Failure Mode And Effect Analysis On Risk Management At An Oil And Gas Survey Company In Indonesia

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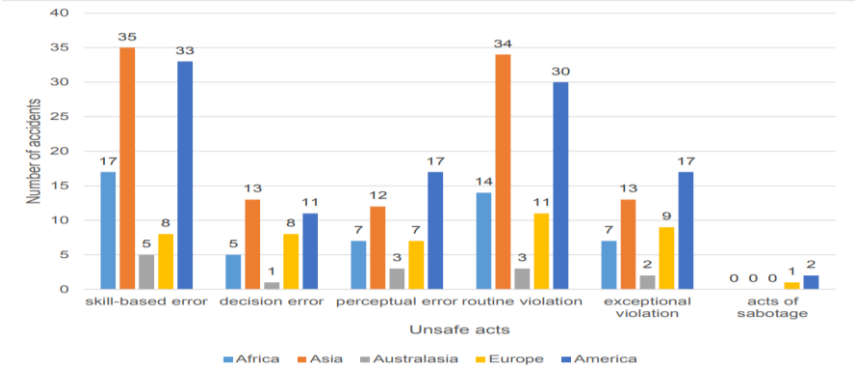
Abstract.

Asia is the second highest number of work accidents in the world after Africa. There are over 30% of major accidents experienced in the oil and gas industry triggered by inadequate maintenance. The fatal accidents in oil and gas accident increased from 2019 to 2022 in Indonesia. This qualitative study aims to analyze the risks that may occur in offshore oil and gas survey activities at Company X, an oil and gas survey company in Indonesia using Failure Mode and Effect Analysis (FMEA). Company X is a company that provides survey activities for oil and gas as the main service. Primary data are collected by interviewing the vessel manager, an Executive, and three employees involved in offshore oil and gas surveys. The FMEA steps are transcribing the answers, arranging them to make them easier to understand, providing a severity rating, setting the occurrence, detection rating, calculate the Risk Priority Number (RPN), prioritizing activities work that has highest RPN value, for determining long-term improvement strategies. The study reveals that the RPN for working accident turned out to be the highest from all risks which is 175 points, meaning that this risk has the highest ranking and need a mitigation as soon as possible. The recommended actions for this risk are regular maintenance for audits and inspections and upgrading FFA (Fire Fighting Appliances) and LSA (Life Saving Appliances) equipment.

Keywords*: Risk management, FMEA and off-shore geo survey.*

I. INTRODUCTION

It is important for companies not only to understand risks in oil surveying and exploration activities but also to prioritize them. This is because there are many risks, such as safety, security, health, social and environmental risks that companies must consider. The 2018 key performance indicators (KPIs) reported by the International Association of Oil and Gas Producers (IOGP) reveal surprising accident down trends in the oil and gas industry from 2009 to 2018. Despite this, the number of fatal accidents and fatalities has reduced drastically over ten years. Against the background of a 2% increase in work hours reported, the number of fatalities has decreased from 33 in 2017 to 31 in 2018. The 31 fatalities occurred in 27 separate incidents. The resulting fatal accident rate (1.01) is 8% lower than last year's figure (1.10). The company and contractor FAR are 0.31 and 1.20 respectively. Onshore and offshore FAR are 1.02 and 0.97 respectively. This raises questions about how strong safety measures are at oil and gas facilities. A study by Tokarski (2013) cited in Nwankwo, C.D. et al. (2022) revealed that more than 30% of major accidents experienced by the oil and gas industry were triggered by inadequate maintenance.



Source: Nwankwo, C.D. *et al.* (2022)

Fig 1. Unsafe Acts from HFACS-OGI Analysis [3]

Data from the Directorate General of Oil and Gas of 2019-2022 show that the accidents regarding oil and gas are high as shown in Table 1. In 2020 there were 109 minor accidents, 12 moderate ones, 3 serious accidents and 4 fatal accidents. Meanwhile, in 2019 there were 156 minor accidents, 16 moderate ones, 1

serious one and 2 fatal ones (TW, 2021).In the year of 2022 regarding oil and gas accident statistics, upstream oil and gas there were 75 work accidents where 67 accidents were minor, 6 were moderate accidents, 1 was serious and 1 was fatal. Meanwhile, in downstream oil and gas, there were 24 work accidents where 13 accidents were minor, 4 moderate, 2 serious and 5 fatal accidents (TW, 2022). Although the minor and moderate accidents numbers decreased significantly from 2019 to 2022, the fatal accidents increased.

Table 1. Oil and Gas Accident Statistic 2019 – 2021

Year	Minor accident	Moderate accident	Serious accident	Fatal accident
2019	156	16	1	2
2020	109	12	3	4
2021	80	10	3	6

Resource: Processed Data from *Kementerian Energi dan Sumber Daya Mineral, 2021 and 2022*

Given the high demand for oil and gas, the implementation of offshore seismic surveys, both in shallow and deep waters, is extremely crucial to discover oil and gas resources using survey vessels. With the increasing number of oil and gas resources that need to be surveyed to meet the global economic demand, especially in the maritime shipping industry, this has led to a significant demand for survey vessels. However, this does not mean that the safety and seaworthiness of these survey vessels can be disregarded. In fact, to support operations in offshore seismic surveys, seaworthy survey vessels are highly essential. This implies that every operating survey vessel must comply with all regulations as stipulated by various conventions from the International Maritime Organization (IMO), ranging from the vessel itself to safety equipment.In 2022, Company X, a leading provider of marine and land survey in Indonesia, has succeeded in properly implementing the HSE program and managed to achieve a zero fatality rate. Company X did not experience any occupational fatality, a death that occurs while a person is at work or performing work related tasks (IADC, 2023). Occupational fatalities are also commonly called "occupational deaths" or "work-related deaths/fatalities" and can occur in any industry or occupation. Neither, there were no Days Away from Work Case (DAWC), Restricted work day case (RWDC) and First Aid Treatment happened in the company.

However, Medical Treatment Case occurred once and there were three near-miss. A near miss is defined by the HSE as any event that does not lead to harm but does have the potential to cause illness or injury. Bearing in mind that as a company that is very concerned about work safety, strives to be zero MTC and near-miss. In addition, Company X is continuously committed to increasing the participation and awareness of its employees on HSE programs; since the workers who are in offshore areas must face a more serious risk because they are in the middle of the ocean, namely dealing with waves and wind currents and there is a high awareness of safety so that they can be equipped to work offshore (Migas, 2022; Murtopo and Chimayati, 2023). Therefore, it is important for companies to know and understand the risks of survey and exploration activities for oil as the main service offered by Company X. In addition, risk analysis and risk management in oil and gas survey and exploration activities are essential to help reduce or address these risks and develop effective risk management strategies. Failure Mode and Effect Analysis is the appropriate analytical method to use because it is a systematic and proactive method used to identify and analyze potential failures, their causes, and the resulting effects or impacts. FMEA is crucial in oil and gas surveys as it helps identify and mitigate risks associated with safety, environmental protection, asset integrity, operational efficiency, regulatory compliance, and decision-making.

II. METHODS

This study applies a mixed-approach with the explanatory sequential design, as figured out at Figure 2.

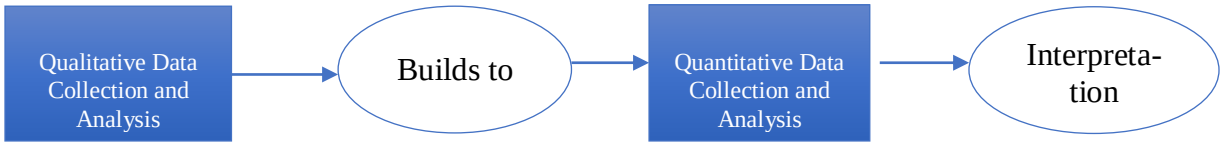


Fig 2. Mixed-Approach with The Explanatory Sequential Design

Mixed-approach with the explanatory sequential design is started by collecting and analyzing qualitative data. Then collecting and analyzing quantitative data in a second phase as a follow-up to the quantitative results. Next, connecting the phases by using the qualitative result to shape the quantitative research questions, sampling, and data collection.This study is in the field of Risk Management. Risk management refers to the process of identifying, analyzing, evaluating, and mitigating risks in order to minimize their negative impact on an organization's objectives or projects. It is an essential part of effective decision-making and planning, as it allows businesses and individuals to anticipate potential problems and take measures to avoid or reduce their adverse effects.This study in particular exploring Failure Mode and Effect Analysis (FMEA) suggested by Stamatis (2019). FMEA is a structured approach used to identify, analyze, and prioritize potential failure modes (or ways in which a process or system can fail) and their potential effects on the overall performance or quality of a product or process. FMEA is commonly used in various industries, such as manufacturing, automotive, aerospace, healthcare, and engineering, as a proactive tool to prevent or mitigate potential failures before they occur.The research object is a leading company of marine survey and underwater services in Indonesia, including the telecommunication industry for the cable installment and maintenance, also have been investing in technology, and infrastructure. In this study the company is identified as Company X. It also has numerous well-known clients, like Pertamina, Chevron, and Petronas.

Data Type and Data Collecting Method

This study employs primary data, the risks that may occur in offshore oil survey and exploration activities, and risk management implemented by the company. To get those data, semi-structured interviews are conducted with The Vessel Manager, Procurement Executive, Vessel Operation Officer, Seismic Officer, and Oceanographer Officer (Costa, 2022). They have been in the company for more than two years.

Data Analysis Tool

The scripts of the interview answers are analyzed based on Failure Mode and Effect Analysis template suggested by Institute for Healthcare Improvement. Failure Mode and Effect Analysis (FMEA) is a systematic approach used to identify and analyze potential failures in a process, system, or product, as well as their potential effects on performance. The primary goal of FMEA is to proactively prevent or mitigate failures before they occur, thereby improving reliability, safety, and overall performance.

An effective FMEA steps involved:

1. Conducting brainstorming on potential hazards of work accidents from potential failure modes.
2. Summarizing potential hazards posed for each work accident.
3. Assigning severity rankings for each potential hazard (magnitude of potential effect).
4. Determining occurrence rankings (probability of failure occurrence).
5. Determining detection rankings (probability of issue detection before hazard emerges).
6. Calculating the Risk Priority Number (RPN) for each activity.
7. Prioritizing work activity tasks with the highest RPN values for follow-up actions.
8. Prioritizing work activity tasks that also have RPN values as the basis for decision-making in determining long-term improvement strategies.

Basically, FMEA consists of two stages; the first step is to identify the potential failure modes and decide the value of Occurrence (O), Severity (S) and Detection (D). These values are used for calculating RPN number with Equation. After this step, the manager should make recommendations for correcting actions, and the RPN needs to be re-calculated after these corrective actions (Chin, Wang, Poon, and Yang, 2009; and Hu, Hsu, Kuo, and Wu, 2009):

RPN = S * O * D. The risk factors for severity, occurrence, and detection are determined by engineers and specialists by using 10-point scales in traditional FMEA. Generally, the highest importance value is obtained from the highest RPN parameter and the failure modes with higher RPNs are assumed to be more important and will be given higher priorities for correction (Adar, Ince, Karatop, & Bilgili, 2017; Wang, Chin, Poon, & Yang, 2009).

III. RESULT AND DISCUSSION

Risk Types

From the interviews it is identified that at Company X there are low risk, medium risk, and high risk categories. The 13 risks stated by the informants are:

1. safety risks
2. weather risks
3. environmental risks
4. technical risks
5. supply risk
6. operational risks
7. demand risk
8. security risks
9. regulatory risk
10. cost risk
11. health risks
12. social issues and hamper operations
13. time risk

Risk Awareness and Risk Management

The analysis reveals that employees understand the main objectives of offshore oil and gas survey activities, namely: Exploration geological structures that have the potential to contain hydrocarbons, development, risk management and provision of up-to-date data. They also understand the performance standards. They are QHSE standards and company policy from Company X and client, Cooperation, attention and communication, safety, environment, data quality, and efficiency. They have awareness that working offshore carries greater risks than working onshore. If an accident occurs, it is not easy to get help and take longer time. Sometimes, the survey location is far from medial centres or hospitals, for example at sea around Papua.Personnel awareness that the survey equipment used is electronics. Carrying out offshore surveys, the team carries various types of liquids, including liquid hazard, as fuel and also lube oil. When carrying out work supported by several other vessels called a support pool, a lot of transfers occur, starting from personnel transfers, then transfers of fuel and food, all of which, if not done carefully and safely, can cause collisions between boat. For this reason, it is necessary to have fenders, safety guards, on the side of the ship.

Regarding the environment, if an incident occurs, namely pollution caused by an oil spill, pollution caused by a spill of lube oil, which is on a massive scale, will be able to affect the ecosystem at that location.In terms of relations with the community around the area surveyed, it is likely that there will be friction with activities, with local communities whose livelihood is fishing, or are on the island, such as fishing activities. Before the operational survey is carried out, there will be more socialization than before, for example from the first day to the 60th day, there will be operational survey activities. socialization was carried out with local fishing groups. Collaboration is also carried out with several agencies, such as the Department of Fisheries, or with the readiness of the airport in place, to inform activity plans. So, it is hoped that when the survey team arrives, they will have noticed and be aware of the team's arrival.Risk management implemented by Company X is based on a standard, operating procedure, implementing safety training, having a weather monitoring system and weather prediction data not only from meteorology, climatology and geophysics agency (BMKG} and Center for Maritime Meteorology but also employing vendors that provides weather forcast data per hour, holding outreach to local fishermen and policy – involving fishing ministery at the province, carrying out routine maintenance on measurement tools.

The Result of FMEA

The answers given by five informants are then put together into a big list. After that, Failure Mode and Effect Analysis (FMEA) is applied. Table 2 describes the result of Failure Mode and Effect Analysis (FMEA) on Risk Management at Company X.

Table 2. The Result of Failure Mode and Effect Analysis

Types of risks	Potential Failure Mode	Potential Effect of Failure	Severity	Potential Cause of Failure	Occurrence	Current Process Control	Detection	RPN	Recommended Action
Safety	Work accident	Deterioration of the company's image regarding K3 culture	7	Lack of K3 implementation in the company	5	Permit to Work Fireman Watcher Emergency Drill	5	175	Regular maintenance for audits and inspections Upgrade FFA & LSA Equipment (Fire Fighting Appliances & Life Saving Appliances Equipment)
Security	Delivery security and security of goods that the company supplies	Loss of reputation, loss of cemmercial, loss of time	4	Leaving aside risk analysis and mitigation	6	Data from the manual book for each component. Then summarized in PMS (Planned Management System).	6	144	Close monitor for supply chain management for each department Runs an automation program for Action Point List to do
Technical	Data collection is less accurate	Hampering operations	4	Technical failure of surveying equipment	5	Carry out routine maintenance on measurement tools	5	100	Use of good equipment Routine inspection procedures Commitment to quality
Weather	Weather problem	Hampering operations	4	Bad weather Storm High sea waves	3	The company has a weather monitoring system and weather prediction data	4	48	Predictive data analysis and continuous monitoring
Environment	Environmental incident	Raising social issues Hampering operations	5	Drilling is carried out inside/beachside	2	Oil drilling is carried out offshore/ocean	4	40	Comply with environmental regulations and be responsible for the marine environment

The FMEA RPN (Risk Priority Number)

FMEA RPN has widely known as a Risk Priority Number (indicator) in an FMEA. Risk Priority Number is a numerical assessment of the risk priority level of a failure mode/failure cause in an FMEA analysis. It helps the responsible team/individual prioritize risks and decide on the corrective actions. Here is how it is calculated. FMEA RPN is calculated by multiplying Severity (S), Occurrence (O) or Probability (P), and Detection (D) indexes. Severity, Occurrence, and Detection indexes are derived from the failure mode and effects analysis. Table 3 presents the RPN values.

Table 3. The FMEA RPN of Company X

Types of risks	Severity	Occurrence	Detection	RPN
safety	7	5	5	**175**
security	4	6	6	**144**
technical	4	5	5	**100**
weather	4	3	4	**48**
environment	5	2	4	**40**

Source: Processed Primary Data

From Table 3 it is known that the RPN highest value is safety and the lowest is environment risks. The RPN can be used to prioritize high-risk issues and determine the requirement for corrective action. Most companies prioritize risks from the highest to the lowest RPN. Based on Relyence User Guide (2023) RPN can be color-coded to help visualize the risk levels and prioritize the corrective actions. For example, one common color-coding scheme is to use green for low-risk RPNs, yellow for medium-risk RPNs and red for high-risk RPNs . The ranges of RPN values for each color can be customized according to the specific needs and criteria of the FMEA team. For instance, one possible color-coding scheme is:

- Green: RPN <= 125
- Yellow: 125 < RPN <= 500
- Red: RPN > 500

This means that technical, weather, and enviroment risks which have green color are considered low-risk and may not require immediate action, while safety and security risks with an RPN between 125 and 500 is considered medium-risk and may require further investigation or monitoring.

Safety Risk

Based on the data obtained, the potential failure mode from the safety type of risk is working accident. The working accidents are fire, burn, injury, explosion, damage of eyes, burns, and electric shock. In this term, those accidents can affect employees, work place, and reputation of the company. The potential cause of failure is the lack of K3 implementation in the company. The current process controls are permit to work, fireman watcher, and emergency drill. The RPN is counted based on severity times by occurrence times by detection rating (Stamatis, 2019; 53). The RPN for working accident turned out to be the highest from all risks which is 175 points. It conveys that this risk has the highest ranking and need a mitigation as soon as possible.

Security Risk

The potential failure mode from the security type of risk is delivery and security of goods that the company supplies. The potential effect of failure is loss of reputation, loss of commercial, and loss of time. This risk can happen because the company quite often leaves aside risk analysis and mitigation. It goes with the study done by Manggalou, Nafi'ah and Uang (2023) that stolen panel is a part of the risk. Even with doing process control by complying data from the manual book for each component then summarized in PMS (Planned Management System), the RPN score is still quite high which is 144 points.

Technical Risk

The potential failure mode from the security type of risk is less accurate data collection. The potential effect of failure is hampering operations. The risk can happen because of technical failure of surveying equipment, with the occurrence of the cause is ranked 5 with the probability of occurrence is moderate or "occasional failures" with the chance of 1 per 80 activities. The current process control of the company is carrying out routine maintenance on measurement tools. The risk itself is quite detectable, ranked 5, and the likelihood of detection by process control as moderate chance the process control will

detect potential cause/mechanism and subsequent failure mode. The RPN score is 100, which is in the limit of the risk that categorized as high prioritized risk that needed to be mitigated as soon as possible.

Weather Risk

It is found that, weather problem is the main potential failure mode of weather risk. It becomes the main potential failure mode, because the effect of the failure is hampering operations, with the severity ranking scored at 4. The failure can happen because of bad weather, storm, and/or high sea waves. However, the company already has a weather monitoring system and weather prediction data. The RPN score is lower than other risks above, it is 48 points.

Environment Risk

Based on the data obtained, the potential failure mode is environmental incident which has the effects to raising social issues and hampering operations. The potential cause of failure is that drilling is carried out inside/beachside and only occur 1 per 15,000 activities, ranked 2, which categorized as remote or "failure is unlikely". The current process control of the failure from the company is oil drilling activity is carried out off shore/ocean. The social issues that may occur are from the fishermen whose sea area where they usually fish is in the survey area. Even though the sea is so wide, they do not want to move when the area they usually visit is used for survey activities. One risk is damage to fish cages installed by fishermen at sea due to being hit by passing vessels. An agreement and socialization needs to be made that if the cage is damaged, the damage party will replace it with money (for example IDR 1,000,000/cage). The agreement must be in writing accompanied by a list of the names of fishermen whose livelihoods are disrupted by survey activities. The agreement must be signed by all involved and witnessed by local government institutions. This is to prevent fake complaints from occurring. Fake complaints can be in the form of demands that are greater than the agreement and an increase in the number of fishermen who submit claims. Fake complaints result in cost risks. The RPN score is the lowest from the other risks, at 40 points.

IV. CONCLUSION AND RECOMENDATION

The RPN for working accident is the highest from all risks which is 175 points. It means this risk has the highest ranking and need a mitigation as soon as possible. RPN score of security risk is still quite high which is 144 points.The recommended action for safety risk is regular maintenance for audits and inspections and upgrading FFA (Fire Fighting Appliances) and LSA (Life Saving Appliances) equipment and the recommended action for the security risk is close monitor for supply chain management for each department and runs an automation program for Action Point List to do. The recommended actions for the security risk are close monitor for supply chain management for each department and runs an automation program for Action Point List to do. The recommended actions for technical risks are using good equipment, having routine inspection procedures, and committing to quality. The recommended action for weather risks is using predictive data analysis and continuous monitoring for weather changes. The recommended action for environment is that the company is complying with environmental regulations and be responsible for the marine environment.This study succeeded interviewing the vessel manager, one executive and three employees, however, it fails in involving top management levels to be the informants with respect to the high level of activities that directors and other managers have. Thus, it is recommended that similar research be conducted involving more management.

V. ACKNOWLEDGMENTS

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