxwell, 2006; Guest, Namey, & Mitchell, 2013). Marshall and Rossman (1995) stated that qualitative research is devised fulfill the following agenda.

1) understand processes in the study environment;
2) illustrate ailing phenomena occurred;
3) understand differences between implemented policies and theories; and
4) uncover unspecified contextual variables.

Adams and Cox (2008) and Tag, Goncalves, Webber, Koval and Kostakos (2021) stated that these questions have also been selected to provide an in-depth understanding. Creswell (2014) went on to say that qualitative research was carried out in order to gain a complicated and in-depth understanding of the problem. Based on this comprehension, the qualitative techniques used in this study, which include;

- Interviews with 10 people who are familiar with the maintenance work process were conducted in accordance with the interview schedule. Unstructured questionnaires to open-ended questions were utilized in this semi-structured interview.

- Direct observations were conducted that includes all individuals, both those who participated and those who did not, ethnographic research, video or any other photographic records that allowed researchers to capture and comprehend the context in which activities and events take place.

Golafshani (2003) and Deacon, Pickering, Golding and Murdock (2021) mentioned in his study that the quality of the qualitative study is dependent upon its validity and reliability meanwhile Lincoln and Guba (1985) and Saldana (2021) concluded that in qualitative studies, validity was replaced by the term trustworthiness, quality or rigor and the term of dependability was used instead of reliability. The researcher can use various approaches in qualitative studies to address the validity issue such as trustworthiness, quality or rigor and in terms of reliability, it can be referred to dependability (Nha, 2021). As mentioned by Yin (2015) the most popular method is the triangulation of information from different sources of data.

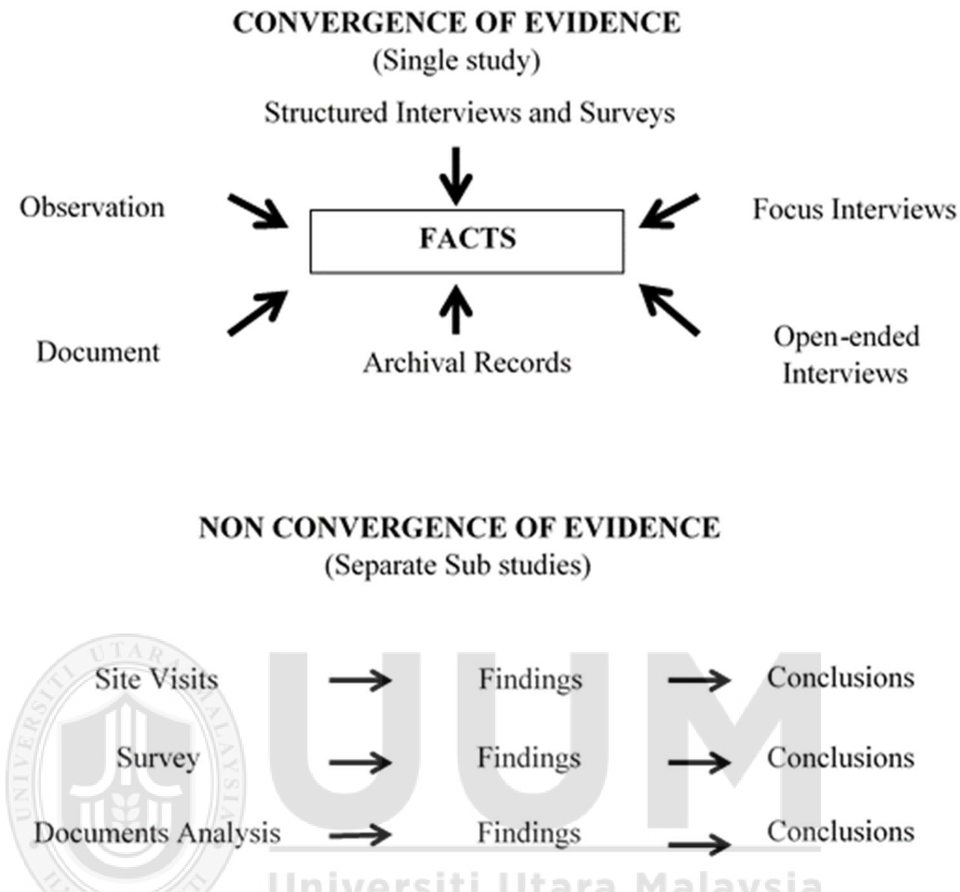
The use of triangulation of information is due to the reason that *"triangulation strengthens a study by combining methods"* (Patton, 2002; Skinner, Edwards, & Smith, 2020).Yin (2015) stated that triangulation can be divided into two condition;

1) The convergence of evidence - single study; and
2) The non-convergence of evidence - separate sub-studies

Both conditioned as define in figure 3.1 below:

Figure 3.1:

Convergence and Non-convergence of Multiple Sources of Evidence



Note: The triangulation of evidence in qualitative research. From Case Study Research: Design and Methods, 6th Edition" by Robert K. Yin (2018). Copyright 2018 by Sage Publications.

Data collected from multiple sources have to be converge or accumulated to warrant it validity and reliability (Schwandt, 2007; Richard, et al., 2020). On the other hand, non-converge evidence will address different facts or finding of the study (Yin, 2018). The evaluation of the research that was backed by the validity or can referred to as trustworthiness, quality or rigor of the study will ensure the credibility of the research and at the same time, the researcher can be more confident of its findings (Guion, 2002; Fisher, Milane, Sullivan, & Tett, 2020).

3.4 Interview Design

To comprehend maintenance people, an interviewing technique was applied. Qualitative interviews can be divided into a few unstructured, semi-structured, and structured categories, according to DiCicco-Bloom and Crabtree (2006) and Looy (2021). Unstructured and semi-structured data were the study's primary emphasis because structured interviews typically produce quantitative data (Henriksen, Englander, & Nordgaard, 2021)

Informal interviews' purpose is to reassure participants that their responses are not being evaluated. Establish protocols for the remaining interview sessions as well, as the researcher will not be aware of all the study-related concerns in advance (Hannabuss, 1996; Qu & Dumay, 2011; Looy, 2021). Establishing rapport between the interviewer and the subject of the interview is another goal of unstructured or open-ended interviewing, which aims to provide access to the subject's perspective (Fontana & Frey, 1994; Hannabuss, 1996; Qu & Dumay, 2011; Looy, 2021).

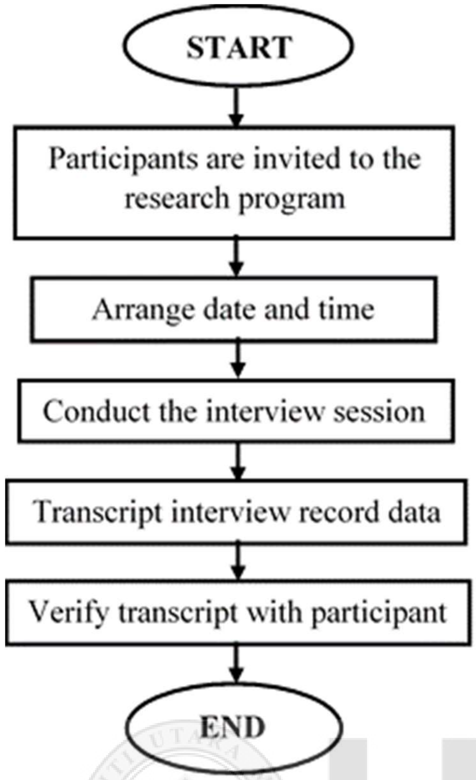
The current study made use of a semi-structured interview that was focused on the key study issues before the interview was actually done (Knox & Burkard, 2009; Qu & Dumay, 2011; Looy, 2021). However, the interviewer must maintain his openness and adaptability so that he can delve deeper into the respondent's story (DiCicco-Bloom & Crabtree, 2006). Significant attention is needed before, during, and after the interview session in terms of how the questions are posed and interpreted, according to Qu and Dumay (2011) and Looy (2021). The fundamental aspect of human communication that enables the researcher to manage the rhythm and modify the questioning approach will result in the optimal response from the respondents (Hannabuss, 1996; Jackson, Mohr, & Kindahl, 2021).

An understanding of the maintenance work process and the job description for oil and gas maintenance staff served as the foundation for the study's questions. In addition, some questions were added or removed from the interview for select interviewees, and the language of the questions was changed. The 2005 book "Qualitative Research Methods: A Data Collector's Field Guide" by Natasha Mack, Cynthia Woodsong, Kathleen M. MacQueen, Greg Guest, and Emily Namey was used in this study to conduct interviews.

The researchers made contact with the interview subjects through email to schedule appointments and provided a brief explanation of the study's goals, methods, and expectations for participants, including the time commitment necessary for participation. In order for respondents to feel confident that their participation in the study is voluntary and that they can stop at any time, it is imperative that they know this. Additionally, respondents are confident that their privacy was protected and that they were informed of the study's risks and benefits.

This is consistent with the ethics of research, which is a very important part of qualitative research. The well-being of research participants should be the top priority, as research itself is always a minor issue (Mack, Woodsong, MacQueen, Guest & Namey, 2005). In other words, if there is an option between harming a participant and harming the research, then the research is sacrificed. Figure 3.2 demonstrates the interview process for this study.

Figure 3.2
Procedure for interview session



Note: The procedure in conducting interview for qualitative study. From Qualitative Research Methods: A Data Collector's Field Guide" by Natasha Mack, Cynthiawoodsong, Kathleen M.Macqueen, Greg Guest, Emily Namey (2005). Copyright 2005 by Family Health International

The question for the present research were adapted from the study of Odeyinde (2008), Dodge (2011) and selected oil and gas portal which will be categorized into 6 parts and each question were illustrated as the key that should be asked as part of the interview session.

Part 1: Introduction and Demographic Information.

This section describes the description and intent of the study. The researcher communicated with the participant and be sure to stay close to the subject. Basic factual/demographic questions to contextualize participants' answers. These vary according to the subject of the interview, but often include the name, age, work experience and title or role of the job.

1. Can you tell me about yourself?
2. How long have you been in your organization?
3. What is your experience with Maintenance Management?
4. What technical training do you receive?
5. How would you describe yourselves as maintenance personnel?

Part 2: Research Question No.1.

How does your organization's maintenance management system work? The aim is to obtain all information relating to the planning of work, the maintenance process and the problem of maintenance activities. This section also seeks any information related to understanding maintenance activities, maintenance prevention activities, including corrective actions. This section also covers the observing function for maintenance personnel.

1. How do you set up your work activities?
2. Can you describe what you do in this organization?
3. What are your thoughts on the work process in this company, particularly in maintenance management activities?
4. What does maintenance mean to you?
5. What should be done to prevent problems?
6. Are you aware of schedule, corrective and preventive maintenance?
7. How many times were maintenance activities postponed or cancelled and why?

8. Are you prepared to make observations or inspections with no instructions from your supervisor? If not, why?
9. Do you have any thoughts on the lack of maintenance monitoring activities?
10. What are your suggestions or expectations for improvement in maintenance planning?

Part 3: Research Question No. 2.

What policies have been applied to the vendor selection process of the company? The objective is to seek out any information relating to the understanding of the process of selecting appropriate suppliers that comply with these regulations extends across the company's entire supply chain. An organization that does business with non-compliant vendors exposes itself to fines, legal battles, and loss of confidence with consumers.

1. What are your company's procurement needs?
2. Who will evaluate potential vendors during the vendor selection process?
3. Do you need a local or offshore provider?
4. What criteria would you follow to determine the appropriate vendors?
5. When is the cheapest bidder not the right one?
6. What would you do to conduct research on new vendors?
7. Based on your experience, which is the most effective way to monitor vendor performance?
8. What is your procurement risk management strategy for untrustworthy vendors?
9. Are there challenges related to past trends and what are your proposed action plans?
10. How are you managing your relationship with your vendor?

Part 4: Research Question No. 3.

How is preventive maintenance performed within this organization to ensure high efficiency? The objective is to obtain all information concerning preventive maintenance activities and the company's performance.

1. What is your process for planning preventive maintenance schedules?
2. Is preventive maintenance expensive?
3. Have you ever had to choose one maintenance project over another due to budget limitations?
4. What's your process for evaluating and updating maintenance procedures?
5. How you can be sure that you run a successful preventive maintenance program?
6. In your opinion, is the budget allocated to tools and equipment acquisition sufficient?
7. Is suitable or advanced maintenance equipment available?
8. Do you think the preventive maintenance strategy can make the equipment and the system more efficient?

Part 5: Research Question No.4.

Why preventive maintenance is the chosen method in your organization? There are many ways in which preventative maintenance can help the company such as reducing overall maintenance costs, ensuring business continuity, promote health & safety, protect the environment and prevent lost production output. The aim is to obtain the feedback on the main reasons for preventive maintenance application.

1. Is preventive maintenance costly?
2. Who is responsible for performing preventive maintenance tasks?

3. What can be included as the elements of a good preventive maintenance checklist?
4. What percentage of task checklists and preventive maintenance inspections are audited to ensure they are complete?
5. Why is preventive maintenance preferable to other types of maintenance strategies?
6. What are the problems in Preventive Maintenance application?

Part 5: Closing of the interview session.

It is crucial that precise data was acquired during interview sessions and that participants completed questionnaires honestly in order to establish successful research conclusions. Upon completion of the research study, additional questions to prompt open suggestions from participants to enhance or change specific aspects of the current situation or procedures will also provide crucial information to formulate recommendations for improvement.

1. Are there any further points you would like to make or suggestions that I might have missed?

All result of the interviews were recorded and written during the interview sessions and later were transcribed to form a complete document and were shown to the corresponding interview participant for their approval. This exercise is very important to the researcher in order to ensure the accuracy of the answer received or the information produced.

3.5 Observation and Monitoring Activities

Qualitative studies typically involved "participant observation" in which the researcher was an active participant in the study (Kaplan & Maxwell, 2006). Observation is considered the best technique for obtaining first-hand insight when the interview participants are unable to explain the phenomenon being researched (Merriam & Tisdell, 2016). "*The researcher engaged in participant observation tries to learn what life is like for an 'insider' while remaining, inevitably, an 'outsider'*" (Mack,et al., 2005). The purpose of observing maintenance activities is to gain an understanding of the work process performed by maintenance personnel. Observation and monitoring have been multifaceted such as;

1. How do they work (individuals / teams)?
2. How are they communicating with others?
3. How do they respond to maintenance issues?
4. How do they document everything?
5. How are maintenance activities carried out?

The result of the observation activities was recorded in a similar manner as the interview procedure. Nonetheless, the subtle elements of the observation will be documented in the following way. (Refer to Table 3.0):

Table 3.0

Maintenance Observation Activity List

No.	Description	Remarks
1.	Date and Time of Observation	
2.	Type of Maintenance Activity	
3.	Type of Observation	

4. Meeting Point / Location

5. Document Reference

6. Representative

7. Maintenance Person in Charge

8. Duration of Observation

9. Observation Status

10. Other Remarks

Note: The checklist for observation work in data collection for qualitative study. From Highway Maintenance Management: A Study Of Lebuhraya Damansara-Puchong (LDP) by Arif Ghani (2018). Copyright 2018 by Universiti Utara Malaysia.

This kind of research is aimed at gathering more reliable information. In other words, researchers can capture information on what participants are doing rather than what they say they are doing. The recording of information depends in large part on the situation of the search. Field notes are usually kept, and tape recorders and video recorders can sometimes be used. Regardless of how the information is stored, it is important to be detailed and design a system that allows easy retrieval of the information (MacDonald & Headlam, 2011; Chauke, Ramohlale, Chauke, & Motlhaka, 2021).

Using the methodology and work instructions, the maintenance workflow was examined during observation and monitoring operations. As a result, the researcher collaborated with the maintenance team to follow and take part in the identified and chosen maintenance work activities that were thought to be pertinent for the study.

3.6 Maintenance Records Review

Document review is a systematic process to review or evaluate documents, whether printed or electronic (electronic or online). As with other analytical methods used in qualitative research, the literature review requires that data be reviewed and interpreted in order to acquire empirical significance, understanding and knowledge (Corbin & Strauss, 2008; Wright, Gabbay, & May, 2021). Documents are comprised of text (words) and images that have been saved without the participation of a researcher (Bowen, 2009; Hayes, 2021). The analytical procedure is to find, select, evaluate (understand) and summarise the data contained in the documents. Document review results in data extracts, quotes or whole passages, which are then organized into broad themes, categories and case examples using content analysis (Labuschagne, 2003; Abeysiriwardana & Jayasinghe-Mudalige, 2021).

The current study reviewed at the maintenance record to acquire data on the maintenance inspection activities, which, according to Ghani (2018), will include identifying the work that needs to be done, planning, coordinating, and scheduling that work, and actually finishing it.

Information about each maintenance employee's specific work restrictions was included in the assessment process. Here, it was confirmed that the written literature and the actual process compared. This increased the triangular data analysis's accuracy. The literature evaluation comprises classifying information into themes, much like how interview transcripts are analysed, according to Bowen (2009) and Bell and Waters (2018). The document was scored and recorded using a grid or rubric. Organisations can use text analysis to transform massive amounts of created text into insightful summaries that enhance evidence-based decision-making (Gandomi & Haider, 2015; Saura, 2021).

The document review serves many functions to help the researcher obtain more comprehensive information on the research question. Bowen (2009) and Bell and Waters (2018) identified the following roles in the document analysis.

a. The materials might provide details on the environment in which research participants operate. Information about the past is provided by documentation and supporting evidence. This knowledge and information can help researchers comprehend the antecedents of certain issues and may reveal circumstances that have an impact on current issues or conditions.

b. The information contained in the materials may suggest questions to be asked during the interview phase and situations to be observed during the research observation activities. Interview data helped to target participant observation activities, document analysis produced new interview questions, and participant observation assisted in document collection, according to Goldstein and Reiboldt (2004) and Söderlund and Pemsel (2021).

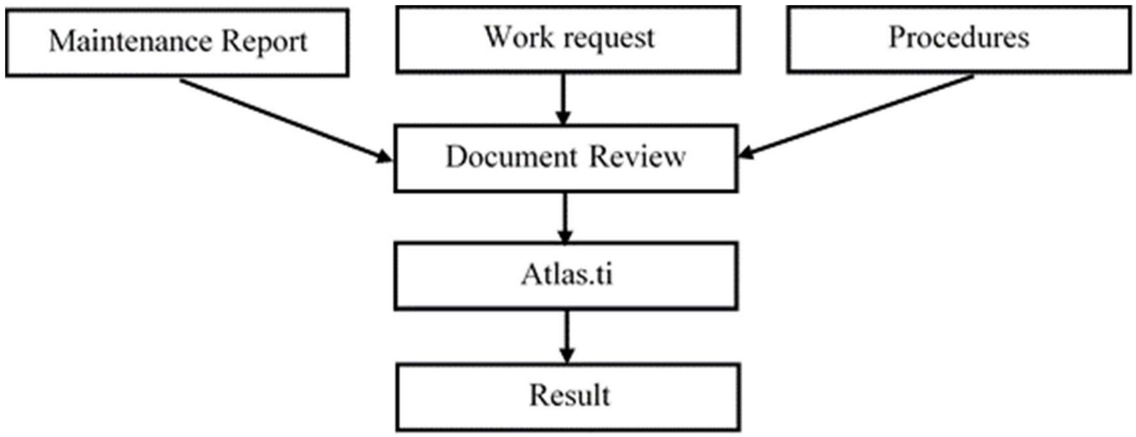
c. The literature review offers more research details. The knowledge base may benefit from the information and insight that come from materials. When done properly, document analysis can lead to new ideas and research paths for any topic or study, produce standards for policy and practise, give proof of an effect, and create new knowledge (Snyder, 2019).

d. Documentation makes it possible to track progress and change. If there are numerous draughts of a certain document, the researcher might compare them to spot changes. Significant developments within a project may be reflected in even minor changes to the project. Academics will be able to note any changes in findings if specific practises or policies are altered in this way..

e. Records may be examined to confirm information from other sources or to support findings. The investigator should look into the matter further if the documentation evidence is contradictory rather than proven. Readers of the study report are typically more assured about the trustworthiness (credibility) of the findings when data from many sources converge. (Angrosino & Mays de Pérez, 2000; Frost, 2021).

In this study, a simple process flow was applied by gathering all related text files, going through each one one at a time, and compiling the results in a folder. Later, the software Atlas.ti helped with the process of disassembling all the data that had been acquired in a file, as depicted in Figure 3.3. The data gathered from these three sources—maintenance reports, work order reports, and procedures—is what the analytical process is based on. It is crucial that this data back up this study's conclusions.

Figure 3.3
Document review process flow

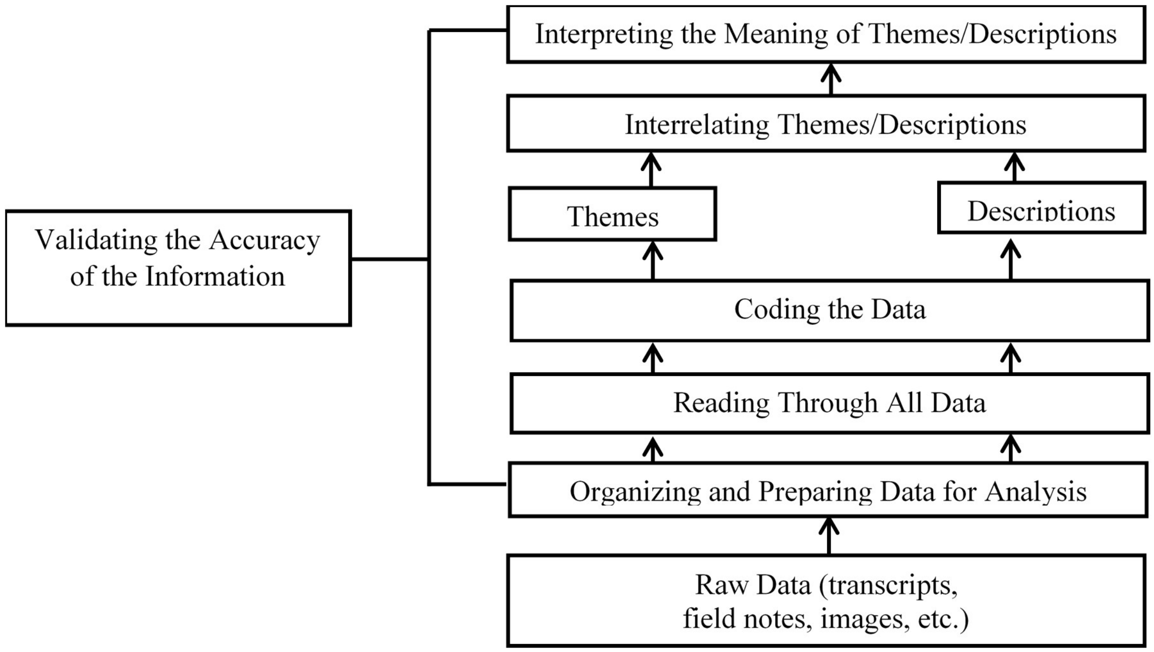


Note: The flow of documentation review in maintenance study. From Development of Criticality Based Maintenance Strategy in Asset Management Perspective by Arttu Partanen (2022). Copyright 2022 by LUT University

3.7 Qualitative Research Data analysis

The analysis of the study data for the qualitative methodology of this study were guided by the six-step data analysis adapted from Creswell (2014). The analysis is performed in a linear and hierarchical order, not in a static order, as shown in Figure 3.4.

Figure 3.4:
Six steps of data analysis in qualitative research



Note: The six steps in conducting data analysis for qualitative study. From Research design: qualitative, quantitative, and mixed methods approaches (4th ed.)" by John W. Cresswell (2014). Copyright 2014 by Sage Publication Inc.

Step 1: Arrange and prepare data for analysis.

All information gathered from the audio recordings and interview document were transferred into a single transcript for each respondent.

Step 2: Read through all data.

Break out the common themes/topics in the data in Step 1 to create the manifestation of the thoughts and information provided by the participants.

Step 3: Data Encoding.

The researcher organized all the data into categories and label all the data provided according to the information provided during the interview session to initiate the data analysis process.

Phase 4: Themes and Descriptions.

The coding procedure was used to create categories for analysis as well as a common topic, description, or thematic region of the field or participant. The researcher then creates codes for all of the data and conducts an analysis of every category in a broad description.

Step 5: Interlinked themes/descriptions.

Qualitative narration were presented in the form of a thematic description. This particular stage brought together all the conclusions that logically followed from the interviewees' responses and integrated them into a narrative format.

Step 6: ***Interpreting the Meaning of Themes/Descriptions.***

Due to its connection to the lesson discovered by the researcher, this step is regarded as the "essence" of the studies conducted by Lincoln and Guba (1985) and Saldana (2021). The researcher will contribute to the complete knowledge of all the data that have been obtained during the sessions if they monitor, investigate, and comprehend the stories of the participants while conducting the interviews.

However, the researcher must be aware that not all data will precisely fit into one group, category of theme, or description. As a result, the report of all findings must cross multiple categories to provide a better understanding and interpretation (Cassell, Symon, Buehring, & Johnson, 2006; Bouncken, Qiu, Sinkovics, & Kürsten, 2021). Using data analysis techniques, the Atlas.ti application was utilised to illustrate how maintenance practises and the efficiency of the oil and gas maintenance management system are related.

3.8 Conclusion of methodology

The current study engaged triangulation method to explain the similarities of phenomenon from the various study methods namely interview, observation and documents review (Golafshani, 2003; Deacon, Pickering, Golding, & Murdock, 2021). Denzin (1978) and (Kasirye, 2021) define triangulation as "the combination of methodologies for investigating the same phenomenon". Hence, the study used a qualitative methodology since the researcher wanted to comprehend the phenomena that occurred in PIC's practises for managing oil and gas maintenance. The chosen research methodology is tasked with explaining and comprehending the significance of the primary topics in the lives of the study participants (Kvale & Brickmann, 2009; Saldana, 2021). The relationship between the elements of maintenance practises and the effectiveness of the oil maintenance management system was explained in terms of data analysis using the Atlas.ti software.

CHAPTER FOUR

DATA ANALYSIS AND RESULT

4.1 Introduction

The interview process, including the procedures and observations, are examined based on these categories and found patterns for the full research in this section, which will analyse the data and be followed by discussion of the research's findings. In-person interviews were the primary technique, with the goal of obtaining participants' most accurate responses to all research questions.

According to the participants' preferences for comfort and convenience, interviews were held there. Creating questionnaires from which the participant's profile can be derived is an element of the interview sessions. An overview of the participant group's characteristics is also provided during the interview process.

With the help of Atlas.ti, a presentation of the research findings was created from the interview sessions to include examples of the raw data collected, a discussion of the themes created from the data, and an explanation of how the findings relate to the main research construct.

Last but not least, the results of this study are anticipated to offer a roadmap for effectively implementing PIC maintenance management practises and enhancing continuous improvement to pursue excellence in PIC's products, services, and operations.

4.2 Research work process

Due to the nature of the qualitative research approach used in the study, gathering data for the research study requires a systematic process that concentrates on objectives and gathers information from a variety of sources, including interviews, observations, and document reviews. These sources are then analysed so that researchers can draw conclusions from the study's findings. In order to achieve triangulation of findings, these three methods were chosen because of their interrelated factors. Interview data helped to focus on particular participant observation activities, and document analysis helped to produce new interview questions.

The transcripts of the interviews were sent to the interviewees to verify what was said during the interviews and to ensure that the written words in the transcript were those said by the interviewees in order to ensure that the information and data captured in the research study are valid and in an ethical manner. Once the contents of the transcript reflected what the interviewees meant, they signed it.

4.3 Analysis Using ATLAS.ti

All data from interviews and observations are uploaded to ATLAS.ti. Then, the quotations are created, and a coding system is applied. The codes are organised into groups based on topics, much like the outcomes of the manual method. A pattern developed from the relationships between groups in the network. A new code of sustainable competitive advantage is subsequently being developed as a result of combining the flows of all the networks.

4.3.1 Generation of Quotations

There are six major entities in ATLAS.ti, consisting of Documents, Quotations, Codes, Memos, Networks and Links. A project entitled "Preventive Maintenance in PIC" is created. The objective is to code all files uploaded to ATLAS.ti and establish the link and hyperlink among the codes and quotations and subsequently develop a concept or theme. Transcripts from the interviews and notes from observations are uploaded to ATLAS.ti and these data is categorized as Document entity in the software. The formats of data are in the form of pdf or format using MS Office applications.

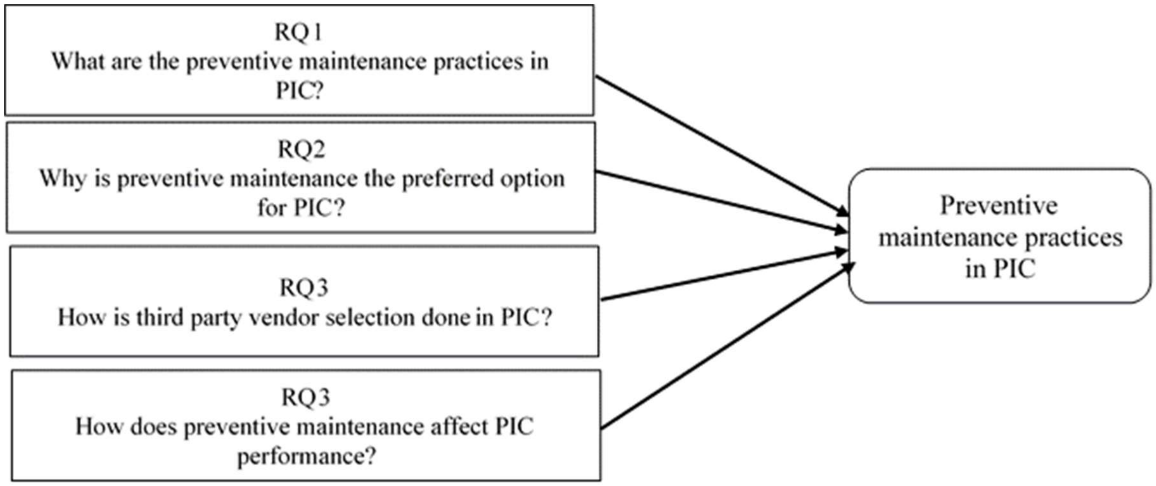
4.3.2 Generation of Codes

Each quotation is assigned codes. Codes are a simple statement representing a meaning to a group of quotations. In this case study, codes are developed and related to RQs. From the findings, under the category of RQ1, RQ2, RQ3 and RQ4, further codes are created to arrive at the groups of codes in explaining the preventive maintenance practices in PIC.

4.3.3 Generation of Network

Some quotations could be assigned to more than one code on the basis this quotation is related to other codes that equally related that may explain other RQs. Figure 4.1 illustrates the formation of the networks that explain the preventive maintenance practices in PIC. Networks were generated from a group of codes that seeks to answer each RQs.

Figure 4.1:
Formation of RQs network



4.4 Data Analysis and Overview of the Results

On the basis of the Head of Division of Maintenance Management's permission beginning in August 2022, the qualitative data was gathered in a matter of two months. As was already noted, the list of employees was chosen based on their roles in the Maintenance Management Division. The head of the maintenance management division received the invitation. The interviews were done based on the staff members' availability in accordance with their time, date, and location after he identified the members of his team who would be taking part in the study. Ten maintenance management employees, all of whom are supervisory level employees under the Maintenance Management Division, took part in the study. This figure corresponded to 50% of the department's relevant employees. Only 10 people were involved in total because many of them had issues that could not be avoided. The typical excuses cited were meetings, time constraints, and condensed work inspection schedules. The participants were given the study's goals, questions to ask, and a glossary of words before each interview.

4.4.1 Participants Demographic

The results of the researcher's interviews are discussed in this section. Staff from the PIC maintenance management team participated in ten sessions of the sessions. The results of the interviews clarified how each respondent from the unit of analysis was referred to. The unit of analysis and respondent lists interviewed to fulfil the objectives of this study are described in Table 4.1. The identification displayed in the 'Respondent' column in the table allows you to identify the respondent.

Table 4.1
Unit of analysis and respondents

Unit of analysis	Respondent	Gender
Maintenance Management Staff (Total = 10)	Respondent 1	Male
	Respondent 2	Male
	Respondent 3	Male
	Respondent 4	Male
	Respondent 5	Male
	Respondent 6	Male
	Respondent 7	Male
	Respondent 8	Male
	Respondent 9	Female
	Respondent 10	Male

4.4.1.1 Profile of Participants

Table 4.2 below provides a profile of the participants who use the Atlas.ti applications. Nearly all of the interviewees offered their full cooperation. They desired to make a significant contribution and have an impact on the study's conclusion. The study's participants intended it to be a way of describing what is going on in their organization.

With all the data collected, the study can be broken down into the following categories: participants; years of employment; technical education level; and respondents' self-descriptions as maintenance personnel.

Table 4.2
Profile of participants

No	Category	Description	Total
1.	Number of years with the company	More than 11 years	7
		6 to 10 years	3
		Less than 5 years	0
2.	Technical education level	No formal technical education	0
		Certificates	0
		Diploma	0
		Degree	10
3.	Describe yourself as a maintenance personnel	Committed to work	8
		Executing orders	2

4.4.1.1.1 Number of years with the company

It was observed that all 10 participants cooperated fully and gave thoughtful answers during the interview sessions. We can plainly see from the data analysis results in participant profiles, as given in Table 4.2, that this is overcrowded because 70% of the employees have worked for the organisation for more than 11 years. On the other hand, no employee joined the company in less than 10 years, and 30% of the workforce has 10 years of service.

The significant amount of time spent in the maintenance management profession also suggests a high level of work experience. Particularly in the area of oil and gas maintenance, their higher level of job knowledge may provide them an advantage in carrying out their maintenance duties. The importance of each employee's prior oil and gas maintenance experience cannot be overstated.

4.4.1.1.2 Technical education level

The participants' degrees of technical education in the field of maintenance are depicted in Figure 4.2. 100% of the personnel have a bachelor's degree or higher, according to the degrees of technical education.

This study discovered that the employees in this Petronas plant were skilled professionals, which will help ensure a high-quality, efficient maintenance process..

4.4.1.1.3 Describe yourself as a maintenance personnel

The participants were split into two groups when characterising themselves as maintenance employees, as shown in Table 4.2. Eighty percent of the respondents said they are dedicated to providing the best service possible to highway users, while twenty percent said they are only carrying out maintenance work orders.

In conclusion, the importance of maintenance is essential for ensuring that the finest service is provided to facility users. The maintenance work completed must always be taken into consideration as the difference between life and death for facility users. Therefore, all maintenance workers must understand that whatever they do has a significant impact on other people's well-being and the overall economy of the country.

4.5 Themes and Significant Statements

The maintenance management department staff's input in PIC led to the coding of four primary themes and the need for more information. preventative maintenance techniques, preferred options for downstream operators' maintenance strategies, choosing third-party vendors, and the impact of preventative maintenance on PIC performance are the themes coded in the Atlas.ti programme.

4.5.1 Theme No. 1: Preventive maintenance practices

The research's Research Question 1, which asks What are the preventive maintenance practices on PIC, is directly related to Theme No. 1 as stated in Chapter 1. The research results are relevant to maintenance management practices, notably in terms of planning tasks for the Maintenance Management Division's maintenance projects and activities. The findings synopsis shown in Table 4.3. As evidence and input for data analysis, pertinent information gleaned from interview sessions, observations, and document reviews was taken into consideration. According to the themes and their key assertions, Table 4.2 presents a separate breakdown of the interviews' responses to this study topic.

Table 4.2
Significant Statements and Interpretative Meaning for Preventive Maintenance Practices

Significant Statements	Interpretative Meaning
Work activities	
Maintenance Facility Work Process	
▪ We have a specific process for maintenance which we call MFWP (maintaining the work process of the facility)... They will create a work order and from that work order they will share it with our team for maintenance to troubleshoot or repair. … From there, we will see what the actual condition is, that is to say that we design our activity according to what is necessary to ensure that the equipment does not break down (Respondent 1)	PIC dedicated maintenance facility work process
▪ We will follow the schedule set by the division. This is because the work schedule is already being streamlined in the Maintain Facility Work Process. This is related to daily activities. (Respondent 2)	
▪ Our work activities will be based on our planner. Any inputs on work or as such will be shared with our planner. We normally just follow plan as per schedule (Respondent 5)	
Daily planning	
▪ …… in our maintenance, we have every grade, for example we have rotating, there is electrical, there is static, there is instrument right, so in each grade we will have engineers for example, which means we managed our work based on the requirement stated in our daily planning. (Respondent 3)	Maintenance work activities based on daily planning
▪ In terms of the work planning, at the beginning of the year, we have a document called Maintenance Strategy. Based on this document, we will break-it into more details work execution. (Respondent 4)	
Petronas Maintenance Management System (PMMS)	

▪ I use Maintenance PMMS to keep track of progress, materials and supply requirements. This has been such an effective tool for keeping my work organized (Respondent 6)	Petronas dedicated maintenance management system
<u>Maintenance Coordinator</u> ▪ Our function also known as Work Maintenance Coordinator. So, we will coordinate of the maintenance work accordingly. (Respondent 7) ▪ In terms of planning, I normally will contribute in terms of inputs for the planner to be incorporated in our Work Plan. The finalize plan will be completed by work coordinator. (Respondent 8) ▪ I will follow the work instruction from Work Coordinator. However, before that, I will give all the work requirements, work activities for the Work Coordinator, then they will incorporate all my inputs in the final work list. (Respondent 9) ▪ Our department will be given Maintenance Strategy at the beginning of the year and we just plan our work from there and also the planner from our Work Maintenance Coordinator. (Respondent 10)	Maintenance Work Coordinator planned the work activities
Work description <u>Asset protector</u> ▪ I have to make sure the company's assets are in good condition. (Respondent 1)	Ensuring the asset in useable condition
<u>Service provider</u> ▪ I provide a service to ensure that Petronas assets are in the best condition. (Respondent 2)	Providing service to ensure the asset is in proper condition
<u>Maintenance personnel</u> ▪ I am responsible for electrical maintenance. (Respondent 3) ▪ As static maintenance personnel, I am required to conduct routine equipment maintenance…. (Respondent 5) ▪ As a rotating equipment personnel, I am responsible for preventive and corrective maintenance activities for rotating equipment… (Respondent 6) ▪ We will plan the work required to ensure smooth operation without any shutdown. So, we will coordinate all the required maintenance task as some of the task requires more planning time than others. (Respondent 7) ▪ I will ensure that all the task be completed according to the requirements as my work is part of the bigger project. (Respondent 8) ▪ I will look after the work being carried out according to the work requirements. Make sure all the checklist being followed accordingly. (Respondent 9)	Performing duties as maintenance staff

- I am in-charge of static maintenance provide day to day asset integrity support. Make sure that all maintenance planning and preparation activities being carried out through detailed work definition. (Respondent 10)

Controller and monitor

- We control and monitor conditions including temperature, pressure, and fluid levels in processing facilities. (Respondent 4)

Monitoring and controlling the work performed

PIC work process opinion

<u>Systematic</u>

- It's really smooth because it's systematic, everything has flowed okay. (Respondent 3)
- At the moment it is been run smoothly and all the plan are being adhere accordingly. (Respondent 7)
- As part of maintenance team, I am proud to say that we are doing a good job at the moment, therefore for me, the work process is good for the organization. (Respondent 8)

Maintenance work being handled in a systematic way

<u>Structured</u>

- Everyone has their own roles. Right now, we are in a good situation for me. (Respondent 2)
- The work processes are fine at the moment. All we need to do is to improve the quality of work, and what is necessary, our men at the same time we have to teach. (Respondent 4)

Maintenance tasks were conducted in a structured manner

Maintenance definition

<u>Ensuring asset in good condition</u>

- Maintenance is to ensure that all assets are in good condition… (Respondent 1)
- …. efforts taken to keep the condition and performance of a machine or asset always like the condition and performance of the machine/asset when it is still new. (Respondent 2)
- keeping the assets in working condition and to restore the assets to working condition once its failed. (Respondent 7)
- Maintenance is to ensure all the assets, system, tools and equipment is in running state (Respondent 9)

Good condition asset

<u>Maintenance work activities</u>

- This maintenance is related to the activities we do. (Respondent 3)

Set of maintenance activities

<u>Ensure business continuous operation</u>

- A very important function in ensuring business can be conducted as usual. (Respondent 4)

▪ Maintenance is being performed to ensure the continuity of the business operation. (Respondent 8)	Maintenance is effort to ensure business sustainability
<u>Protecting or restoring equipment</u>	
▪ Maintenance is the practice of protecting or restoring equipment in order to maintain function and integrity. (Respondent 5) ▪ maintenance is ensuring the availability and integrity of the installed systems and equipment in terms of safety and reliability. (Respondent 6)	Maintenance is referred to protecting and restoring asset tasks
Problem prevention initiative	
<u>Comprehensive maintenance program</u>	
▪ We always need to have a comprehensive maintenance program to prevent any problem. (Respondent 1) ▪ To prevent any problem, proper planning needs to be put in place. (Respondent 7)	Availability of a comprehensive maintenance program
<u>Equipment reliability strategy</u>	
▪ We have developed for equipment reliability strategy. (Respondent 2)	Formulation of equipment reliability strategy
<u>Equipment criticality assessment</u>	
▪ If we can detect something that can be dangerous or something that the machine will fail, we need to repair or upgrade immediately. (Respondent 3) ▪ We will identify which equipment that has the most serious potential consequences on business performance that we will do the necessary. (Respondent 4) ▪ When scheduled preventive maintenance is not followed, premature breakdown is a certain outcome. (Respondent 6)	Assessment activities to detect problem
<u>Preventive Maintenance Program</u>	
▪ Preventive is the best in making sure that we can avoid any problem as we can detect any problem before it happens. (Respondent 8) ▪ we have our main maintenance method, PPM which is Planned Preventive Maintenance. (Respondent 9)	Development of preventive maintenance program
Maintenance type awareness	
<u>Aware</u>	
▪ That's basically we subscribe to preventive, predictive and also reactive. (Respondent 1) ▪ We have PPM (Planned Preventive Maintenance). Then we have reactive maintenance. (Respondent 2) ▪ We do have all the stated maintenance practice. (Respondent 5)	Maintenance personnel recognized the maintenance methods applies

- We have many maintenance methods such as preventive, corrective, predictive, condition based, reactive. (Respondent 8)

Cancellation or delayed of maintenance work
<u>No cancellation only delay</u>

- The cancellation of maintenance works has never happened. (Respondent 1)
- So far, no cancellation only delay. (Respondent 2)
- No cancellation. Only delays. (Respondent 4)
- We do not cancel the maintenance activity, only delays will happen due to work priority or maybe there are other alternative ways of doing it better. (Respondent 5)
- No cancellation. Delays happened based on the limitation of resources, mainly manpower. (Respondent 6)
- We normally experienced delays due to lack of manpower. However, no cancellation so far for any of our maintenance task. (Respondent 8)

No cancellation ever recorded only postponement permitted

Observation or inspection duties
<u>Yes</u>

- Yes. I will do observations because for me if we don't go down to the field, we won't see what's on the field, what's happening on the field we won't be able to describe. (Respondent 1)
- Based on the scope of work, if required I will do it. Sometimes, we need to do the monitoring because every day something happens. (Respondent 3)
- Yes. I will do my own observation as it will give me a clear picture of what is happening in my workplace. (Respondent 6)
- Yes. Because sometimes I also need to view myself the picture on the ground. It will be clearer for me if I take a look myself and get the inputs from the personnel on the ground. (Respondent 7)
- Yes. I have no issue in conducting observation or inspection as I need to understand the situation on the ground. Therefore, I make it a must for me to do observation or inspection on daily basis. (Respondent 8)

The task of observation or inspections are required in understanding maintenance work that need to be done

Monitoring duties
Sufficient monitoring function

- No issues on the lack of maintenance monitoring activities. (Respondent 3)
- It is sufficient as we have designated teams to execute this function. (Respondent 4)
- At the moment we have sufficient personnel in performing the monitoring activities. (Respondent 5)
- At the moment, no as we have adequate teams performing this function and they do it according to the proper schedule. (Respondent 7)

The task of conducting monitoring function is adequate

▪ The monitoring activities is being performed extremely well so I have no issue pertaining to monitoring activities. (Respondent 8) ▪ Maintenance monitoring is being handled in proper manner. (Respondent 9) ▪ Monitoring activities is being done in sufficient manner. So, no issue of insufficient monitoring activities at the moment. (Respondent 10)	
Suggestion for maintenance work planning	
<u>Maintenance work is at the best level</u> ▪ For now, all planning related to maintenance work is at the best level. (Respondent 1) ▪ We already created MWC (Maintenance Work Coordinator), so our planning is good at the moment. (Respondent 2) ▪ At the moment I have no suggestion. Everything's seems to be in order. (Respondent 9)	The maintenance work at the optimum level
<u>Maintenance planning is sufficient</u> ▪ All system regarding the maintenance planning is functioning smoothly so no issue or recommendation on this end. (Respondent 3) ▪ At the moment, every is being conducted in a very efficient and effective manner. (Respondent 4) ▪ The maintenance planning is properly being done. (Respondent 8)	The maintenance planning is adequate
<u>Proper maintenance documentation</u> ▪ We have a proper documentation with regards to our work activities. (Respondent 5)	Appropriate maintenance documentation
<u>Capable maintenance personnel</u> ▪ Equipment changes constantly due to technological advancements, so maintenance technicians who work on various types of equipment must stay current on any new developments and techniques. (Respondent 6) ▪ I just hope that whatever practices that we are currently doing will be properly executed. (Respondent 7) ▪ I just hope that we will keep on improving by incorporating all the latest practices in our maintenance planning. (Respondent 10)	Sufficient skills and knowledge for maintenance workers

The four research questions of this study can, in general, be answered using the significant statements' findings and interpretive significance. The following part goes into great depth about the findings and responds to the pertinent research queries. The respondent's compilation of responses indicates that although they generally stated that they understood the maintenance strategy adopted by the PIC, the responses varies from maintenance conducted based on maintenance facilities work, daily planning, Petronas Maintenance Management Strategy (PMMS) and maintenance coordinator.

> *"We have a specific process for maintenance which we call MFWP (maintaining the work process of the facility). In terms of the types of maintenance, for example, we have quite a few. It means that it is reactive, preventive and proactive. It's specific to let me know if the thing is broken, so we start from the operational team's work notice. The personnel will tell me that there are issues with the equipment. It creates a notification and the following workflow within our planner. They will create a work order and from that work order they will share it with our team for maintenance to troubleshoot or repair. That one maybe for things that have been damaged. But for the things people say are preventive maintenance, okay, so we've based our work on an equipment reliability strategy. From there, we will see what the actual condition is, that is to say that we design our activity according to what is necessary to ensure that the equipment does not break down"*
>
> *Respondent 1*

> *"We will follow the schedule set by the division. This is because the work schedule is already being streamlined in the Maintenance Facility Work Process. This is related to daily activities. All that planning will come out with a notification, if there is an issue in the plant, or if there is something that has been scheduled under preventive maintenance."*
>
> *Respondent 2*

> *"I use Maintenance PMMS to keep track of progress, materials and supply requirements. This has been such an effective tool for keeping my work organized."*
>
> *Respondent 6*

> *"I normally will not do my work activity. I normally will be given task to perform by the planner. I will make sure that all the work was executed accordingly. In terms of planning, I normally will contribute in terms of inputs for the planner to be incorporated in our Work Plan. The finalize plan will be completed by work coordinator."*

Respondent 8

The other respondents echoed the mentioned responses with the main feedback that maintenance coordinator is the main party that handled the maintenance work planning.

> *"I will follow the work instruction from Work Coordinator. However, before that, I will give all the work requirements, work activities for the Work Coordinator, then they will incorporate all my inputs in the final work list."*

Respondent 9

> *"Our department will be given Maintenance Strategy at the beginning of the year and we just plan our work from there and also the planner from our Work Maintenance Coordinator."*

Respondent 10

Based on the first theme of RQ1, the researcher would like to highlight that there were contradicting view in the practice of the preventive maintenance in PIC. Relating to the feedback on describing their work, 70% of the respondent stated that their work were as maintenance personnel. Others more detailed responses such as asset protector, service provider and controller and monitor.

> *"I have to make sure the company's assets are in good condition. Conditions that can provide comfort and safety to users."*

Respondent 1

> *"I provide a service to ensure that Petronas assets are in the best condition. So, I will make sure that all tasks are carried out according to the plan that has been set."*

Respondent 2

"In processing facilities, we regulate and keep an eye on variables like temperature, pressure, and fluid levels. Additionally, we monitor emissions for pollution control and the presence of flammable and combustible gases in production and storage areas.."

Respondent 4

The maintenance personnel responses explained more about their work function. The following quotation detailed out the feedback gathered;

"I am responsible for electrical maintenance, which required me to inspect the site regularly, perform routine maintenance, make repairs and fix faulty wiring if necessary."

Respondent 3

"As static maintenance personnel, I am required to conduct routine equipment maintenance, troubleshoot issues, and make on-site repairs when needed."

Respondent 5

"As a rotating equipment personnel, I am responsible for preventive and corrective maintenance activities for rotating equipment such as turbines, compressors, engines, and pumps."

Respondent 6

"I will ensure that all the task be completed according to the requirements as my work is part of the bigger project. When we are talking about big project such as Turnaround Maintenance, my work is a part of it so ensuring that my work is being performed according to the schedule is my top priority."

Respondent 8

In respect to the maintenance work process, everybody seems to agree that it was in systematic and structured condition. On that note, it is understood that all the respondents were satisfied with the PIC current work process. A few of the feedbacks as follows;

"The work processes are fine at the moment. All we need to do is to improve the quality of work, and what is necessary, our men at the same time we have to teach. If this person increases his work quality, other employees will follow, God willing."

Respondent 4

"Today's assets and equipment are becoming more and more complex and more advanced. The potential cost of breakdown to these critical systems and assets is becoming an increasing risk to facility and maintenance management. Therefore, we have our own system to keep track of the work required and at the moment, our PMMS is working fine."

Respondent 6

"As part of maintenance team, I am proud to say that we are doing a good job at the moment, therefore for me, the work process is good for the organization."

Respondent 8

Maintenance concept was somewhat being explained in various ways by the respondents involved in this study. About 50% stated that maintenance can be defined as ensuring all assets are in good condition.

"Maintenance is to ensure that all assets are in good condition and able to carry out tasks at an optimal level."

Respondent 1

"The maintenance for me is simple, keeping the assets in working condition and to restore the assets to working condition once its failed. To prevent any unwanted shutdown."

Respondent 7

"Maintenance is to ensure all the assets, system, tools and equipment is in running state. No shutdown or failure will happen if we do have a proper maintenance program."

Respondent 9

Other feedback recorded by the researcher such as ensuring business operations, protecting and restoring equipments, and lastly maintenance function is activities of maintenance work;

> *"For me, maintenance includes functional audits, maintenance, repair or replacement of commercial equipment, machinery, building infrastructure and support utilities. A very important function in ensuring business can be conducted as usual."*
>
> *Respondent 4*

> *"Maintenance is being performed to ensure the continuity of the business operation. It is very crucial to ensure that you are doing a good maintenance work for the benefits of the organization"*
>
> *Respondent 8*

> *"This maintenance is related to the activities we do. Not only repair, we also need to monitor and ensure that there is no shutdown in our company's operations due to damage to parts or systems."*
>
> *Respondent 3*

These responses indicated that understanding the maintenance concept is very much on individual own definitions based on their experiences and knowledge. The same issue faced in relation to the problem prevention initiatives. The respondents highlighted a few methods to avoid any problem such as having a comprehensive maintenance program; equipment reliability strategy; equipment criticality assessment; and 40% stated the need for adequate preventive maintenance practice. Their responses recorded as follows;

> *"We have preventive maintenance is planned and requires engineers and technicians to review past and current inspection and maintenance data in order to predict damage that may result in failure."*
>
> *Respondent 5*

"We need to have a proper maintenance management to prevent any problem or shutdown. Preventive is the best in making sure that we can avoid any problem as we can detect any problem before it happens."

Respondent 8

"First of all, we have our main maintenance method, PPM which is Planned Preventive Maintenance. So, we can prevent any problem with regards to our business operation. No interruption so we need to detect a problem before it happened. Preventive Maintenance gives us that ability. "

Respondent 9

"To prevent any problem, we need to have a proper maintenance strategy. One of the ways is having preventive maintenance program."

Respondent 10

Other feedback recorded such as;

"We always need to have a comprehensive maintenance program to prevent any problem."

Respondent 1

"To prevent any problem, proper planning needs to be put in place. This is the main function for Work Maintenance Coordinator. Everything is being recorded, inputted into PMMS so relevant people or parties will be aware of all thing happen regarding the maintenance works and maintenance work requirements."

Respondent 7

"We have developed for Equipment Reliability Strategy. So, in that strategy we have critical equipment. At our site, there is more or less our equipment. So, we will put it critical one, critical two and critical three. So, from there we will develop a plan to prevent any problem."

Respondent 2

"If we can detect something that can be dangerous or something that the machine will fail, we need to repair or upgrade immediately."

Respondent 3

"We will follow our own strategy, ECA (Equipment Criticality Assessment). We will identify which equipment that has the most serious potential consequences on business performance that we will do the necessary."

Respondent 4

"Maintaining the safe operation of the equipment at work is a major responsibility for maintenance employees. As a result, we must follow the safety procedures at work. Premature breakdown is a given when scheduled preventative maintenance is not performed. Operation is riskier and maintenance and repair expenses are higher for older machines and equipment with significant wear and tear."

Respondent 6

In terms of the maintenance types practices, all the respondent stated that they understand the maintenance method practices in PIC. The usage of the preventive maintenance, corrective maintenance, predictive maintenance, condition-based maintenance and time-based maintenance all were cited in the interview feedback.

"Yes, I do, sir. For the record, we have a physical inspection every three months. That means our team is going to attend, let me tell you at the pump. It appears on the visual. That is number one. On the second one, we have six months, every six-month we will make a load walling basement. And we also have something like by our CBM team on the vibration. We therefore have a timetable for the frequent collection of data from our analyser. From there, someone is going to take a reading, and the team is going to analyse it as well. Let me say any repair is required. That's basically we subscribe to preventive, predictive and also reactive."

Respondent 1

"Yes. We do have all the stated maintenance practice. CM is a sort of maintenance activity that is typically carried out following equipment failure. It's simply regarded as all actions taken to put damaged or malfunctioning equipment back in working order. PM is a sort of maintenance that is typically carried out prior to equipment failure. It can be summed up as all actions taken to maintain assets and keep them from breaking down or failing. Any task that has a due date and is given to a technician is considered scheduled maintenance. It may be a one-time task or a recurring task carried out at regular intervals. Planned shutdowns, routine service, and changes are all considered to be part of scheduled maintenance."

Respondent 5

"Yes, all this is part of our maintenance program, PETRONAS Maintenance Management. System (PMMS). PMMS is for viewing on the PM. Preventive maintenance is something that regular people use. Predictive maintenance is for the expert users."

Respondent 3

With respect to the cancellation or delay of the maintenance program, all interviewees reported that the work or maintenance activities were never cancelled. This is because work is important to the viability of the organization. However, the delays may happen due to many reasons such as performing maintenance work based on priority, lack of budget, unavailability of the personnel or manpower as well as limitation on resources. The documented comments are as follows:

"So far, no cancellation only delay. We regarded delay as defect. Defect due to lack of resources. This resource is what I mean in terms of manpower and also equipment. The equipment we want is not available. We have found a failure or we have found a defect but we want to wash it, we can't do anything because the equipment is not there. So those things sometimes happen."

Respondent 2

"No cancellation. Only delays. This is because sometime we have certain limitation such as manpower and required equipment. For example, sometime our personnel

were asked to perform rectification work in other plants for like in Kerteh, Gurun, etc. So, our own work will be delayed. But I never experience cancellation.

"Respondent 4

"We do not cancel the maintenance activity, only delays will happen due to work priority or maybe there are other alternative ways of doing it better. But normally the delays won't happen without option or alternative. We don't cancel it because it's part of the maintenance planning."

Respondent 5

"Delayed happen due to resource, lack of resources. Mainly manpower. The delays generally associated with corrective maintenance. In terms of cancellation, there's never been a cancellation case reported."

Respondent 7

"We normally experienced delays due to lack of manpower. However, no cancellation so far for any of our maintenance task. How many times, I cannot remember. But delays are something that is happen once in while due to some project were deemed more important than the other project."

Respondent 8

"We faced delays but never cancellation. All these maintenance work has been included in our work planner because it need to be performed regardless so no cancellation will happen. Delays happen due to work priority and sometimes lack of resources such as manpower."

Respondent 10

Based on these responses, it is well understood that all respondent participated in the current study were very much aware of the maintenance work arrangement. Their understanding indicates that they know the value of maintenance work in ensuring the business sustainability and reducing costs which related to the corrective maintenance.

"On the other aspect of preventive maintenance practice in PIC, the respondents agreed that they were willing to the monitoring or observation on their own without any instruction from their superior. They also highlighted that the monitoring duties were performed sufficiently.

Yes. I will do observations because for me if we don't go down to the field, we won't see what's on the field, what's happening on the field we won't be able to describe."

Respondent 1

"Yes. I have no issue in conducting observation or inspection as I need to understand the situation on the ground. Therefore, I make it a must for me to do observation or inspection on daily basis."

Respondent 8

"At the moment, the monitoring activities are done according to our work plan. It is sufficient as we have designated teams to execute this function."

Respondent 4

"The monitoring activities is being conducted by few teams. So, for me, the monitoring function is being performed properly."

Respondent 6

In the last section of theme 1, the researcher gathered the opinion of respondents on how to improve the maintenance planning. The responses were various which includes proper documentation and the need for maintenance personnel to be keep up to date with regards to the maintenance activities practices. 60% of the respondents were satisfied with regards to the current methods and the maintenance practices already at their most optimum level. Some of the responses recorded as follows;

"We already created MWC (Maintenance Work Coordinator), so our planning is good at the moment."

Respondent 2

"All system regarding the maintenance planning is functioning smoothly so no issue or recommendation on this end."

Respondent 3

"At the moment, every is being conducted in a very efficient and effective manner. The only improvement would be in terms of have required resources when it is needed like manpower and equipment."

Respondent 4

"We have a proper documentation with regards to our work activities. In relation to that, it will be good if everybody follows the task accordingly and able to share any inputs or any suggestion for the benefits for all."

Respondent 5

"Equipment changes constantly due to technological advancements, so maintenance technicians who work on various types of equipment must stay current on any new developments and techniques."

Respondent 6

"I just hope that whatever practices that we are currently doing will be properly executed. Sometimes, even though the planning is done properly, the execution part failed to deliver. So, the planning also needs to have a few alternatives as a back-up plan."

Respondent 7

The preventive maintenance practices theme has showcased the that the maintenance personnel involved in maintenance program/work/activities understood the practices used in PIC. The various feedbacks originated from the different background and the formal and informal knowledge accumulated. Table 4.3 simplified the finding of the theme for the RQ1 of preventive maintenance practice in PIC.

Table 4.3
Theme 1: Preventive maintenance practices

Aspect:	**1. Maintenance work planning**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Maintenance Facility Work	3	Respondent 1, 2, 5
ii.	Daily planning	2	Respondent 3, 4
iii.	Maintenance PMMS	1	Respondent 6
iv.	Maintenance Coordinator	4	Respondent 7, 8, 9, 10
Aspect:	**2. Work description**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Asset protector	1	Respondent 1
ii.	Service provider	1	Respondent 2
iii.	Maintenance personnel	7	Respondent 3, 5, 6, 7, 8, 9, 10
iv.	Controller and monitor	1	Respondent 4
Aspect:	**3. Maintenance work process**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Systematic	8	Respondent 1, 3, 5, 6, 7, 8, 9, 10
ii.	Structured	2	Respondent 2, 4
Aspect:	**4. Definition of maintenance**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Ensure that all assets are in good condition	5	Respondent 1, 2, 7, 9, 10
ii.	Activities of maintenance work	1	Respondent 3
iii.	Ensure business operation	2	Respondent 4, 8
iv.	Protecting or restoring equipment	2	Respondent 5, 6
Aspect:	**5. Problem prevention initiative**		

	Responses	Times mentioned	Who mentioned
i.	Comprehensive maintenance program	2	Respondent 1, 7
ii.	Equipment Reliability Strategy	1	Respondent 2
iii.	Equipment Criticality Assessment	3	Respondent 3, 4, 6
iv.	Preventive Maintenance Program	4	Respondent 5, 8, 9, 10

Aspect: 6. Maintenance types understanding

	Responses	Times mentioned	Who mentioned
i.	Yes	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect: 7. Cancellation or delayed maintenance program occurrence

	Responses	Times mentioned	Who mentioned
i.	No cancellation, only delays happen	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect: 8. Observation or inspection duties

	Responses	Times mentioned	Who mentioned
i.	Yes	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect: 9. Lack of monitoring activities

	Responses	Times mentioned	Who mentioned
i.	No. Monitoring is sufficient	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

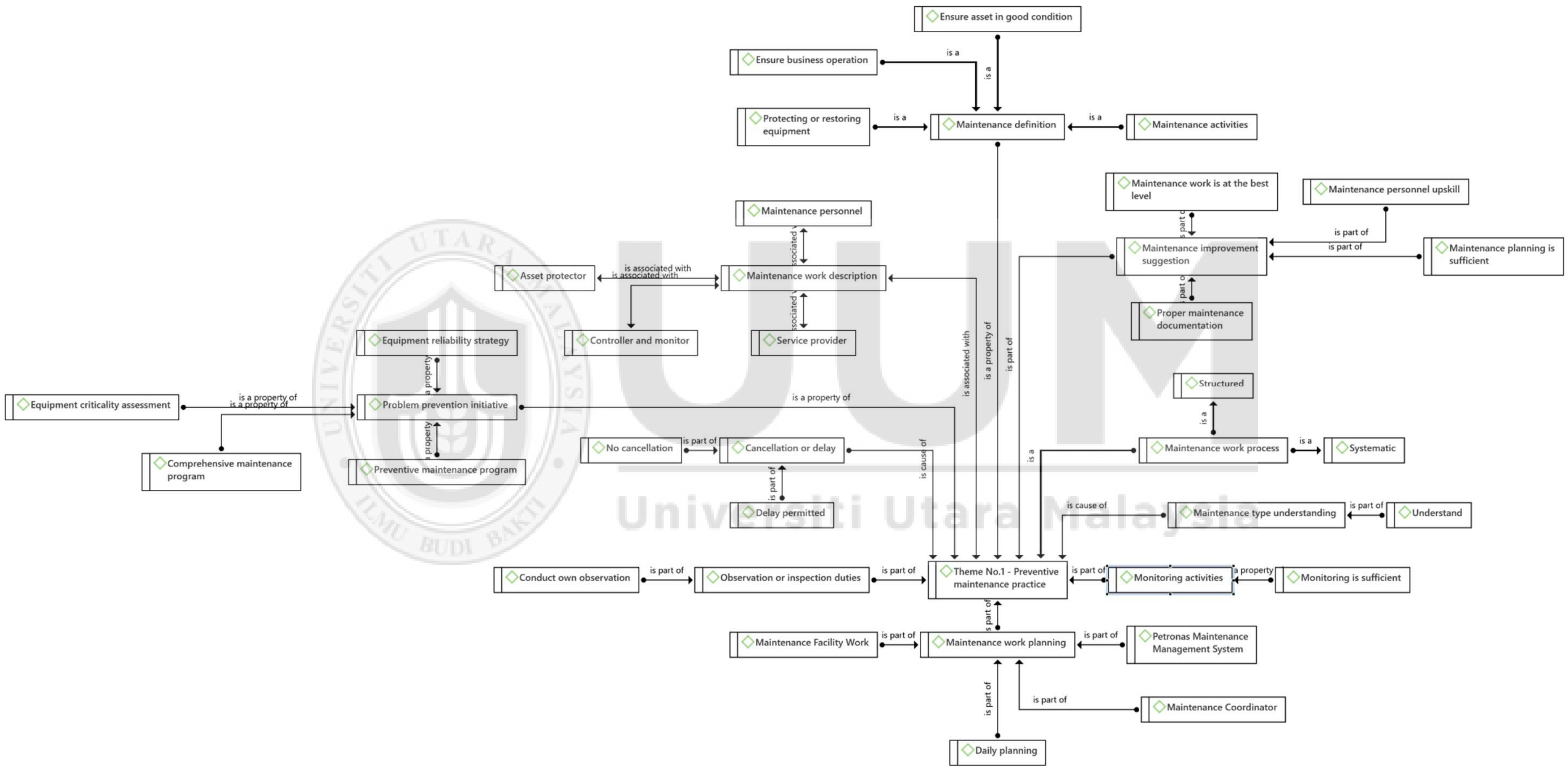
Aspect: 10. Maintenance planning improvement

	Responses	Times mentioned	Who mentioned
1.	Maintenance work is at the best level	3	Respondent 1, 2, 9
2.	Maintenance planning is sufficient	3	Respondent 3, 4, 8
3.	Proper maintenance documentation	1	Respondent 5

4.	Maintenance personnel need to be keep up to date	3	Respondent 6, 7, 10

Figure 4.1 is the output generated from Atlas.ti version 9 in relation to the Theme No. 1 for the RQ1 of preventive maintenance practice in PIC.

Figure 4.1
Atlas.ti output for Theme No. 1 – Preventive Maintenance Practice in PIC



4.5.2 Theme No. 2: The preferred option for downstream operators maintenance strategy

Theme No.2 relates directly to Research Question 2 as stated in Chapter 1 as part of the research which addresses the preferred option for downstream operators. The detailed breakdown of the interviews response for this research question is presented separately in Table 4.4 according to the themes and its significant statements The summary of the findings is presented in Table 4.5.

Table 4.4
Significant Statements and Interpretative Meaning for PIC's Preferred Maintenance Strategy

Significant Statements	Interpretative Meaning
Cost of preventive maintenance	
Expensive	
▪ Sometimes things are simple. And we want to take care of safety, we have all kinds of procedures and that thing involves cost. The cost will be high. (Respondent 1) ▪ Even though, initially the cost is very high, but once utilize it can contribute to a lot of saving. (Respondent 4) ▪ Yes, as it involves equipment and also relevant system. (Respondent 5) ▪ Yes, because it involved the latest systems, tools and also equipment. (Respondent 6) ▪ Yes, as the system, equipment and tools required is associated with technology. Therefore, you need to allocate huge sum of investment to acquire those items. (Respondent 7) ▪ Yes, because its involved new technology and also more expensive tools and equipment. Not only that it also will include the new processes and new systems. (Respondent 9)	The cost of investment for preventive maintenance is high
In-charge of preventive maintenance	
Maintenance Division	
▪ Our department, the Maintenance Division (Respondent 1) ▪ The Maintenance Division (Respondent 2) ▪ Maintenance Division. (Respondent 3)	The maintenance work being performed by the internal Maintenance Division
Maintenance Division and appointed vendor	
▪ Our division with the support of selected vendors. (Respondent 5) ▪ We will perform the task with the assistance of our vendors. (Respondent 6)	Maintenance activities conducted by Maintenance Division and selected vendors

- It will be performed by the maintenance department with the aid of selected vendors for certain task. (Respondent 7)
- Depends on the project. Some project is performed by in-house personnel and some project is being tasked to outside vendors. (Respondent 8)
- Our own maintenance teams. Sometimes we will have the outside vendors performing the preventive maintenance activities such as turnaround maintenance. (Respondent 9)

Element in good preventive maintenance checklist

Zero shutdown

- The most important element is to ensure that no tasks or assets experience shutdown. (Respondent 1)
- We always aimed to achieve zero shutdown. (Respondent 2)

The aim to achieve zero shutdown

Reliability Score

- For me, it's the reliability score. (Respondent 3)
- Equipment reliability strategy. (Respondent 4)
- The preventive maintenance needs to include the Reliability Score so that all the task performed comply to the score. (Respondent 7)

The need for Reliability Score element

Zero downtime

- Zero downtime. (Respondent 5)
- For me, the good preventive maintenance should be based on zero downtime. (Respondent 6)
- Good preventive maintenance will produce zero shutdown or failure. (Respondent 8)
- Good preventive maintenance needs to have the element of zero shutdown or failure. (Respondent 10)

The zero downtime objective

Knowledgeable and experience personnel

- Good preventive maintenance will have the element of knowledgeable and experience personnel. (Respondent 9)

The requirement to have capable personnel

Preventive maintenance completion percentage

100%

It needs to be overall or 100%. (Respondent 1)

- We need to ensure 100% completeness. (Respondent 4)
- It has to be 100%, otherwise the task won't be check as completed. (Respondent 6)
- It needs to be 100% as we understand that the assets in oil and gas operation will have certain impact on the safety of people, company and also the environment. (Respondent 9)
- We need to ensure 100% completeness before can be registered as complete. (Respondent 10)

The checklist completion is set at 100% for any maintenance task to be registered as completed

Preventive maintenance equipment awareness

Aware

- Yes, as it is a requirement in our daily work. (Respondent 2)
- Yes. We have to as its is the requirement. (Respondent 3)
- Yes. Based on our Planned preventative Maintenance (PPM) we will have all our required equipment to perform our task. (Respondent 5)
- Yes, and we have to because these equipment's are the things that we work with on daily basis. (Respondent 6)
- Yes. To use the items, equipment's, tools and systems we need to know them first. (Respondent 9)
- Yes, I am aware of all the equipment involved in relation to my maintenance work requirements. (Respondent 10)

The maintenance personnel are fully aware of maintenance equipment available for them

Benefits of preventive maintenance strategy

<u>Problem prevention</u>

- Preventive is better because it can avoid any problems, both in terms of safety and also the closure of operations. (Respondent 1)
- It prevents from any problem from happen. (Respondent 8)
- Preventive maintenance is better as it can prevent any problem. (Respondent 10)

Preventive maintenance can prevent from any problem that may arise

<u>Achieve zero shutdown</u>

- Preventive is better so zero shutdown can be achieved. (Respondent 2)
- Because we conduct the preventive first to avoid any shutdown. (Respondent 5)
- It can prevent any incident, any shutdown and failure. (Respondent 9)

Preventive maintenance can ensure zero shutdown

<u>Safety and reliability</u>

- Because it is more important due to our requirement of safety and reliability. (Respondent 3)

Preventive maintenance able to provide safety and reliability

<u>Reduce breakdown</u>

- Preventive maintenance will reduce the risk of equipment breakdowns and malfunctions. (Respondent 6)

Preventive maintenance can reduce breakdown

<u>Ensure business continuation</u>

- Preventive maintenance can save life, save lot of money for the company and the most important thing is that it enables the business operation being conducted in the most optimum level. (Respondent 7)

Preventive maintenance can contribute to the sustainability of the organization

Problems of preventive maintenance application

<u>Lack of manpower</u>

For me, the only problem for preventive maintenance application is the lack of manpower to carry out the tasks. (Respondent 1)

Proper application of preventive maintenance will be effected when there

	are not enough manpower scenario happened
Lack of budget Lack of resources, manpower, required equipment and budget. (Respondent 2)	Insufficient budget will contribute to maintenance application difficulties
Completion time insufficiency One of the challenges faced was to complete the task as quickly as we could. (Respondent 3)	Limited time given to properly completed the maintenance task
Insufficient budget The problem will lie on the budget and also on the proper planning. (Respondent 6) The problem always in relation to the budget. (Respondent 9)	Insufficient budget will lead to improper preventive maintenance application
Inadequate training The problem may be relating to the inadequate training received by the maintenance personnel. (Respondent 7)	The preventive maintenance application issue regarding inadequate training for staffs
Right vendor selection The problem for me is identify the right vendors as sometimes we have an issue of runaway workers, in other word the manpower that goes missing or do not turnup for work. (Respondent 8)	Maintenance problem application relating to the right vendor selection

The first question concerning this theme was about the costing of preventive maintenance. The feedback gathered from all the respondent stated that the preventive maintenance strategy is expensive.

> *"Yes, because it involved the latest systems, tools and also equipment, So the cost also will be high."*
>
> *Respondent 6*

> *"Yes, because its involved new technology and also more expensive tools and equipment. Not only that it also will include the new processes and new systems. Therefore, it is expensive."*
>
> *Respondent 9*

However, even though the high investment is associated with preventive maintenance application, the savings that it contributed outweigh the money spent.

> *"Yes, of course. But it will assist in ensuring our operation is in a good, functional state. It is very crucial element in our business operation. Some of our preventive maintenance strategy includes equipment and systems. Even though, initially the cost is very high, but once utilise it can contribute to a lot of saving. So, the cost will be even out in the end."*
>
> *Respondent 4*
>
> *"For me, the answer is yes and no. I said yes because the tools, equipment and even the system associated with preventive maintenance is expensive. But this preventive maintenance also can be considered as not expensive because of the saving that it brings due to corrective maintenance will outweigh the capital spent."*
>
> *Respondent 8*
>
> *"The preventive maintenance supposed to be more expensive as it requires new technology but the saving it provide will ensure the initial investment will be money well spent."*
>
> *Respondent 10*

It is well understood that the cost or the capital that need to be invested in implementing preventive maintenance is high. However, this expenditure is considered as the investment as the saving that it will bring in relation to cost of repair or rectifying the shutdown problem is more significant contribution.

The second issue highlighted in this theme was the ownership of the maintenance program performed in PIC. About 30% of the respondent stated that the work is done by the Maintenance Division. However, the majority, 70% mentioned that the works were conducted together with their selected vendors. The discrepancies happen because some of the respondent regarded that the vendors were part of their own teams. A few of related feedbacks as follows;

> *"Our department, the Maintenance Division."*
>
> *Respondent 1*

"Our division, the Maintenance Division, together with our vendors."

Respondent 4

"It will be performed by the maintenance department with the aid of selected vendors for certain task. Mainly will be performed by in-house personnel."

Respondent 7

"Our own maintenance teams. Sometimes we will have the outside vendors performing the preventive maintenance activities such as turnaround maintenance."

Respondent 9

The other matter of upstream operator maintenance strategy is on the elements of the good preventive maintenance checklist. The researcher would like to examine the items which is considered as a must have in a proper checklist for preventive maintenance program. Based on the feedbacks, there were divided opinion on this matter. 60% stated the zero shutdown or zero downtime. Whereas, 30% mentioned about the Reliability Score and the other 10% highlighted the need for knowledgeable and experience personnel.

"The most important element is to ensure that no tasks or assets experience shutdown."

Respondent 1

"Zero downtime. For me, that one of the major elements for good preventive maintenance checklist."

Respondent 5

"Good preventive maintenance will produce zero shutdown or failure. Therefore, the element that need to be included in the maintenance checklist are the preparation of resources required, safety measures and visual aids. All this element will give a clear picture on the scale of work that are required to be performed."

Respondent 8

"For me, it's the reliability score. As long as we can have reliability score for Olefin, glycols as well as chemicals at 97%, 98% and 99%, respectively, we are okay."

Respondent 3

"Equipment reliability strategy. So, from there we will see what it is, meaning that we will design what's required to make sure we have the equipment that doesn't break down. For example, we have a physical inspection every 3 months."

Respondent 4

"The preventive maintenance needs to include the Reliability Score so that all the task performed comply to the score."

Respondent 7

"Good preventive maintenance will have the element of knowledgeable and experience personnel. This is because the system, tools and equipment's need to be handled by people who knows about these items to enable a proper execution."

Respondent 9

In terms of the percentage of work that need to be done for any maintenance activities before it is regarded as a completed work, all respondent mentioned that it need to be 100%.

"It has to be 100%, otherwise the task won't be check as completed."

Respondent 6

"It needs to be 100% as we understand that the assets in oil and gas operation will have certain impact on the safety of people, company and also the environment. So, the completeness achieved when we have checked for 100% completeness."

Respondent 9

On the other aspect of upstream operator maintenance strategy, the researcher notified that all the participating respondent were aware about all the preventive maintenance equipment that made available to them.

"Yes. We have to as its is the requirement. If we do not know certain skills to operate any equipment, we will be instructed to attend training organized by Capability Department."

Respondent 3

"Yes. Based on our Planned preventative Maintenance (PPM) we will have all our required equipment to perform our task."

Respondent 5

"Yes. To use the items, equipment's, tools and systems we need to know them first. So, I am fully aware of all the items involved in preventive maintenance."

Respondent 9

In relation to the question of why preventive maintenance strategy are better than other maintenance practice, the response collected were varied. Respondents stated 1) To prevent any problem; 2) To achieve zero shutdown; 3) To provide safety and reliability; 4) To reduce breakdown; and 5) To ensure business continuation.

"Preventive is better because it can avoid any problems, both in terms of safety and also the closure of operations."

Respondent 1

"Preventive is better so zero shutdown can be achieved."

Respondent 2

"Because we conduct the preventive first to avoid any shutdown. We have other maintenance strategies such as TDM, condition management, corrective. But the important one is preventive. Predictive is used to certain cases or scenarios."

Respondent 5

"Preventive maintenance will reduce the risk of equipment breakdowns and malfunctions. Therefore, here in Petronas, we put more focus on preventive maintenance compared to other methods."

Respondent 6

"Because it is more important due to our requirement of safety and reliability. Reliability score was introduced to accommodate the preventive maintenance practice."

Respondent 3

"Preventive maintenance can save life, save lot of money for the company and the most important thing is that it enables the business operation being conducted in the most optimum level. That's why the preventive maintenance is the primary method in Petronas."

Respondent 7

"Because preventive able to assist in preventing any unwanted shutdown, ensuring business continuity and also can prevent any accident."

Respondent 4

The various feedback indicate that the respondents have a proper understanding on how significant preventive maintenance function for the business of PIC.

The last aspect regarding this theme is on the problem of preventive maintenance strategy application for the upstream operator. The researcher found out that each and every respondent face or highlighted different feedback. Even though some of the responses were the same, but the elements mentioned were not entirely identical. 30% mentioned about lack of manpower, 50% stated the issues pertaining to the budget and cost, 30% highlighted the time requirements for the maintenance program to be completed, 10% said need to have proper planning, another 10% mentioned about the inadequate training received by the maintenance personnel and 10% also stated issue pertaining to selecting a correct vendor.

"For me, the only problem for preventive maintenance application is the lack of manpower to carry out the tasks."

Respondent 1

"Lack of resources, manpower, required equipment and budget."

Respondent 2

"One of the challenges faced was to complete the task as quickly as we could. The operation side wanted maintenance work to be concluded as soon as possible so that they can resume their operation."

Respondent 3

"The cost and required resources. Sometime, this practice will take time. We have developed Equipment Reliability Strategy. In that strategy, we have critical equipment. At our site, there is more or less our equipment. So, we will put it as critical one, critical two and critical three. From there we will develop work plan. So, there will be something like 3 months, 6 months, 1-year maintenance work interval."

Respondent 4

"The cost. It's not actually a problem. But I consider it as something that will prevent any preventive maintenance practice from being conducted straightaway when we do not have adequate budget for it."

Respondent 5

"The problem will lie on the budget and also on the proper planning. Sometimes, the work required will be planned for the next 3 or 5 years as our main priority is ensuring we have adequate resources and at the same time keeping the operation continues."

Respondent 6

"The problem may be relating to the inadequate training received by the maintenance personnel. The tools and equipment's sometimes too advance for the personnel who are using it, therefore requires certain training which also will contribute to certain cost increase when obtaining new tools and equipment."

Respondent 7

"The problem for me is identify the right vendors as sometimes we have an issue of runaway workers, in other word the manpower that goes missing or do not turnup for work."

Respondent 8

"The problem always in relation to the budget. As you already know certain maintenance will need to have a bigger budget for in implementation of maintenance program, we may need to ask for additional budget."

Respondent 9

"The problem is with regards to execution as sometimes work will be delays due to unavailable resources such as manpower and budget."

Respondent 10

The theme No. 2 for this study found out that the respondents were aware of the PIC maintenance strategy and have a proper understanding of their job function in order to achieve the objectives set by the organization when they selected preventive maintenance as their maintenance strategy. The summary of the feedback by the respondents pertaining to the theme No. 2 were recorded in Table 4.5

Table 4.5

Theme 2: Downstream Operator Maintenance Strategy

Aspect	**1. Costing for preventive maintenance**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Expensive	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
ii.	Expensive and cheap	1	Respondent 8
Aspect	**2. Preventive maintenance personnel**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Maintenance Division	3	Respondent 1, 2, 3
ii.	Maintenance Division and Vendors	7	Respondent 4, 5, 6, 7, 8, 9, 10
Aspect	**3. Elements of a good preventive maintenance checklist**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Zero shutdown	2	Respondent 1, 2
ii.	Reliability Score	3	Respondent 3, 4, 7
iii.	Zero downtime	4	Respondent 5, 6, 8, 10
iv.	Knowledgeable and experience personnel	1	Respondent 9

Aspect	4. Percentage for Preventive inspection/task checklists completion		
	Responses	**Times mentioned**	**Who mentioned**
i.	100%	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

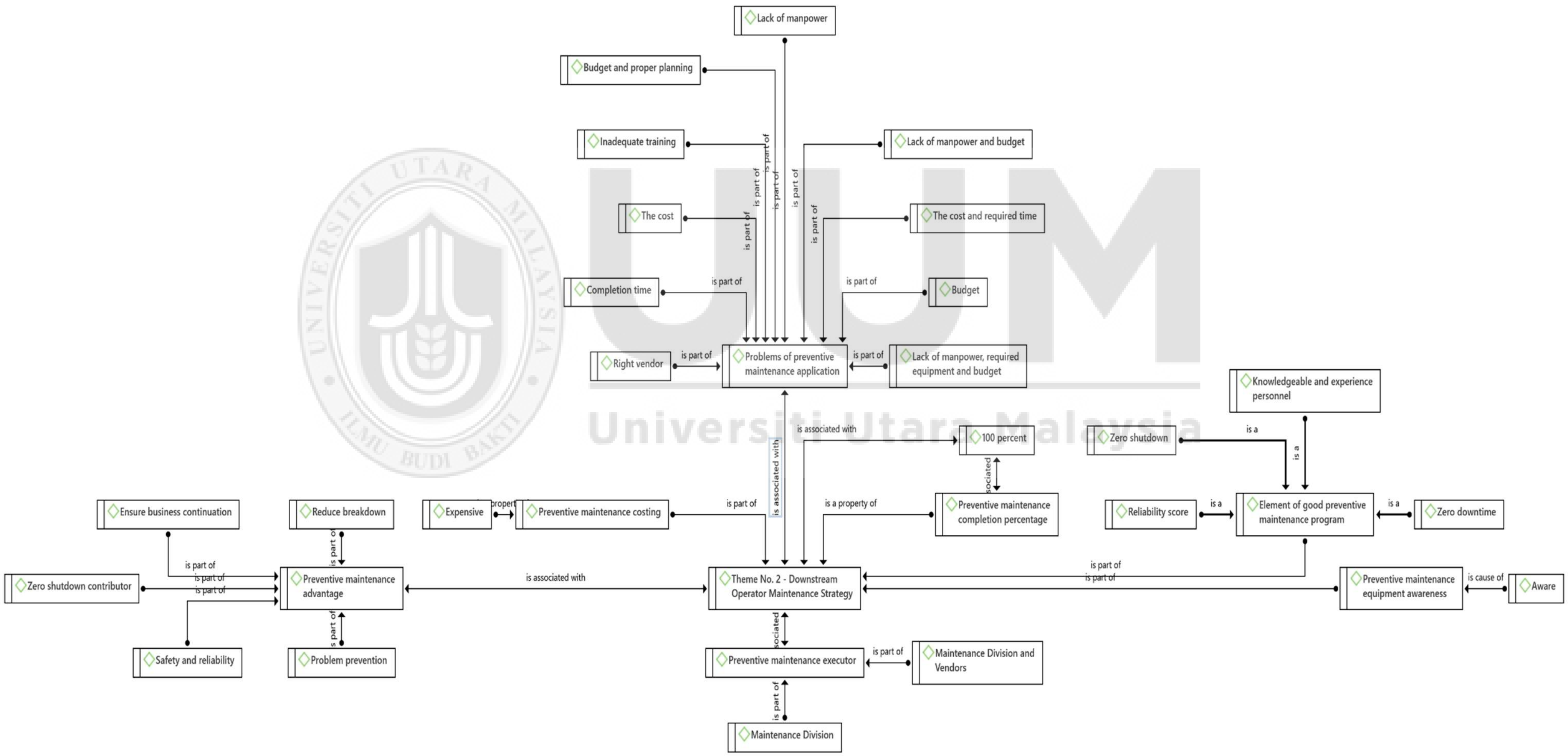
Aspect	5. Awareness of all of the preventive maintenance equipment		
	Responses	**Times mentioned**	**Who mentioned**
i.	Aware	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect	6. Benefits of preventive maintenance strategy		
	Responses	**Times mentioned**	**Who mentioned**
i.	Problem prevention	3	Respondent 1, 8, 10
ii.	Achieve zero shutdown	4	Respondent 2, 4, 5, 9
iii.	Safety and reliability	1	Respondent 3
iv.	Reduce breakdown	1	Respondent 6
v.	Ensure business continuation	1	Respondent 7

Aspect	7. Problems of preventive maintenance application		
	Responses	**Times mentioned**	**Who mentioned**
i.	Lack of manpower	1	Respondent 1
ii.	Lack of manpower, required equipment and budget	1	Respondent 2
iii.	Completion time	1	Respondent 3
iv.	The cost and required time	1	Respondent 4
v.	Cost	1	Respondent 5
vi.	Budget and proper planning	1	Respondent 6
vii.	Inadequate training	1	Respondent 7
i.	Right vendor	1	Respondent 8
ii.	Budget	1	Respondent 9
iii.	Lack of manpower and budget	1	Respondent 10

Figure 4.2

Atlas.ti output for Theme No. 2 – Downstream Operator Maintenance Strategy



4.5.3 Theme No. 3: Third party vendor selection

Theme No.3 relates directly to Research Question 3 as stated in Chapter 1 as part of the research which addresses the third-party vendor selection for PIC. Relevant information acquired through interview sessions, observations and document reviews were considered as evidence and input for data analysis. The summary of the findings is presented in Table 4.7. The detailed breakdown of the interviews response for this research question is presented separately in Table 4.6 according to the themes and its significant statements.

Table 4.6
Significant Statements and Interpretative Meaning for Third party Vendor Selection

Significant Statements	Interpretative Meaning
PIC's maintenance requirements	
Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Condition-based maintenance (CBM), Time-based maintenance (TBM	
▪ Our requirements in maintenance are Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Condition-based maintenance (CBM)... and one more, Time-based maintenance (TBM).(Respondent #1)	PPM, PDM, CBM, TBM
Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Reactive maintenance (REM).	
▪ Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Reactive maintenance (REM). (Respondent #2)	PPM, PDM, REM
Planned Preventive Maintenance (PPM), Corrective maintenance (CM)	
▪ Planned Preventive Maintenance (PPM) and Corrective maintenance (CM). (Respondent #3)	PPM, CM
▪ Preventive equipment maintenance is key to extending equipment life and ultimately saving time and money. The preventive maintenance is necessary because we need to ensure continuous production, shutdown prevention, ensure the safety for personnel and assets, and reduce the unwanted expenses in terms of correction measures. (Respondent 6)	
Reactive Maintenance, Preventive Maintenance, Proactive Maintenance	
▪ Actually, we have several types. It means there is reactive, preventive and proactive. (Respondent #4)	RM, PM
Preventive Maintenance, Corrective Maintenance, Predictive Maintenance	

- Our requirement will be based mainly on preventive, corrective and predictive. (Respondent 5)
- Petronas used Preventive Maintenance, Corrective Maintenance and Predictive Maintenance. (Respondent 10)

PM, CM, PDM

<u>Preventive Maintenance (PM), Corrective Maintenance (CM), Predictive Maintenance (PDM), Condition-based maintenance (CBM)</u>

- Preventive is the main one, followed by others such as Corrective, PDM, condition management. (Respondent 7)
- Our main requirements are preventive maintenance. The other maintenance performed are corrective, predictive, condition-based, etc. (Respondent 8)

PM, CM, PDM, CBM

Preventive Maintenance, Reactive Maintenance, Condition-based Maintenance, Predictive Maintenance

- Our requirement will be in the sequence of PPM, Preventive Maintenance, followed by Reactive Maintenance or also known as Corrective Maintenance. (Respondent 9)

PM, RM, CBM, PDM

Potential vendors evaluation role

<u>Procurement Division</u>

- On the contract part, procurement division is in charge for awarding any project to contractor. (Respondent #1)
- Evaluation will be based on the bidding war. Then procurement division will select. (Respondent 2)

Procurement Division will evaluate and choose the vendor

<u>Category Management Division</u>

- That is the function of Petronas Category Management. (Respondent #4)
- Our dedicated division, the Category Management. (Respondent 5)
- The vendors evaluation will be done by the Category Management. (Respondent 7)
- We have a division that handled the vendors valuation, Category Management Division. (Respondent 10)

The function relating vendor evaluation and contract awarded performed by Category Management Division

Vendor requirement

<u>Local and offshore vendor</u>

- Both, depends on the work requirement. (Respondent 1)
- We certainly require both for certain services. (Respondent 2)
- We utilized both party and the selection were based on contract. (Respondent 3)
- We need both as we need to provide 2 crucial elements which are safety and reliability. (Respondent 4)
- We will award the contract regardless of their origin as long as they can accommodate our request. (Respondent 5)
- Based on the work/contract and also based on experience. Therefore, both set of vendors are required. (Respondent 6)

Maintenance work being awarded to local and offshore vendor based on the contract.

▪ We used both based on the work requirements, the experience and also resources that is required for the activities that need to be performed. (Respondent 7)	
▪ Based on the project. Some project was handled by local vendors, some project handled by offshore vendors. (Respondent 8)	
▪ We required both, offshore and also local vendors to work with us in maintenance projects. (Respondent 9)	
▪ Certain project will be awarded to local vendors and certain work will be given to offshore vendors. (Respondent 10)	
Criteria for vendor selection	
Experience, number of manpower, manpower capability, response time	
▪ Criteria are usually based on experience, number of manpower, in terms of manpower capability, in terms of response time. (Respondent 1)	Experience, manpower and response time criteria
Maintenance work activities	
▪ A statement of work (SOW). (Respondent 2)	Statement of Work criteria
Capabilities, experience and resources	
▪ Selection will be based on capabilities, experience and resources that they have. (Respondent 3)	Criteria based on capabilities, experience and resources
Experiences, resources and equipment	
▪ Experiences is the most important thing, followed by ability to commit resources such as manpower and equipment. (Respondent 4)	Experiences, resources and equipment criteria
Experience, performance, quality of work	
▪ We will select according to experience, performance, quality of work. (Respondent 5)	The selection was based on experience, performance and quality of work
Experiences, manpower, resources, vendor's rating	
▪ Experiences, manpower, resources and also vendor's rating. (Respondent 6)	Vendor selected based on experience, manpower and rating
Experience, manpower availability, response time	
▪ Firstly, we will look at experience, followed by man power availability, and also their response time. (Respondent 7)	Experience, manpower and response time
Experience, response time, resources	
▪ The main criteria are the experience of the vendor. We must ensure that the selected vendor has relevant experience as the oil and gas industry, we have certain rules and regulation that we have to comply so the vendor need to know all these things. We also select vendors based on their response time and the resources that that have. (Respondent 8)	The selected vendor required to have experience, adequate resources and response time

▪ Sometimes, the most important criteria are the work experience. Sometimes based on the resources. Sometimes is based on response time by the vendors. (Respondent 9)	
Work requirements, experience, resources availability	
▪ Selection requirement will be based on work requirements, then we will look at vendor's experience and the availability of their resources. (Respondent 10)	Work requirement, experience and resource are the criteria required before selection are made
Unpracticality of lowest bidder policy	
<u>Fulfil scope of work</u>	
▪ Based on scope of work as sometimes we need to ensure that the works is performed by the parties that has sufficient experience. (Respondent 1)	Vendor must fulfil the work requirement
<u>Efficient and effective work conducted</u>	
▪ Sometimes, we cannot award the contract to the lowest bidders because we need to ensure the work required get done in the most efficient and effective manner. (Respondent 2)	Selection done to address the issue of work requirements and be performed in efficient and effective manner
<u>Provide safety and reliability</u>	
▪ When you are aiming to provide safety and reliability, the lowest price bidder would not be the case. (Respondent 3)	Adhere to provide safety and reliability requirement
<u>Experience, manpower and equipment</u>	
▪ Experiences is the most important thing, followed by ability to commit resources such as manpower and equipment's. (Respondent 4)	Experience is the major criteria, followed by manpower and equipment
<u>Quality of work consideration</u>	
▪ In my opinion, the lowest best was not going to be the best choice if the quality of work will be compromised. (Respondent 5) ▪ Lowest bidder is not the good choice when the vendor does not meet the selection criteria as we are talking about the maintenance project so the quality of the work is very crucial. (Respondent 10)	In maintenance work, quality cannot be compromised
<u>Experiences and resources</u>	
▪ Some of it will not be based on the lowest bidder only as sometimes it will be based on experiences and resources provided by the vendors. (Respondent 6)	Experiences and resources are more important
<u>Experience personnel</u>	
▪ Lowest bidder won't be the best choice when the task required you to have more experience personnel. (Respondent 7)	Experience personnel are required
<u>Criteria of work performed</u>	

- Sometimes, the project is a big project for example Turnaround which cost 40 million, therefore, we must make sure the selected vendor has all the criteria required. (Respondent 8)

Criteria of work performed are more important

Requirements of the maintenance project

- As I mentioned before, it's based on the requirements of the maintenance project. (Respondent 9)

The criteria based on the maintenance work requirement are crucial

Conducting research on new vendors role

Category Management Division

- We have CAT MENT. Category Management Petronas. (Respondent 1)
- All info regarding vendors, new or old will be kept by Category Management Division. (Respondent 3)
- The review, the evaluation will be done by Petronas Category Management. (Respondent 4)
- This role is performed by our Category Management. We just the executioner. (Respondent 5)
- We will give out inputs to the Category Management on what vendor we would like to work on certain project but it's all will depend on them to make the final decision. (Respondent 6)
- As I mentioned before, Category Management will perform this kind of function. (Respondent 7)
- We don't do the research on new vendors. Category Management will do this function. (Respondent 8)

Category Management Division responsible in conducting research on new vendor

Effective way of monitoring vendor performance

Category Management Division analysis

- Category Management Petronas will analyse vendor performance. Any decision will be based on their analysis. (Respondent 1)
- CAT MAN who will review vendor performance. (Respondent 2)
- CAT MAN will be monitoring vendors performance; we just give our inputs for them. (Respondent 6)

Category Management Division performing the analysis on vendor and come out with suggestion on their performance

User evaluation

- We will monitor the contractor performance. (Respondent 3)

Vendor performance based on user evaluation

Performance and the job quality

- The performance and the job quality need to be perceived as the most effective methods to evaluate the performance of vendors. (Respondent 5)

Job quality of the vendor will decide their performance rating

Complying to the work requirements

- Ensuring the work done according to the work requirements. (Respondent 7)

The need to ensure the work done according to the work is crucial

Achievement of work objectives

▪ We need to be on the field to know the work being performed according to the requirements. (Respondent 8) ▪ For me, it is based on the vendor's work quality as we need to make sure that all the project aims are met. (Respondent 9)	Vendor performance rating based on maintenance work objective achievement
<u>Quality of work performed</u>	
▪ We need to see the quality of their work. (Respondent 10)	The quality of work will decide vendor performance
Procurement risk management strategy for unreliable vendors <u>Category Management Division evaluation</u>	
▪ Risk management based on unreliable vendors will be taken care of by CAT MAN. (Respondent 2) ▪ The risk evaluation pertaining to vendor is being handled by Petronas Category Management. (Respondent 5) ▪ This is CAT jurisdiction. They will make all decision pertaining to the vendors. (Respondent 6) ▪ Cat Management will categorize the vendors according to their rating A is the best and C is the worst. (Respondent 7) ▪ Category Management has all the complete information with regards to unreliable vendors. (Respondent 8) ▪ Unreliable vendors will be dealt with by the Category Management. (Respondent 9) ▪ Category Management Division will take care of that. (Respondent 10)	Category Management Division will perform the evaluation task on vendor performance and shall award the maintenance contract to the reliable vendors only
Past trends challenges and action plans <u>Black listed vendor – Need to use proper channel</u>	
▪ The system will block. Whatever you do, the system will block. It has to go through the right channel. (Respondent 1)	When vendor has been blacklisted by Category Management. Need to go through proper channel
<u>No leader – Need a proper system</u>	
▪ There is no leader to see everything. Leaders only look at things that are necessary. So that's why we create a system. (Respondent 2)	No leader to oversee everything. Need a proper system
<u>No spare-parts and aging assets – Need proper planning</u>	
▪ So, among the challenges we have are challenges on the spare parts, aging issue. So, we need to prepare for all this issues. (Respondent 3)	Lack of proper spare-parts and aging assets. Need to have proper planning
<u>No proper material – Need proper planning</u>	
▪ Sometimes the material we use initially, is from a different material, the valves may meet the material spec, but when we change it, the machine or the equipment do not function as good as it was before. What can we do is to always improve our work by having a complete picture of work to be done to avoid any issue. (Respondent 4)	Unsuitable materials for maintenance. Need to have adequate planning
<u>Keep 97% Reliability Score – Need practice improvement</u>	

▪ The only challenge is how to keep the reliability score at 97% and above like we are doing currently for all of our plants. Therefore, we need to be doing whatever that we currently practice. We also need to enhance our practice. (Respondent 5)	Keep reliability score above 97%. Need to always improve practices
No resources available - Need to reduce corrective maintenance	
▪ In our work, the main challenges will be based on the work that need to be done Sometimes, no resources available. Therefore, we will try limit the corrective maintenance as much possible. (Respondent 6)	Resources not available. Need to reduce corrective maintenance
No resource - Need proper planning	
▪ Challenges will be based on the certain issue for example the resources or our parts do not arrive on time. We need to go the ministry to ask them for some exemption on certain rules and regulation to ensure we can obtain our needed resource accordingly. (Respondent 7)	Resource unavailability. Need to have proper planning
Work delays - Need alternatives	
▪ So far, there is not much of a challenge faced. The normal delays and hiccups are something that cannot be avoided. It just that we need to be wiser in terms of coming up with alternatives remedy. (Respondent 8)	Work delays. Need to come up with alternatives
No major challenges - Need to be prepare	
▪ Based on the past trends, I do not face major challenges. Action plan available already sufficient to handle any set-back if happen. (Respondent 9)	No major challenges faced however need to always be prepare
No major challenges - Keep up the good work	
▪ No major challenges faced. All the maintenance program is on order and performed accurately. (Respondent 10)	Maintenance personnel faced no major challenges. Keep up the good work
Vendor relationship management	
<u>Category Management Division</u>	
▪ CAT MAN who will take care of all the vendors. (Respondent 1) ▪ Vendor management was done by the CAT MAN. (Respondent 3) ▪ Vendors' relationship management will be handled by Category Management. (Respondent 4) ▪ This one also falls under the jurisdiction of Category Management. (Respondent 5)	The relationship management handled by Category Management Division
<u>Vendor as partner. Treat as own staffs</u>	
▪ Vendor is our partner. We treat them the same as staff. (Respondent 2) ▪ Our relation is based on work. We treat them as our own staffs. (Respondent 6) ▪ We treat our vendors just like our own staffs so our relationship with our vendor is good. (Respondent 8) ▪ We have a good relationship with our vendors. (Respondent 9)	Vendor relationship is good, treated as partner and as own staff

- We have no issues with regards to our existing vendors. They work hand-in-hand with us and our relationship is good. (Respondent 10)

The first aspect discussed in relation to the RQ3 was focused on the PIC's maintenance requirements. The selection of vendors will be based on the maintenance work/activities/program/project. Consequently, it is understood that maintenance task personnel must be familiar with the organization's maintenance requirements or maintenance practices. Based on respondent feedback, the researcher found that the maintenance requirements were slightly different from one respondent to another. Although some of the practices mentioned referenced the same maintenance procedures, the various responses indicated that these respondents were unsure of the PIC's maintenance requirements.

The feedback collected based percentage mentioned; 1) 60% - predictive maintenance; 2) 40% - preventive maintenance; 3) 40% - condition-based maintenance; 4) 40% - planned preventive maintenance; 5) 40% - corrective maintenance; 6) 30% - reactive maintenance; 7) 10% - time-based maintenance; and 8) 10% - proactive maintenance.

"Our requirements in maintenance are Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Condition-based maintenance (CBM)... and one more, Time-based maintenance (TBM)."

Respondent 1

"Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Reactive maintenance (REM). REM is. Reactive maintenance. REM is done once failure occurred."

Respondent 2

"Planned Preventive Maintenance (PPM) and Corrective maintenance (CM)."

Respondent 3

"Actually, we have several types. It means there is reactive, preventive and proactive. So, it's specific to know if the thing is broken, it starts from the job notification from the operation team. They will initiate the reports if there are any issues on the equipment. Then a notification will be created. Next workflow will be prepared by our planner, which will create a work order and from that work order, it will flow to our team to do the maintenance, to troubleshoot or to repair."

Respondent 4

"Our requirement will be based mainly on preventive, corrective and predictive. Everything is embedded in our PMMS."

Respondent 5

"Preventive equipment maintenance is key to extending equipment life and ultimately saving time and money. The preventive maintenance is necessary because we need to ensure continuous production, shutdown prevention, ensure the safety for personnel and assets, and reduce the unwanted expenses in terms of correction measures."

Respondent 6

"The maintenance practice here will be according to the priority, Preventive is the main one, followed by others such as Corrective, PDM, condition management."

Respondent 7

"Our main requirements are preventive maintenance. The other maintenance performed are corrective, predictive, condition-based, etc. But our primary maintenance is preventive."

Respondent 8

"Our requirement will be in the sequence of PPM, Preventive Maintenance, followed by Reactive Maintenance or also known as Corrective Maintenance. We also have other practice such as condition based and predictive but this one is in small scale."

Respondent 9

"Petronas used Preventive Maintenance, Corrective Maintenance and Predictive Maintenance."

Respondent 10

The next aspect on the third-party vendor selection was on the evaluation of vendors. Based on the responses, 100% stated that the particular function was done by their Category Management Division.

> *"On the contract part, procurement division is in charge for awarding any project to contractor. It is not as Category Management."*
>
> *Respondent 1*

> *"That is the function of Petronas Category Management. They will do all the analysis, evaluation of all the vendors for Petronas."*
>
> *Respondent 4*

> *"Our dedicated division, the Category Management. They are the one who is in-charge of vendors."*
>
> *Respondent 5*

> *"Category Management Petronas. This contract is held by all CAT events. They have all the information. They will have a data bank and will analyse the evaluation of vendors."*
>
> *Respondent 6*

> *"The vendors evaluation will be done by the Category Management. They will assess the performance of vendors; do the evaluation and they also will categorize all the vendors according to the performance."*
>
> *Respondent 7*

The next part will be based on vendor requirements for PIC operations and maintenance projects. The researcher would like to know PIC's preference for vendor appointments, whether based on nationality or other considerations. It is well understood that Petronas's Integrated Turnaround Main Mechanical and Maintenance Mechanical Static (TA4MS) required the task been performed on their Liquefied Natural Gas (LNG) Regasification Terminal (RGT) involving 28 operating units (OPU). Responses indicated that it was not important for selection to be based on a local vendor or an offshore vendor because everything will be connected with the work that will be done. The current vendors for maintenance which includes the turnaround were awarded to i) Perbadanan Urusan Kejuruteraan dan Limbungan Brooke;ii) Malaysia Marine and Heavy Engineering Sdn Bhd; iii) Serba Dinamik Holdings Berhad; iv) Uzma Engineering Sdn Bhd, v) Asian Supply Base Sdn Bhd; vi) Sapura Energy Berhad, vii) Schlumberger WTA (Malaysia) Sdn Bhd; viii) Halliburton Energy Services (M) Sdn Bhd; ix) Velesto Energy Berhad (Formerly known as UMW Oil & Gas Corporation Berhad); x) Deleum Berhad; xi) Eastern Pacific Industrial Corporation Berhad;and xii) Petra Resources Sdn Bhd

> *"We certainly require both for certain services. Mainly based on priority or time, if we wanted to have some work completed quickly."*
>
> *Respondent 2*

> *"We need both as we need to provide 2 crucial elements which are safety and reliability. Therefore, we will give the contract to any party who has adequate experiences and expertise, plus all the required resources."*
>
> *Respondent 4*

> *"We used both based on the work requirements, the experience and also resources that is required for the activities that need to be performed."*
>
> *Respondent 7*

> *"Based on the project. Some project was handled by local vendors, some project handled by offshore vendors. It depends on the project requirement."*
>
> *Respondent 9*

In terms of the criteria for vendor selection, the feedback gathered were varied such as, 1) experience; 2) number of manpower; 3) manpower capability; 4) resources; 5) equipment; 6) quality of work; 7) vendor's rating; 8) respond time; and 9) statement-of-work (SOW) . 80%

stated experience is the key criteria for vendor selection, 60% mentioned the resources element of the vendor and 30% highlighted the need for a proper manpower.

> *"Criteria are usually based on experience, number of manpower, in terms of manpower capability, in terms of response time."*
>
> *Respondent 1*

> *"This one is of course - A statement of work (SOW). We use a term that is technically acceptable and commissionable."*
>
> *Respondent 2*

> *"Selection will be based on capabilities, experience and resources that they have."*
>
> *Respondent 3*

> *"Experiences is the most important thing, followed by ability to commit resources such as manpower and equipment's. This is because, sometime, will only ask manpower from our vendor to perform certain task."*
>
> *Respondent 4*

> *"We will select according to experience, performance, quality of work."*
>
> *Respondent 5*

> *"Experiences, manpower, resources and also vendor's rating."*
>
> *Respondent 6*

> *"Firstly, we will look at experience, followed by manpower availability, and also their response time."*
>
> *Respondent 7*

> *"The main criteria are the experience of the vendor. We must ensure that the selected vendor has relevant experience as the oil and gas industry, we have certain rules and regulation that we have to comply, so the vendor need to know all these things. We also select vendors based on their response time and the resources that that have."*

Respondent 8

"Based on the set's requirement of the project. Sometimes, the most important criteria are the work experience. Sometimes based on the resources. Sometimes is based on response time by the vendors. It's all depends on the project requirements."

Respondent 9

"Selection requirement will be based on work requirements, then we will look at vendor's experience and the availability of their resources."

Respondent 10

The other important aspect in understanding the vendor selection process for CIP is whether awarding the contract based on the lowest bidder policy is practical. Responses indicated that 100% of respondents said that the lowest bidder's policy is not an appropriate choice. This is due to various reasons such as 1) need to fulfil scope of work; 2) the requirement in providing efficient and effective work; 3) provide safety and reliability; 4) the work requires experience; 5) quality of work consideration; 6) specific resources required; and 7) certain requirement or criteria of work that need to be performed.

"Based on scope of work as sometimes we need to ensure that the works is performed by the parties that has sufficient experience."

Respondent 1

"Sometimes, we cannot award the contract to the lowest bidders because we need to ensure the work required get done in the most efficient and effective manner. Petronas is a big company, Malaysian biggest corporation. So, we need to uphold that reputation. That's why we at our best level will award the contract to our in-house vendors. Furthermore, awarding contact also need to go through Johor Corp. So, there's a lot of other consideration other than lowest bidder."

Respondent 2

"When you are aiming to provide safety and reliability, the lowest price bidder would not be the case."

Respondent 3

"Experiences is the most important thing, followed by ability to commit resources such as manpower and equipment's. This is because, sometime, will only ask manpower from our vendor to perform certain task."

Respondent 4

"In my opinion, the lowest best was not going to be the best choice if the quality of work will be compromised. In maintenance field, you cannot do that. Especially when you are safeguarding the national assets."

Respondent 5

"All the projects have its own budget. Some of it will not be based on the lowest bidder only as sometimes it will be based on experiences and resources provided by the vendors."

Respondent 6

"Lowest bidder won't be the best choice when the task required you to have more experience personnel. With experience, of course you need to spend more."

Respondent 7

"This one also will be based on the project. Sometimes, the project is a big project for example Turnaround which cost 40 million, therefore, we must make sure the selected vendor has all the criteria required. We have the budget already, so the lowest bidder sometimes does not win contract if they do not fulfil the criteria."

Respondent 8

"As I mentioned before, it's based on the requirements of the maintenance project. The lowest bidders sometimes do not possess the required criteria."

Respondent 9

"Lowest bidder is not the good choice when the vendor does not meet the selection criteria as we are talking about the maintenance project so the quality of the work is

very crucial. That is why for us, the work experience is our main criteria of vendor selection."

Respondent 10

As for the aspect of conducting research on new vendors, all of the respondent reverted that it is under the jurisdiction of Category Management Division. The role played by the Maintenance Division is providing Category Management (CAT MAN) will all the inputs requested by CAT MAN.

"We have CAT MENT. Category Management Petronas. All CAT event contracts held. They have all the info. He will have a data bank and they will do vendor performance analysis. We can get all the info from them."

Respondent 1

"All info regarding vendors, new or old will be kept by Category Management Division. They will do all the necessary task in ensuring we award the contract to the vendor that will complement Petronas reputation."

Respondent 3

"The review, the evaluation will be done by Petronas Category Management. They will do all the analysis, the ranking, the category, A, B or C for vendors."

Respondent 4

"As I mentioned before, Category Management will perform this kind of function. We may supply them with contacts and inputs for vendor selection, but they are the one who managed and keep all the information pertaining to vendor. This is across all Petronas plant."

Respondent 7

"We don't do the research on new vendors. Category Management will do this function. They have all the information with regards to all vendors under all plants in Petronas."

Respondent 8

Next, the researcher will highlight the effective way of monitoring vendor performance based on the feedback by the respondents. 50% mentioned about the need to map it to the requirement of the work and also the quality of work performed, another 40% stated that the vendor performance matter will handled by CAT MAN and 20% highlighted the important of user evaluation aspect.

> *"The performance and the job quality need to be perceived as the most effective methods to evaluate the performance of vendors."*
>
> *Respondent 5*

> *"Ensuring the work done according to the work requirements. That is why experience, resources and response time is important when to measure the vendor performance."*
>
> *Respondent 7*

> *"We need to be on the field to know the work being performed according to the requirements. That why we normally work together with our vendors in ensuring the objective of the project achieved."*
>
> *Respondent 8*

> *"Category Management Petronas will analyze vendor performance. Any decision will be based on their analysis."*
>
> *Respondent 1*

> *"CAT MAN will be monitoring vendors performance; we just give our inputs for them."*
>
> *Respondent 6*

> *"We will monitor the contractor performance. Every time they did a job, they will have an evaluation from the user. So, they will be scored based on grade of A, B, C, right. Basically, from that score. If the score is C or below, the chances for us to get them back are usually less."*
>
> *Respondent 3*

"User evaluation. User will rate the performance of the vendor. This information, which is the rating will be sent to Petronas Category Management. Other than that, we also look at their compliance with Health & Safety Commission (HSC). We want them to comply to the HSC while they are preforming their work."

Respondent 4

The respondent in this study was asked about the procurement risk management strategy for unreliable suppliers. Responses from all respondents indicate that they are not exposed to such a risk since this role is performed by the Category Management Division.

"Category Management has all the complete information with regards to unreliable vendors. They normally will not award any contract to the vendor which are not reliable."

Respondent 8

"Unreliable vendors will be dealt with by the Category Management. So, we do not have any problem in terms of procurement risk."

Respondent 9

"Category Management Division will take care of that. They will advise us on that, and they generally already did a proper analysis on the vendors. So, they already took care of the procurement risk."

Respondent 10

In terms of challenges from the past trends for the vendors selection matter and action plans offer to rectify the issue, the respondents reverted with their personalized opinion such as 1) when vendor has been blacklisted by Category Management. Need to go through proper channel; 2) No leader to oversee everything. Need a proper system; 3) Lack of proper spare-parts and aging assets. Need to have proper planning; 4) Unsuitable materials for maintenance. Need to have adequate planning; 5) Keep reliability score above 97%. Need to always improve practices; 6) Resources not available. Need to reduce corrective maintenance; 7) Work delays.

Need to come up with alternatives; and 8) No major challenges. Need to always be prepare. Some of the feedback as follows;

> *"There are also situations where we want a vendor to do the work because they are experienced, but they have a case that has been recorded in the system by CAT MAN, we have to ask for approval from legal. Because our request will not go be entertained. I can't do anything. Because of the system. The system will block. Whatever you do, the system will block. It has to go through the right channel."*
>
> *Respondent 1*

> *"There is no leader to see everything. Leaders only look at things that are necessary. So, only these 2 people will see it. So that's why we create a system for control because there is no one who can use it in terms of governance."*
>
> *Respondent 2*

> *"Basically, so far, we have quite good PR (plant reliability) and world class has a figure for plant reliability. So, 97% and above. So, among the challenges we have are challenges on the spare parts, aging issue. And in fact, sometimes even the process has its challenges. Sometimes there may be a spec change in the material that flows through the pipeline as well, right? So that thing is sometimes related to static, related to instrumentation. So sometimes the material we use initially, if it's a different material, the valves may meet the material spec, but when he changes it. Sometimes the information does not arrive. So sometimes we have leaking somewhere. So, we need to prepare for all these issues."*
>
> *Respondent 3*

> *"Sometimes there may be a spec change in the material that flows through the pipeline. So that thing is sometimes related to static, related to instrumentation. Sometimes the material we use initially, is from a different material, the valves may meet the material spec, but when we change it, the machine or the equipment do not function as good as it was before. Sometimes the information does not receive properly from the planner. This all creates a lot of challenges. What can we do is to always improve our work by having a complete picture of work to be done to avoid any issue."*
>
> *Respondent 4*

> *"In our work, the main challenges will be based on the work that need to be done. Sometimes, no resources available. Therefore, we will try limit the corrective maintenance as much possible. If we only need to do the preventive maintenance, the issue of unavailable resource won't be faced."*

Respondent 6

"Challenges will be based on the certain issue for example the resources or our parts do not arrive on time. Sometimes it is because of certain uncontrollable factors such as lock-down that we experienced recently. We need to go the ministry to ask them for some exemption on certain rules and regulation to ensure we can obtain our needed resource accordingly."

Respondent 7

The last aspect covered in theme No. 3 was the vendor relationship management matter. According to the interview, the respondents stated that the relationship with the vendor has been taking care of the CAT MAN (30%), the vendor has been treated as own staff (30%) and the relationship was good (40%).

"CAT MAN who will take care of all the vendors. Any matter, problem will be regulated by them"

Respondent 1

"Vendor management was done by the CAT MAN. We just follow the instruction."

Respondent 3

"Vendors' relationship management will be handled by Category Management. We just have relationship with the vendor on the execution stage."

Respondent 4

"Vendor is our partner. We treat them the same as staff."

Respondent 2

"We treat our vendors just like our own staffs so our relationship with our vendor is good."

Respondent 8

We have a good relationship with our vendors. They have the same objective as we are so we need to create a good relationship with them.

Respondent 9

The compilation of the responses on Theme 3: Vendor selection were detailed out in Table 4.5.

Table 4.5

Theme 3: Vendor Selection

Aspect	1. PIC's maintenance requirements		
	Responses	**Times mentioned**	**Who mentioned**
i.	Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Condition-based maintenance (CBM), Time-based maintenance (TBM).	1	Respondent 1
ii.	Planned Preventive Maintenance (PPM), Predictive Maintenance (PDM), Reactive maintenance (REM).	1	Respondent 2
iii.	Planned Preventive Maintenance (PPM), Corrective maintenance (CM).	2	Respondent 3, 6
iv.	Reactive Maintenance, Preventive Maintenance, Proactive Maintenance	1	Respondent 4
v.	Preventive Maintenance, Corrective Maintenance, Predictive Maintenance	2	Respondent 5, 10
vi.	Planned Preventive Maintenance (PPM), Corrective Maintenance (CM), Predictive Maintenance (PDM), Condition-based maintenance (CBM)	1	Respondent 7
vii.	Preventive Maintenance, Corrective Maintenance, Predictive Maintenance, Condition-based Maintenance	1	Respondent 8
viii.	Preventive Maintenance, Reactive Maintenance, Condition-based Maintenance, Predictive Maintenance	1	Respondent 9
Aspect	**2. Potential vendors evaluation**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Procurement Division	2	Respondent 1, 2
ii.	Category Management Division	8	Respondent 3, 4, 5, 6, 7, 8, 9, 10
Aspect	**3. Requirement for offshore or local vendor**		
	Responses	**Times mentioned**	**Who mentioned**

i.	Both local and offshore vendor required	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect 4. Criteria of selecting suitable vendors

	Responses	Times mentioned	Who mentioned
i.	Experience, number of manpower, manpower capability, response time	1	Respondent 1
ii.	A statement of work (SOW)	1	Respondent 2
iii.	Capabilities, experience and resources	1	Respondent 3
iv.	Experiences, resources and equipments	1	Respondent 4
v.	Experience, performance, quality of work	1	Respondent 5
vi.	Experiences, manpower, resources, vendor's rating	1	Respondent 6
vii.	Experience, manpower availability, response time	1	Respondent 7
viii.	Experience, response time, resources	2	Respondent 8, 9
ix.	Work requirements, experience, resources availability	1	Respondent 10

Aspect 5. Unpracticality of lowest bidder policy scenario

	Responses	Times mentioned	Who mentioned
i.	Fulfil scope of work	1	Respondent 1
ii.	Efficient and effective work conducted	1	Respondent 2
iii.	Provide safety and reliability	1	Respondent 3
iv.	Experience is the major criteria	1	Respondent 4
v.	Quality of work consideration	2	Respondent 5, 10
vi.	Experiences and resources are more important	1	Respondent 6
vii.	Experience personnel are required	1	Respondent 7
viii.	Criteria of work performed are more important	1	Respondent 8
ix.	Requirements of the maintenance project are more important	1	Respondent 9

Aspect 6. Conducting research on new vendors

	Responses	Times mentioned	Who mentioned
i.	Category Management Division	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect 7. The most effective way of monitoring vendor performance

	Responses	Times mentioned	Who mentioned
i.	Category Management Division analysis	4	Respondent 1, 2, 4, 6
ii.	User evaluation	1	Respondent 3
iii.	Performance and the job quality	1	Respondent 5
iv.	Complying to the work requirements	1	Respondent 7
v.	Achievement of work objectives	2	Respondent 8, 9

vi.	Quality of work performed	1	Respondent 10

Aspect 8. Procurement risk management strategy for unreliable vendors

	Responses	**Times mentioned**	**Who mentioned**
i.	Category Management Division evaluation	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect 9. Challenges from the past trends and action plans offer

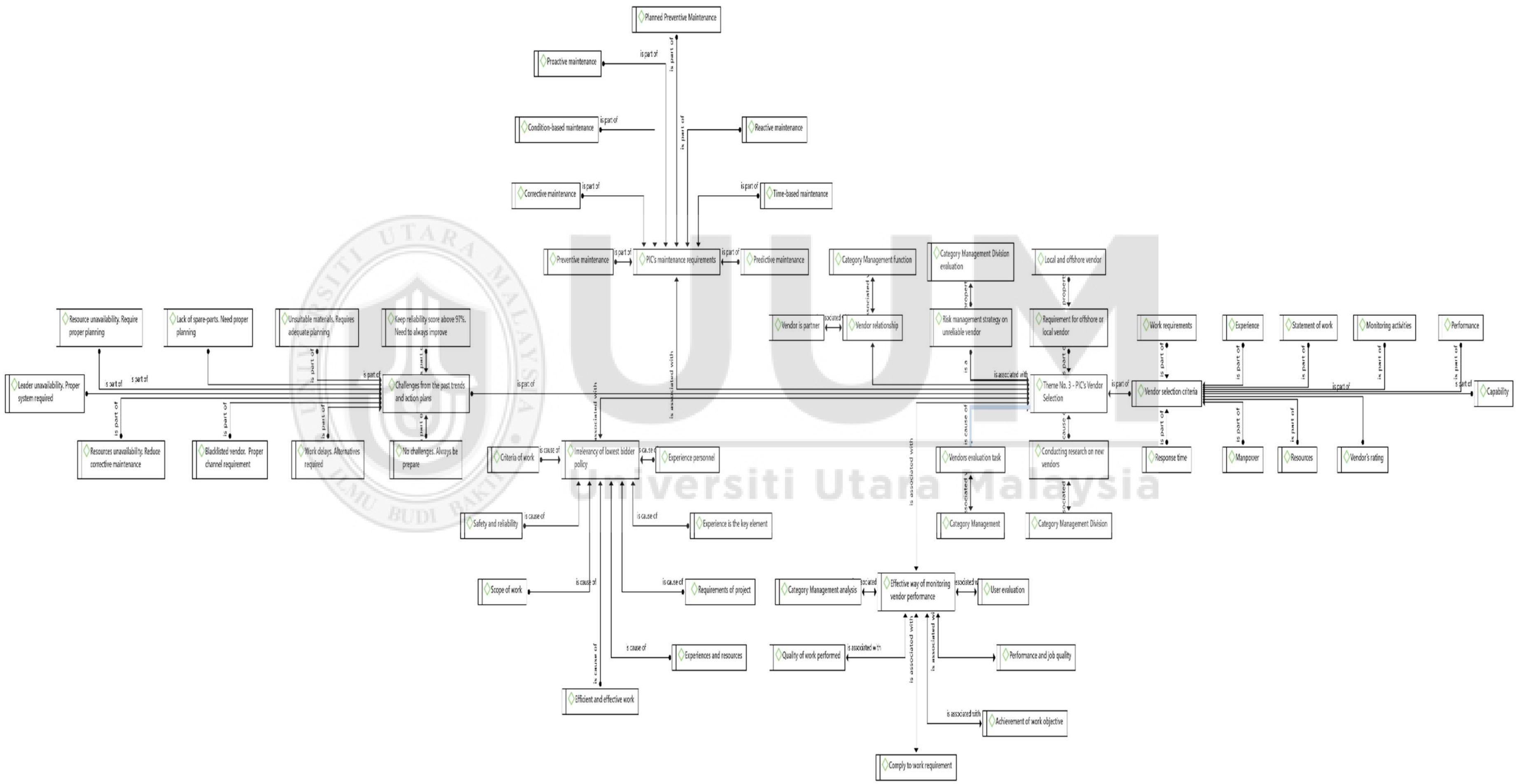
	Responses	**Times mentioned**	**Who mentioned**
i.	When vendor has been blacklisted by Category Management. Need to go through proper channel	1	Respondent 1
ii.	No leader to oversee everything. Need a proper system	1	Respondent 2
iii.	Lack of proper spare-parts and aging assets. Need to have proper planning	1	Respondent 3
iv.	Unsuitable materials for maintenance. Need to have adequate planning	1	Respondent 4
v.	Keep reliability score above 97%. Need to always improve practices	1	Respondent 5
vi.	Resources not available. Need to reduce corrective maintenance	1	Respondent 6
vii.	Resource unavailability. Need to have proper planning	1	Respondent 7
viii.	Work delays. Need to come up with alternatives	1	Respondent 8
ix.	No major challenges. Need to always be prepare	1	Respondent 9
x.	No major challenges. Keep up the good work	1	Respondent 10

Aspect 10. Vendor relationship management

	Responses	**Times mentioned**	**Who mentioned**
i.	Category Management Division	4	Respondent 1, 3, 4, 5
i.	Vendor as partner. Treat as own staffs	1	Respondent 2
ii.	Based on work. Treat as own staffs	1	Respondent 6
iii.	Good relationship	2	Respondent 7, 10
iv.	Good relationship. Treat as own staffs	2	Respondent 8, 9

Figure 4.3

Atlas.ti output for Theme No. 3 – Vendor selection



4.5.4 Theme No. 4: The effect of preventive maintenance on PIC performance

Theme No.4 relates directly to Research Question 4 as stated in Chapter 1 as part of the research which addresses the effect of preventive maintenance on PIC performance. The detailed breakdown of the interviews response for this research question is presented separately in Table 4.8 according to the themes and its significant statements. The summary of the findings is presented in Table 4.9. Responses from study participants demonstrated that current maintenance practice has been successful in helping the organization to be in good condition from an operational and profitability point of view.

Table 4.8
Significant Statements and Interpretative Meaning for the effect of Preventive Maintenance on PIC Performance

Significant Statements	Interpretative Meaning
Current preventive maintenance program satisfaction Satisfied	
▪ Yes, I am satisfied as we do not experience any major issue with regards to shut down, etc (Respondent 1) ▪ Yes, I am satisfied with our preventive maintenance program. (Respondent 2) ▪ Our reliability score is on the good reading. Therefore, I am satisfied with the maintenance program. (Respondent 3) ▪ Yes. All the maintenance program is being run in proper manner so I am satisfied with the current practice. (Respondent 8) ▪ Yes, I am. I am fully satisfied. (Respondent 10)	Maintenance personnel fully satisfied with the current maintenance practices
Maintenance project selection due to budget limitations Maintenance activities has to take place regardless	
▪ Yes. I never experience such thing as maintenance work need to take place regardless. (Respondent 1) ▪ Yes. But very seldom and it doesn't involve any cancellation of maintenance project. (Respondent 5) ▪ Yes. Some of the project being delays due to lack of budget. What we need to do is to wait for the approval of the new amount. (Respondent 8)	
Maintenance work performed based on priority	
▪ Based on priority. This one we have a system. (Respondent 1) ▪ Yes. This one is due to task priority and also the available resources. (Respondent 3) ▪ Maybe delays will happen. And sometimes, the work performed based on priority. (Respondent 4)	Maintenance work activities conducted based on priority

- . Budget limitation is not a new issue as new and more advance equipment's and tools becomes available. Therefore, it is up to the management to decide which project will take priority over others. (Respondent 6)
- Yes of course. Its all depends also on the priority. (Respondent 7)
- Sometimes the maintenance work has been performed based on priority. (Respondent 9)
- Yes. Certain project will take the priority over others due to budget limitation. (Respondent 10)

Preventive maintenance program success indicator

Zero downtime

- When we achieved zero downtime. (Respondent 1)

Zero downtime

Plan-do-check-act (PDCA)

- We run successful preventive maintenance program based on PDCA (Plan, Do, Check, Act). (Respondent 8)

Successful implementation of maintenance work indicates by PDCA

Reliability Score

- The indicator of success will be the Reliability Score. (Respondent 3)
- We have Reliability Score. (Respondent 4)
- When we are achieving 97% and above for our reliability score for all of our plants. (Respondent 5)
- We are running our maintenance program effectively by monitoring our reliability score. (Respondent 7)
- We can ensure to be running a successful preventive program when we achieved more than 97% reliability score for each of our plants. (Respondent 10)

The Reliability Score is the indicator for maintenance programme successfulness

Zero shutdown

- We can be sure to run a successful preventive maintenance when we achieve zero shutdown. (Respondent 6)

Zero shutdown indicates the success of maintenance work

Nonexistence of problem

- As I mentioned that we do not faced any major issue with regards to the maintenance program. Therefore, I am sure that we have a proper program in place. (Respondent 9)

No major problem faced was regarded as maintenance work success indicator

Preventive maintenance process effectiveness criteria

People, Environment, Asset, and Reputation (PEAR)

- Our assessment is based on the four critical elements to a company, which include People, Environment, Asset, and Reputation (PEAR)

People, Environment, Asset, and Reputation (PEAR)

Plan-do-check-act (PDCA)

- Job pack analysis. It's usually part of PDCA. (Respondent 2)

Plan-do-check-act (PDCA)

Reliability Score

- In evaluating preventive maintenance effectiveness, we will look at the reliability score. (Respondent 6)
- The effectiveness will be portrayed in terms of Reliability Score. (Respondent 8)
- We have the Reliability Score. (Respondent 9)
- The Reliability Score is one of the good elements in evaluating maintenance programme effectiveness. (Respondent 10)

Reliability Score as the criteria to measure preventive maintenance programme

Maintenance strategy

- Beginning of the year, we are given the maintenance strategy document. We will develop our maintenance planning based on this document. After that, we need to ensure all the maintenance activities are being performed and met all the required objectives. (Respondent 7)

Maintenance strategy contribute to the success of maintenance task

Budget allocation tor tools and equipment acquisition

<u>Sufficient</u>

- When we talk about maintenance work, we cannot run away from the budget. Cost for us to carry out the maintenance work.(Respondent 1)
- Now Petronas has introduced a platform called APM (Asset Performance Management). Based on this platform, we will sure that our budget is enough. (Respondent 3)
- Yes. However certain things will be required to be conducted even if it is not budgeted. Sometimes we will ask for a supplementary budget. (Respondent 4)
- Yes, and if we need to ask for additional budget, we will get the approval to do that. (Respondent 6)
- I think that we have sufficient budget for equipment and tool for our maintenance task. (Respondent 7)
- Yes. We have sufficient budget to perform our function at the most optimum level. (Respondent 8)

Sufficient budget to acquire maintenance equipment

Availability of advanced maintenance equipment

<u>Available</u>

- HQ will ensure all required maintenance equipment available, as best as they can. (Respondent 2)
- Yes. We have adequate equipment to perform our task. (Respondent 3)
- Yes. We have state-of-the-art maintenance equipment to complement our reputation. (Respondent 4)
- Yes. We have all the required equipment. (Respondent 5)
- Yes, it is. Therefore, our maintenance activities are being carried out accordingly. (Respondent 7)
- Yes, we do have. We always keeping pace with the latest piece of technology and equipment. (Respondent 10)

Adequate maintenance equipment

Preventive maintenance increases the organization's performance

<u>Agreed</u>

- In my opinion, our preventive maintenance strategy did increase our performance because we have high score of

reliability score and this benchmark is at the world standard. (Respondent 3) ▪ Yes. This is showcased in our excellent profit generation due to the preventive maintenance practice that implemented across the company. (Respondent 4) ▪ Yes, definitely. Our performance never being impacted as we use the correct maintenance strategy. (Respondent 5) ▪ Definitely. This is because any shutdown happens, the plant will be affected and the production will somewhat be negatively impacted. (Respondent 6) ▪ Of course. That is why we can see from the increase in performance for Petronas plants across Malaysia as we used preventive maintenance as our main method to ensure the continued operation of Petronas plants. (Respondent 7) ▪ Yes. We managed to record an increased in our profit on yearly basis. (Respondent 8) ▪ Definitely. We keep on improving our productivity. This is enabled as we have a proper maintenance philosophy in place. (Respondent 9) ▪ Yes. The performance is good due to appropriate preventive maintenance strategy that is put in practice. (Respondent 10)	Preventive maintenance contribute positively to PIC performance

In respect to the satisfaction of the current preventive maintenance program, all respondents reverted with their satisfaction.

> *"Yes, I am satisfied as we do not experience any major issue with regards to shut down, etc."*
>
> *Respondent 1*

> *"Yes, I am satisfied with our preventive maintenance program. Our reliability score is the evident of successful program that we put in place."*
>
> *Respondent 2*

Meanwhile, under the issue of maintenance project selection due to budget limitation, all of the respondents stated that this is something that cannot be avoided but the work still need to be done on a later date. The work chosen normally will be based on work ranking or work priority.

> *"Based on priority. This one we have a system. We create a system; we list all non-routine jobs that are not routine. So that the maintenance work will be done based on*

priority. We choose the maintenance work based on ranking which one need to be performed first."

Respondent 2

"Yes. This one is due to task priority and also the available resources. "

Respondent 3

"As I said before, we do not cancel any maintenance project. Maybe delays will happen. And sometimes, the work performed based on priority. Sometimes, certain project needs to happen first compared to other. In terms of budget limitation, we normally will ask for additional budget if required."

Respondent 4

"Yes. But very seldom and it doesn't involve any cancellation of maintenance project. It just that we need to ask for additional budget."

Respondent 5

"This one will fall under the decision of the management. We on the execution level, we will follow whatever the work planner has set for us. Budget limitation is not a new issue as new and more advance equipment's and tools becomes available. Therefore, it is up to the management to decide which project will take priority over others."

Respondent 6

In relation to the issue of preventive maintenance program successfulness, 50% of the respondents stated that this can be measured through the Reliability Score, 30% mentioned the zero downtime/shutdown and another 20% were based on Plan-do-check-act (PDCA) indicator.

"The indicator of success will be the Reliability Score. We have 97% and above reliability score for our plants."

Respondent 3

"We have Reliability Score. We know we are practicing a good and effective maintenance system when our Reliability Score is 97% percent at the minimum level for all our plants."

Respondent 4

"We are running our maintenance program effectively by monitoring our reliability score. As long as the score is good, then we know we are running an effective preventive program."

Respondent 7

"We can be sure to run a successful preventive maintenance when we achieve zero shutdown."

Respondent 6

"We run successful preventive maintenance program based on PDCA (Plan, Do, Check, Act)."

Respondent 8

In relation to the evaluation of preventive maintenance effectiveness, the Reliability Score also mooted as the main indicator with 70% of the respondents approved it. 10% stated the People, Environment, Asset, and Reputation (PEAR), another 10% mentioned PDCA (Plan, Do, Check, Act) and the balance 10% said the maintenance strategy.

"Reliability Score. We use this in evaluating preventive maintenance effectiveness."

Respondent 4

"By having the reliability score. We practice this method for the entire organization."

Respondent 5

"In evaluating preventive maintenance effectiveness, we will look at the reliability score. As long as we are meeting or above our aim, then we know that we are doing our job well."

Respondent 6

"Our assessment is based on the four critical elements to a company, which include People, Environment, Asset, and Reputation (PEAR)."

Respondent 1

"Job pack analysis. It's usually part of PDCA."

Respondent 2

"The process starts of by planning the maintenance activities according to the maintenance strategy. Beginning of the year, we are given the maintenance strategy document. We will develop our maintenance planning based on this document. After that, we need to ensure all the maintenance activities are being performed and met all the required objectives."

Respondent 7

In terms of sufficient budget allocation tor tools and equipment acquisition aspect, all of the respondents agreed that there is sufficient budget allocated for the function. If the budget is not enough, additional budget will be granted in order to ensure the maintenance work can take place.

"When we talk about maintenance work, we cannot run away from the budget. Cost for us to carry out the maintenance work. So, my hope is that the management or certain parties supply us with a sufficient budget to carry out the maintenance work so that we can achieve the most satisfactory level of quality, especially in terms of customer satisfaction."

Respondent 1

"Yes. However certain things will be required to be conducted even if it is not budgeted. Sometimes we will ask for a supplementary budget. If that thing is really urgent for us to make a replacement. For example, Victaulic coupling, we have an issue about it. We have had an incident about this Victaulic coupling. So, this issue come to our management's immediate attention. And we need a certain big budget to tackle this issue. So, things like that will be process immediately. It won't wait too long. So, continue the process of getting a budget. The execution took place instantly. This means that safety is one of the things that is considered as having a very high priority."

Respondent 4

Yes, and if we need to ask for additional budget, we will get the approval to do that. This is because maintenance is element that will determine the sustainability of our operation."

Respondent 5

The other aspect considered in Theme 4 was the availability of advanced maintenance equipment. Based on the responses, all respondents approved the availability of advanced maintenance equipment.

"Yes. As I said earlier, we have a sufficient system. HQ will make an analysis about any equipment that is needed."

Respondent 1

"HQ will ensure all required maintenance equipment available, as best as the can."

Respondent 2

"Yes. We have adequate equipment to perform our task."

Respondent 3

"Yes. We have state-of-the-art maintenance equipment to complement our reputation. Plus, safety and reliability are the two major aim for our function."

Respondent 4

"Yes. We have all the required equipment. Based on our work and the benchmark from other players in the industry, we are using the advance equipment in performing our tasks."

Respondent 5

The last aspect reviewed was whether preventive maintenance increased the organization's performance. The statement was approved by all of the respondent.

> *"Of course, because Petronas is an important entity. So, the performance needs to be taken care of and preventive maintenance can ensure that the company does not experience any shutdown that can affect the performance and reputation of Petronas."*
>
> *Respondent 1*

> *"Yes. With preventive maintenance we can be sure of our work planning and what to do."*
>
> *Respondent 2*

> *"In my opinion, our preventive maintenance strategy did increase our performance because we have high score of reliability score and this benchmark is at the world standard."*
>
> *Respondent 3*

> *"Yes. This is showcased in our excellent profit generation due to the preventive maintenance practice that implemented across the company."*
>
> *Respondent 4*

> *"Yes, definitely. Our performance never being impacted as we use the correct maintenance strategy."*
>
> *Respondent 5*

> *"Definitely. This is because any shutdown happens, the plant will be affected and the production will somewhat be negatively impacted. So preventive maintenance practiced at the moment is contributing to the organization's performance."*
>
> *Respondent 6*

> *"Of course. That is why we can see from the increase in performance for Petronas plants across Malaysia as we used preventive maintenance as our main method to ensure the continued operation of Petronas plants."*
>
> *Respondent 7*

"Yes. We managed to record an increased in our profit on yearly basis, Therefore, I can come to conclusion that our preventive maintenance philosophy is contributing positively to our good performance."

Respondent 8

"Definitely. We keep on improving our productivity. This is enabled as we have a proper maintenance philosophy in place."

Respondent 9

"Yes. The performance is good due to appropriate preventive maintenance strategy that is put in practice."

Respondent 10

In summary, the preventive maintenance in PIC is has allow them to plan and schedule effective maintenance work. A longer-term goal is to shift to a more predictive maintenance model in conjunction with PPM activities.

Table 4.9

The effect of preventive maintenance on PIC performance

Aspect	**1. Current preventive maintenance program satisfaction**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Yes satisfied	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Aspect	**2. Maintenance project selection due to budget limitations**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Yes. Maintenance work need to be proceeded regardless	3	Respondent 1, 5, 8
ii.	Based on priority	7	Respondent 2, 3, 4, 6, 7, 9, 10
Aspect	**3. Preventive maintenance program successfulness**		
	Responses	**Times mentioned**	**Who mentioned**
i.	Zero downtime	1	Respondent 1
ii.	Plan-do-check-act (PDCA)	2	Respondent 1, 8

iii.	Reliability Score	5	Respondent 3, 4, 5, 7, 10
iv.	Zero shutdown	1	Respondent 6
v.	No problem encounter	1	Respondent 9

Aspect 4. Evaluating preventive maintenance effectiveness process

	Responses	Times mentioned	Who mentioned
i.	People, Environment, Asset, and Reputation (PEAR)	1	Respondent 1
ii.	Plan-do-check-act (PDCA)	1	Respondent 2
iii.	Reliability Score	7	Respondent 3, 4, 5, 6, 8, 9, 10
iv.	Maintenance strategy	1	Respondent 7

Aspect 5. Sufficient budget allocation tor tools and equipment acquisition

	Responses	Times mentioned	Who mentioned
i.	Sufficient	4	Respondent 1, 2, 6, 8
ii.	Sufficient with APM (Asset Performance Management)	1	Respondent 3
iii.	Sufficient. If not, need to ask for additional budget	5	Respondent 4, 5, 7, 9, 10

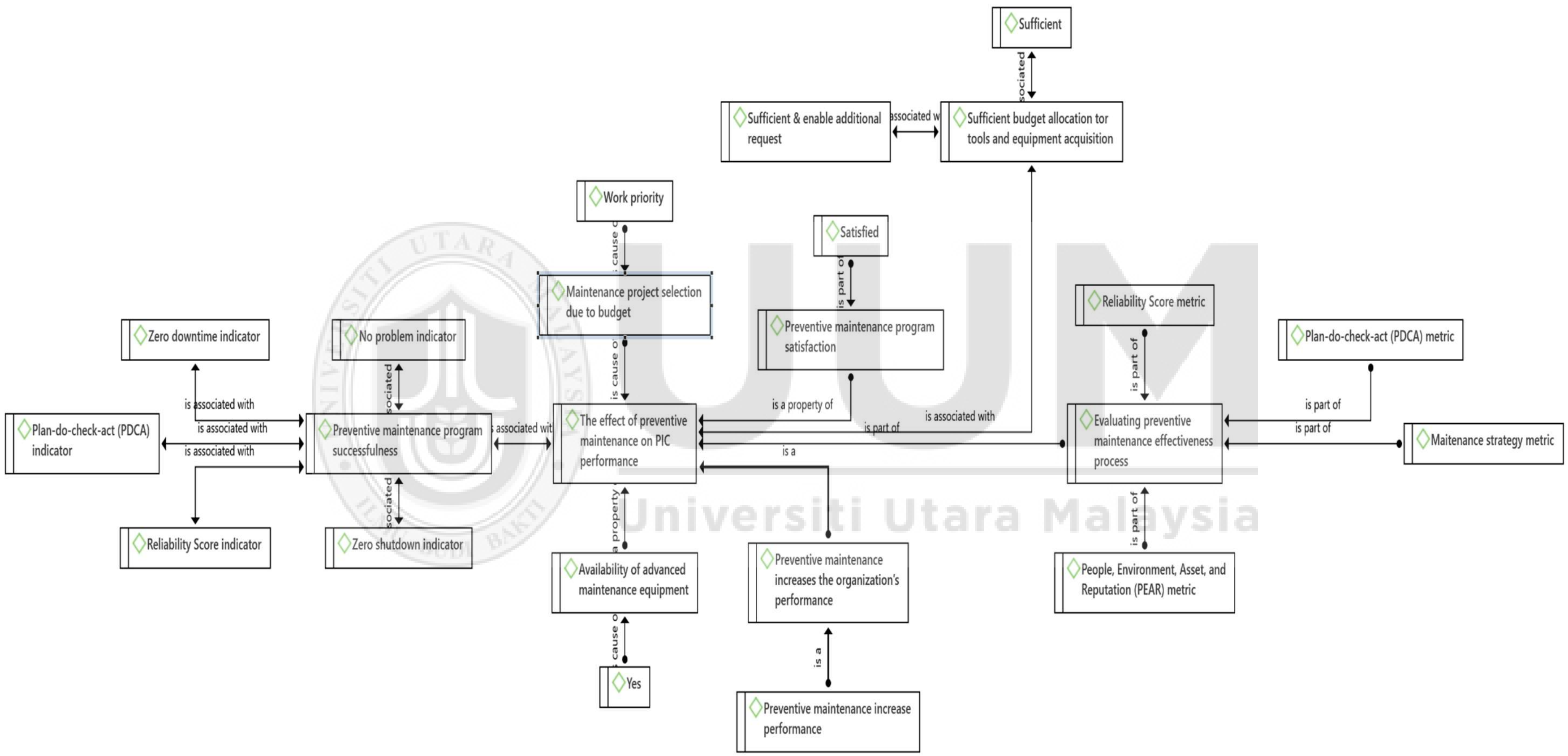
Aspect 6. Availability of advanced maintenance equipment

	Responses	Times mentioned	Who mentioned
i.	Yes	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Aspect 7. Preventive maintenance increases the organization's performance

	Responses	Times mentioned	Who mentioned
1.	Yes	10	Respondent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Figure 4.4
Atlas.ti output for Theme No. 4 – The effect of preventive maintenance on PIC performance



4.6 Chapter summary

The results and data analysis performed on the raw data from the preceding process through interview sessions, document reviews, and research observations are discussed in detail in this chapter. Transcripts of the raw data were created and used as inputs for the Atlas.ti software system, a useful tool for qualitative data analysis in studies and researches. This chapter also included a full presentation of the Atlas.ti output..

The following chapter, Chapter 5, which also includes recommendations for improvements in the practices, contains a thorough explanation and advice on how to handle the issue mentioned.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This final chapter begins by discussing the conclusion and recommendation for this entire study. Next, this chapter will also look at the implications of the study, the limitation of the study, recommendations for further study, recommendation for Pengerang Integrated Complex (PIC) and the conclusion of the study.

5.2 Implication of the Study

The analysis of the findings of the study reveals the practice of maintenance management in PIC which includes the main activities known as Integrated Turnaround Main Mechanical and Maintenance Mechanical Static (TA4MS). The TA4MS were examined in detail in interview, observations, and document reviews session. Accordingly, the findings of this study are able to provide important implications for theoretical (academic implication), methodological, and practical (managerial implication). The current study also proposed, appropriate maintenance implementation as well as the involvement of several parties in aspects of planning and formulating maintenance policy up to the implementation stage in PIC. The details of the discussion are described as follows.

The implication of this study in theoretical terms is exploring theories that include prioritization that reflect the desired performance pursued by PIC that involved organizational scheme in maintenance management practiced. In previous work, researchers involved in study with regards to turnaround maintenance from the perspective of, managing people (Ghazali & Shamim, 2014; Iheukwumere-Esotu & Kaltungo, 2020); quality management (Ghadaffi, 2020); value adding and non-value adding activities (Shou, Wang, Wu, & Wang, 2020); lean management (Tripathi, et al., 2021; Shou, Wang, Wu, & Wang, 2021); organizational context (Emiris, 2014), team alignment (Akbar & Ghazali, 2016); leadership and leader's behavioral characteristics (Khan, Ghazali, & Isha, 2014; Madhanga, Msosa, & Chikukwa, 2022); and turnaround maintenance optimization (Elfeituri & Elemnifi, 2007; Al-Marria, Nechi, Ben-Ayed, & Charfeddine, 2020). The current study highlighted the criteria of vendor's selection for PIC which were based on i) experience; ii) manpower; iii) resources; iv) tools; v) equipment; vi) quality of works; vii) performance; viii) response time; ix) vendor's rating; and x) work requirements. As a result, the study indicated that these elements were crucial as a basis for successful turnaround maintenance implementation. Hence, this study is able to bring significant results to all existing knowledge through its perception of technological capabilities. Findings from past studies have reinforced the research framework based on ranges of environments and situations. In this study, empirical data were gathered from Malaysia's oil and gas industry.

Generally, this study echoed the previous studies findings which stated preventive maintenance is vital for oil and gas operators (Bello, 2021; Sahli, Evans, & Manohar, 2021). As for the establishment of PIC is important for the nation, sustainability in the market is vital to ensure the continuity of existence in the O&G industry. Thus, the intention to sustain competitive advantage is important to PIC. The insights gained from the research contribute to the current thinking about the relationship between preventive maintenance and the intent to maintain a competitive edge. utilizing the technology and relevant capabilities of the system or strategy, which ultimately leads to real performance. This added value to the existing body of knowledge as a result of the overall framework.

Moreover, the theoretical contribution of the present study can also be seen by the organisation's understanding of its resources. The findings highlighted the fact that the company relies on the capability and availability of its resources to carry out maintenance activities, both internal and external. On that note, the Resource-Based View (RBV) strategy has been widely embraced as a powerful perspective for gaining a competitive advantage. Its core tenet is that the ability to acquire, deploy, and leverage intangible resources is the key determinant of a business's competitive position. The RBV can be used to help organizations identify and deploy strategies that create and sustain competitive advantage by understanding and managing the organization's unique resources.

The RBV can be a valuable tool for guiding turnaround maintenance efforts in troubled organizations. While traditional maintenance focuses on physical assets, an RBV approach emphasizes the organization's resources, structure and culture as well as its physical assets. By identifying and understanding the organization's intangible assets, strengths and weaknesses, an RBV approach can help prioritize which areas should be addressed first in terms of turnaround maintenance. This can result in a focused and targeted maintenance strategy tailored to the organization's specific challenges.

In addition, the RBV can help diagnose the key challenges facing the organization. This can enable the organization to manage its resources and address those challenges before they become more serious more effectively. For instance, understanding the organizational structure and culture can help identify areas where resources are being misallocated or wasted. Hence, the RBV can provide a model for assessing the sources of competitive advantage that the organization can use to become more successful. By understanding the unique resources and capabilities of the organization, it can be better positioned to develop and deploy strategies to gain a competitive edge and achieve long-term performance improvements.

Overall, the RBV can be a powerful tool for aiding turnaround maintenance in organizations. It can help identify and understand the underlying challenges of operation and direct the organization to target areas that need to be addressed. In addition, the RBV can help uncover areas of competitive advantage, enabling the organization to develop and implement strategies to build a sustainable future.

The magnitude of the current study likewise is viewed from the perspective of methodological. The originality of the thesis is also supported by its methodology. The methodology is based on exploiting the informational value of individual classification acts for the identification of relevant participant in an area of interest (Benabdelkrim, Levallois, Savinien, & Robardet, 2020). When field studies are used, methodological contributions may entail changes in the design of previous studies which; 1) Reduce potential variance problems in the shared method through the judicious use of several measurement methods; 2) Enhance the generalization of research through more appropriate sampling methods; 3) Enable the study of the plausibility of the "explanations of the third variable" for the results of past studies; and 4) Improve the conceptual validity of key metrics by using more specific multi-element metrics and/or measurement approaches that are not based on self-declarations (Asgari, 2015; Ågerfalk & Karlsson, 2020).

The current study utilized semi-structure interview session with relevant personnel attached to PIC uncovering issues pertaining maintenance practices in their company which are the first research in this kind conducted for the company. In addition, the observation approach also conducted to enhance the understanding of the researcher relating to matter under study. These approaches in addition to the review of PIC documents in justifying and explaining certain practices regarding PIC maintenance management practice which complements other O&G industry researches in terms of methodological contribution.

The study correspondingly have the impact on the managerial contribution in terms of developing a profile of top management contributions and to understand; 1) the way management work influences work processes and organizational outcomes; 2) factors that undermine management's contribution to performance; and 3) the way a "enabling environment" for management work can be assembled and maintained (Buchanan, et al., 2013; Sorce & Issa, 2021). The management functions are generally categorized as Planning, Organization, Leading and Controlling (POLC) regardless of the field of study (Harris, McCaffe, Baldwin, & Edum-Fotwe, 2020). In downstream activities, planning will allow work to be safer, more cost-effective and more efficient than unplanned work. Poor planning is costly as it leads to over-manpower, overtime, missed deadlines and costly urgent orders. Larger and precipitous operations and activities can create unsafe conditions. The elimination of inefficiencies and unproductive operating time contributes to safe, reliable and cost-effective operations (McCreery & Phillips, 2013; Sircar, Yadav, Rayavarapu, Bist, & Oza, 2021).

In terms of organization, today's downstream oil and gas companies must understand the old adage of resource scarcity. Consequently, businesses build large, complex organizations with strong centralized functions. This model enables them to address formidable technical challenges, manage major political and operational risks, and deploy rare talent around the world, as required (Handscomb, Sharabura, & Woxholth, 2016; Baro-Tijerina & Piña-Monarrez, 2021). Leading function for downstream oil and gas operators is to determine how the company can remain ahead of the competition. In doing so, the company have to be dynamic in addressing the issues such as increased competition, new technologies that open up unconventional plays, the rise of NOCs, large Independents and service companies (Shuen, Feiler, & Teece, 2014; Adeleke, Ajibike, Muuka, Darun, & Moshood, 2021). The last managerial function to be discussed is controlling. Companies are responsible for ensuring that all practices related to maintenance activities are monitored and controlled to ensure proper functioning operations. Companies put health, safety and environment (HSE), assets, production, local and public image at the forefront of their operations (Yakoot, Elgibaly, Ragab, & Mahmoud, 2021). Based on this understanding the downstream oil and gas operators such as PIC, need to be on top of thing in ensuring all facets of operation been run in the most effective and efficient manner. On that note, the finding of this research stated that the management need to understand the requirements of the maintenance program as the maintenance personnel requires as much assistance from the management as they can. The study also highlighted that the personnel involved in the maintenance has proper understanding on the task performed, know the required tools/equipment and well-versed with the practice employed by PIC. Hence, the only way forward for the PIC's maintenance strategy is the improvement from the all aspects of the operation such as upskilling the personnel, revising the required expenditure, and streamlining the reporting system. All in all the outcomes of the current study provided the necessary input to safeguard and keep the Reliability Score of PIC above the 97%.

5.3 Limitation of the Study

There are a few issues with this study that must be addressed. Limitations are typically related to the study's methodology and generalizability. The restrictions were specifically brought on by time and money restraints. The methodology's shortcomings in this study had a minimal impact on the study's findings. There wasn't much support for similar findings conducted by other academics in earlier chapters. No suitable measures were available. As a result, this study's decision to adopt the triangulation method of the study has certain drawbacks because there have been no earlier investigations. However, the researcher was aware of the limitations and chose to continue with the study in order to add to the body of knowledge for academics and business professionals.

The time period or duration was the next methodological restriction. This has to do with the maintenance staff of the PIC's availability and schedule times. The staff had a very constrained amount of time to organise the interview session. Appointments were occasionally cancelled at the last minute, which also cost time without data. Only a few staff members were willing to cooperate and attend the meeting, even though an invitation email was sent two weeks prior. This restriction was bypassed by sending a phone call and email reminder before the interview session. However, some employees are still unable to take part because of other commitments. Naturally, the researcher's time was limited while gathering qualitative data.

This study was solely done in PIC, as stated in the study's scope. Consequently, extrapolating the results to other industries or nations is irrelevant, and vice versa. The results on preventative maintenance practises, particularly the focus on turnaround maintenance to maintain competitive advantage in the context of that organisation, were also limited to respondents from one organisation. Therefore, it is challenging to draw generalizations.

5.4 Recommendation for Future Research

According to the conclusions of this study's triangulations, preventive maintenance competence is crucial for maintaining Pengerang Integrated Complex's (PIC) high performance. Regarding suggestions for future research, great performance in other industries can also be attributed to the ability to execute preventive maintenance. According to the findings of the semi-structured interviews, preventative maintenance capabilities can be utilized to gauge the relationship between maintenance practices and organizational performance. The results of the triangulation also show how important the research method is to the research design of any study. Future studies looking at the benefits of implementing turnaround maintenance to improve business performance may use this sort of research design. This is due to the fact that very few studies using the TAM in O&G operations have been carried out in Malaysia. Future researchers can also study different Petronas operations. Only PIC staff members are currently conducting this study. Additionally, Petronas engages in other business ventures, particularly upstream activities like the refining, trading, and marketing of crude oil and petroleum products as well as the production and marketing of petrochemical products. By soliciting suggestions and opinions from the other organization, Petronas' strategic and operational levels might be raised. As a result, Petronas' capabilities could be strengthened, which might boost the company's financial performance. Furthermore, this study can be carried out in other sectors and nations to enable generalizability. The findings can improve conceptualization, measurement techniques, and generalizability.

5.5 Conclusion

In the difficult and volatile oil and gas industry, operators are confronted with uncertainty to meet all challenges. The important thing is to know if the organization is managing stakeholder interests properly. In the case of PIC, the main stakeholder is the nation. Like any other corporate institution, profit is what matters. This underscored the importance of maintaining and keep on improving the organizational performance. In this context, PIC, must use the current and relevant technologies/system available the market. In addition, having personnel with adequate knowledge, capability, skill and competency are also a crucial element in achieving the organization objectives.

In a conclusive manner, this study has contributed to the literature on the TAM and it contribution to the organizational performance. The results of this study are expected to benefit PIC in particular and the O&G industry as a whole. Recommendations for future studies offer a few ideas for improvising this study. The insightful thought of this study hopefully will enable the PIC to achieve greater heights of excellence.

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QUESTIONNAIRE

THE INTERVIEW TRANSCRIPT

A QUALITATIVE STUDY OF PREVENTIVE MAINTENANCE PRACTICE IN MALAYSIAN OILS AND GAS INDUSTRY

Date : ______________________

Time : ______________________

Department : ______________________

Name : ______________________

Position : ______________________

Instructions (to be read to the interviewee)

These interview sessions were conducted as a part of A Qualitative Study of Preventive Maintenance Practice in Malaysian Oils And Gas Industry. The purposes of this research are:

- To identify how deep the knowledge of maintenance management in oil and gas operator, especially in the maintenance department.

- To identify in more detail about the issues that occur in maintenance management in this company.

- To provide an analysis of the study and also suggestions that can improve and enhance the maintenance management in providing a safe operating condition.

- To accomplish the company's shared values -"*Our values are embedded in our culture as the backbone of our business conduct, reflecting our sense of duty and responsibility in upholding our commitment towards contributing to the well-being of peoples and nations wherever we operate*".

This interview sessions will be audio-recorded and write out within a day of the completion of the interviews sessions. This is confidential information and it will only be use in this research study. The copy of written transcript from the interview will be given to interviewee. Interviewees were guaranteed complete secrecy and their responses will be kept completely confidential. The interview will be conducted in 5 mains topics. This entire interview is designed to take approximately one hour. The interviewee can freely ask any question regarding this interview session.

THE INTERVIEW SESSION RECORD

Part 1:	Introduction and Demographic Information

1. Tell me about yourself?

2. How long have you been in your organization?

3. What is your experience with Maintenance Management?

4. What technical training do you receive?

5. How would you describe yourself as a maintenance personnel?

Part 2:	**Research Question No.1**

How does the maintenance management system work in your organization? The intention is to seek out any information concerning work planning, the maintenance process and the problem of maintenance activities.

1. How do you plan your work activities?

2. Can you describe your work in this organization?

3. How do you feel about the work process in this company, especially in maintenance management activities?

4. What does maintenance mean to you?

5. What should be done to prevent problems?

6. Are you aware of schedule, corrective and preventive maintenance?

7. How many times have maintenance activities been delayed or cancelled and why?

8. Are you prepared to make observations or inspection with no instructions from your supervisor? If not, why?

9. Do you have any thoughts on the lack of maintenance monitoring activities?

10. What suggestions or expectations do you have for improving maintenance planning?

Part 3:	**Research Question No.2**

What policies have been applied to the vendor selection process in the company? The objective is to search for any information relating to the understanding of process of selecting suitable vendors that compliant with those regulations extends to the company's entire supply chain?

1. What are your company's supply requirements?

2. Who will evaluate potential vendors during the vendors selection process?

3. Do you need an offshore or local vendor?

4. What criteria would you follow when selecting suitable vendors?

5. When is the lowest bidder not the right choice?

6. How would you go about conducting research on new vendors?

7. In your experience, what is the most effective way of monitoring vendor performance?

8. What is your procurement risk management strategy against unreliable suppliers?

9 Are there any challenges with past trends and what action plans do you offer?

10. How do you manage your relationship with your supplier?

Part 4:	**Research Question No.3**

How is preventive maintenance carried out in this organization to ensure high performance? The aim is to obtain all information relating to preventive maintenance activities and the relationship with the performance of the company?

1. What is your process for planning preventive maintenance schedules?

2. Is preventive maintenance expensive?

3. Have you ever had to choose one maintenance project over another due to budget limitations?

4. What's your process for evaluating and updating maintenance procedures?

5. How you can be sure that you run a successful preventive maintenance program?

6. In your opinion, do think that budget allocated tor tools and equipment acquisition is sufficient?

7. Have appropriate or advanced maintenance equipment is available?

8. Do you think that preventive maintenance strategy can increase in equipment/system efficiency?

Part 5:	Research Question No.4

Why preventive maintenance is the chosen method in your organization? There are many ways in which preventative maintenance can help the company such as reducing overall maintenance costs, ensuring business continuity, promote health & safety, protect the environment and prevent lost production output.

1. Is preventive maintenance expensive?

2. Who is responsible for performing preventive maintenance tasks?

3. What can be included as the elements of a good preventive maintenance checklist?

4. What percent of the PM inspection/task checklists are checked to insure completeness?

5. Why preventive maintenance is better than other types of maintenance strategies?

6. What are the problems of preventive maintenance application?

Part 5:	Closing the interview Session

1. Is there something else that you might want to offer that I didn't specifically get some information about?

Verification

Name of Interviewee : ____________________

Section : ____________________

Signature : ____________________

Date of Interview : ____________________

Thank you for your time and willingness to participate in this research study. As mentioned earlier, this information is confidential, and it will only be used for this research project. You will receive a copy of the written transcript from this interview for your review.