Analyzing the Safety Risk Factors and Adaptation Measures in Downstream Oil and Gas Industry

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Existing risk management practices in Downstream Oil and Gas Industry (DOGI) are ineffective in reducing the frequency of incidents and delays in the turnaround projects. The underestimation of safety risk impacts during the turnaround projects is the root cause of shocking accidents and delays in the DOGI. The paper focuses on analyzing the critical Safety Risk Factors (SRFs) and the potential Risk Adaptation Measures (RAMs) associated with turnaround projects. Current literature was reviewed to explore the complexity of risk management approaches and design a questionnaire survey based on the literature findings. The survey was conducted via online, and the collected data based on 72 samples were analyzed to identify the critical SRFs and the effective RAMs using the relative risk index method. Interviews were conducted with experts to evaluate the survey findings. It is found that SRFs such as fire and explosion hazards are the most critical, followed by slips, trips, and falls; confined space; motor and vehicle accidents and injuries. The study reveals that increasing safety awareness and empowering to key staffs may be an effective way of mitigating the safety risks. The paper concludes that there is strategic difference in risk assessment practices and adopted technology in safety risk mitigations between underdeveloped and developed countries.

Key Words: Oil and gas projects, downstream, safety risk factors, maintenance, and turnaround.

Introduction

Compared to other projects, Oil and Gas Projects (OGPs) are recognized as highly technical projects and complex in nature. And they have a high level of uncertainty, which forces the stakeholders to analyze Safety Risk Factors (SRFs) carefully and adopt appropriate risk management strategies in the projects (Kraidi et al., 2020a). In other words, there are an unidentified number of SRFs, and safety hazards associated with the OGPs due to the volatile nature of the transportation and refining processes of the petrochemical products. However, the stakeholders in OGPs often underestimate or overestimate the SRFs and their impacts on performance, especially turnaround maintenance projects (Karner, 2010). OGPs are divided into three sectors: upstream, midstream, and downstream. Upstream projects deal with exploration and drilling activities and extracting crude oil and natural gas from the ground. Midstream projects involve the infrastructure and facilities transporting extracted products to the

refinery from upstream projects. Downstream includes refinery facilities and linkage to petrol stations and other consuming units (Kraidi, 2020). As shown in figure 1, this paper focuses on the safety risk and the delay in the turnaround maintenance projects in the Downstream of the DOGI.
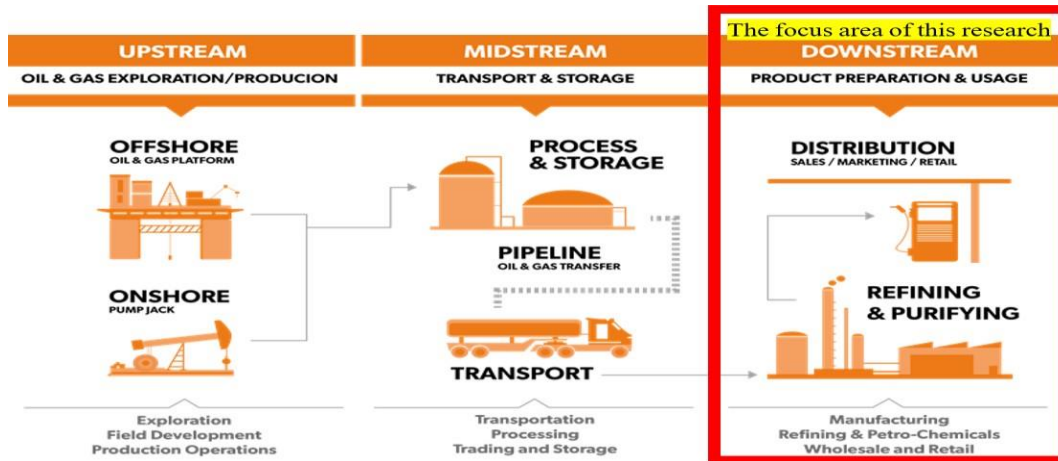

Figure 1. Upstream, midstream, and downstream projects in the oil and gas industry (Kraidi, 2020).

The insufficient and uncertain information about the SRFs and their root causes and the inaccurate estimation of their severity and impact levels on the projects untimely lead to ineffective decision-making during the risk analysis and management processes in DOGI (Aven and Thekdi, 2019). Risk management is driven by uncertainty resulting in time and cost not being estimated effectively, poor specification of project requirements, unforeseen events within the project, and asymmetrical objectives and ground priorities in the projects (Badiru and Osisanya, 2016). Counting, the unpractical maintenance projects in the DOGI sector usually obscure the efficiency and functionality of this industrial sector in different ways, such as shutting the projects down and increasing the cost of the fixing, repairing and replacement work.

Although risks, accidents and failures cannot be avoided entirely in any project, they can be controlled and mitigated by using effective risk management strategies throughout the lifecycle of the projects (Kraidi et al., 2020b). Assessing and ranking the SRFs regarding their degree of influence on a project is significant because dealing with each risk as if it is the most critical one results in substantial losses in terms of resources (Kraidi et al., 2019). Therefore, it is vital to analyze the SRFs in a project accurately, as providing accurate results about the degree of impact of the SRFs enhances the outcomes of the risk management system. Consequently, adequate risk identification and precise risk analysis will enhance the stakeholders' strategies and plan to provide more practical risk adaptation measures in their projects (Bitkowska, 2018).

This paper aims to carefully identify and accurately analyze the RFs associated with OGPs in the turnaround project and suggest the potential Risk Adaptation Measures (RAMs). These measures could be helpful to mitigate the SRFs in the DOGI by evaluating their degree of effectiveness in the projects. The study findings will ultimately help to the decision-makers to identify a sound risk assessment while developing the execution plan for turnaround maintenance projects. The objectives of this paper are:

- To identify the SRFs associated with the turnaround maintenance projects in the downstream sector based on a comprehensive literature review and gain an in-depth understanding of project risk adaptation measures.

- To analyze and rank the SRFs in the DOGI based on their degrees of impact on the projects.
- To enhance the understanding of the RAMs and their effectiveness levels in the DOGI.
- To highlight the crucial difference between SRFs associated with the DOGI in underdeveloped and developed countries.

Literature Review

The oil and gas industry has constantly faced challenges in both developed and underdeveloped countries worldwide. Some of these challenges are caused by the lack of understanding of the SRFs in OGPs (Casa et al., 2009). Furthermore, distributing petrochemical products between upstream and downstream in oil and gas projects is a hazardous process that requires an efficient risk management system. Therefore, the projects in the DOGI are continuously designed, operated, maintained, and managed in a way where risk adaptation is the priority. Besides there are contending views on the effective delivery of turnaround maintenance projects in the DOGI because of the complexity and the cost overruns, which are widespread problems in these projects (Cooper et al., 2005). However, a practical risk adaptation framework could contribute to reducing the project complexity by providing a more insightful understanding of the SRFs and the RAMs and their effectiveness degree in the projects (Kraidi, 2020; Kraidi et al., 2021b).

On the other side, the DOGI requires effective turnaround maintenance, which is "a planned stoppage of production for conducting a comprehensive maintenance of plants and equipment to restore the processes to their original state" (Al-Turki et al., 2019). This is because practical turnaround maintenance projects in DOGI have a success rate of 80% in keeping the refineries operating without shutting down periods (Obiajunwa, 2012). At the same time, an effective turnaround maintenance practice requires proper identification of the SRFs in the projects, as defending a system from an unknown risk is impossible (Kraidi et al., 2021b). Moreover, it requires an accurate assessment and ranking of the SRFs regarding their degree of influence on a project, which is a significant step in the risk management process. Because dealing with each risk as if it is the most critical one results in substantial losses in terms of resources (Kraidi et al., 2019a).

Therefore, this paper conducted an inclusive literature review to identify the SRFs threatening the DOGI comprehensively. As presented in Kraidi (2020) and Kraidi et al. (2021), the literature review has identified but not limited to the following RFs in OGPs.
- **Client risk**. Such as the government relegating RFs; delays in the process and payments; and constant changes in the legations, etc.
- **Contractor risk**. For example, lack of experience; improper training for the staff; execution errors; shortage and low labor productivity and injuries, etc.
- **Planning and feasibility study**. Such as improper project feasibility study; lack of data accuracy and survey information; frequent change of designs; and wrong project cost and schedule estimation, etc.
- **Tendering and contract risk**. Like inadequate tendering; lack of detailed and unclear items; unclear terms and conditions; and poor contract management, etc.
- **Resources and material supply risk**. For example, delays in the delivery of materials to the site; fluctuations in the materials' cost; poor quality of construction materials and shortage of modern equipment, etc.
- **Project management risk**, which could be because of an inappropriate organizational structure; a lack of effective communication and coordination; poor planning and controlling for scheduling, and budgeting; an ineffective quality control; an unclear description of responsibilities and duties of staffs; and difference between the safety cultures of the team, etc.

The literature review has highlighted some of the RAMs in OGPs. Such as increasing safety awareness and authority of the project managers; reducing the complexity of the process; improving communications; changing the existing strategies; improving budget planning; extending the schedule and scope reduction (Kraidi et al., 2021a).

As explained in the rest of the paper, the SRFs and RAMs identified via the literature review were used to design an online questionnaire survey, which was used to analyze the impact of the SRFs and RAMs in the DOGI. The ethical committee board at Liverpool John Moores University has approved the questionnaire survey before distribution. The risk was very minimal, and all the data were protected and dealt with carefully. In addition to the questionnaire survey, interviews from industry expertise were conducted to enhance the understanding and evaluate the survey findings in the DOGI.

Research Methodology

This paper adopted a mixed research methodology that includes qualitative and quantitative risk identification and analysis methods. The SRFs in the DOGI were identified based on current literature review about the potential risks that threaten turnaround maintenance projects in the DOGI. The SRFs and RAMs in the OGPs were identified via the literature review then they have been listed in a questionnaire survey to analyze their probability and severity levels on a five-point Likert scale. The online survey was created using Google Forms and it has been sent to the potential participants via email. The questionnaire survey has been designed in four sections as follows.

- Section I introduced the research topic and the survey's aim to the participants. The participants were also asked about their country of work, occupations, and experience levels.
- Section II highlighted the projects' most common factors and analyzed their probability and severity levels in the DOGI.
- Section III compared the SRFs associated with the turnaround maintenance projects in the DOGI in different locations and countries. Moreover, the survey has tried to understand the difference between RFs and safety standards in developed and underdeveloped countries.
- Section IV focused on evaluating the effectiveness levels of different RAMs that could be used to understand maintenance projects in the DOGI.

The qualitative part of this paper was about enhancing the knowledge and understanding of the RFs and the RAMs in the turnaround maintenance projects in the downstream industry. The interview focused on evaluating the survey results by highlighting the common SRFs in the DOGI and analyzing their levels of impact on the projects. The interviews also focused on the difference between the SRFs in different projects and locations. Finally, the survey tried to evaluate the effectiveness of RAMs that could be used to mitigate the SRFs in the turnaround maintenance projects in the DOGI.

Results

Due to the nature of human observations and responses, surveys may come with a range of errors. Therefore, testing the reliability levels of the data collected from research surveys is important. Keeping the data of the study confidential reduces personal biases during data collection and helps avoid any threats to the reliability and validation levels of the survey (Dzudie, 2013). Cronbach's alpha correlation coefficient (α) has been calculated to assess the reliability level of the questionnaire survey. It measures the average correlation and the internal consistency of the survey items and between the respondents' answers (Cronbach, 1951; Webb et al., 2006). The value of α equals 0.7 means the survey results are

above the minimum level of reliability (Prasad et al., 2019). The reliability of the survey was 0.81, which is above the acceptable value of 0.7.

The survey was sent to 130 potential participants, who work in the oil and gas industry. The potential participants were randomly selected and contacted via email, Linked and other social media platforms industry. 72 out of 130 participants have completed the questionnaire survey with a response rate of 55.6%, which is acceptable as per (Kraidi et al., 2021b). Figure 2 below explains the participants' demographic information, which are the country of work, experience, and occupations.
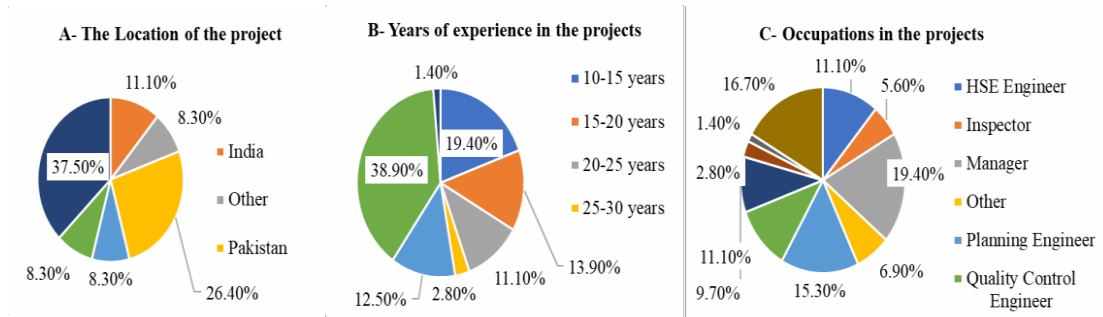

Figure 2. Participants' demographic information: country of work, experience, and occupations.

According to the survey's results, it was found that health and safety-related risks are the most common SRFs in the turnaround maintenance projects in the DOGI. Moreover, the fire and explosion risk under health and safety have the highest probability of threatening the turnaround maintenance projects in the DOGI, followed by slips, trips, and falls; confined space risks; motor vehicle accident risks and injuries; as shown in figure 3 below.
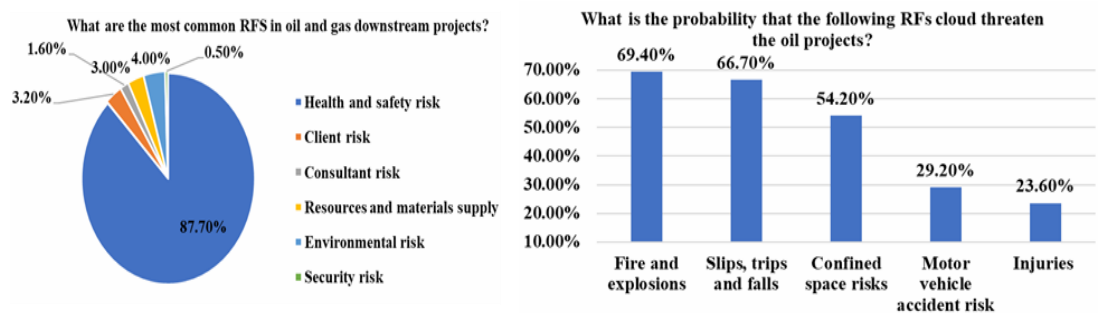

Figure 3. The most common safety risk factors in oil and gas projects and their probability levels.

The impact of the Safety Risk Factors (SRFs) on the projects was evaluated against a six-point Likert scale, as shown in table 1 below. The survey results showed that the fire and explosion-related safety risks are the critical factors with the highest impact on the turnaround projects in the DOGI, followed by slips, trips, and falls; confined space; motor and vehicle accidents and injuries-related RFs, which is lowest impact on the project.

Table 1

The severity levels of the safety risk factor in the oil and gas downstream projects.

Safety Risk Factor (SRFs)	Very high	High	Moderate	Low	Very low	No effect
1. Fire and explosions	55.6%	13.9%	11.1%	5.6%	5.6%	8.3%
2. Slips, trips, and falls	47.2%	20.8%	15.3%	5.6%	9.7%	1.4%
3. Confined space risks	38.9%	22.2%	12.5%	20.8%	4.2%	1.4%
4. Motor & vehicle accidents	9.7%	35.0%	18.0%	19.0%	7.3%	11.0%
5. Injuries	8.0%	5.0%	27.8%	27.2%	6.0%	26.0%

As shown in figure 4 below, where the grey color stands for yes, the SRFs in OGPs vary according to their locations as confirmed by 87.5% of the participants in the survey. Notably, 87% of the participants agreed that OGPs in underdeveloped countries are subjected to different SRFs compared to developed countries. For example, 72.25% of the participants indicated that the downstream projects are subjected to longer shutdown maintenance projects in underdeveloped countries than in developed countries.
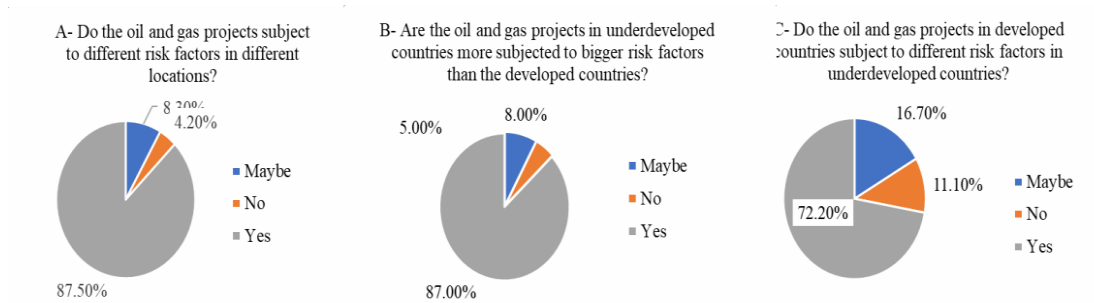

Figure 4. Do the oil and gas projects subject to different safety risk factors in different locations?

It is found that 50% of the participants agreed that OGPs in underdeveloped countries are at higher risk than projects in developed countries. This is because of the lack of infrastructure and safety standards in underdeveloped countries, as 42.7% of the participants said; see figure 5 below.
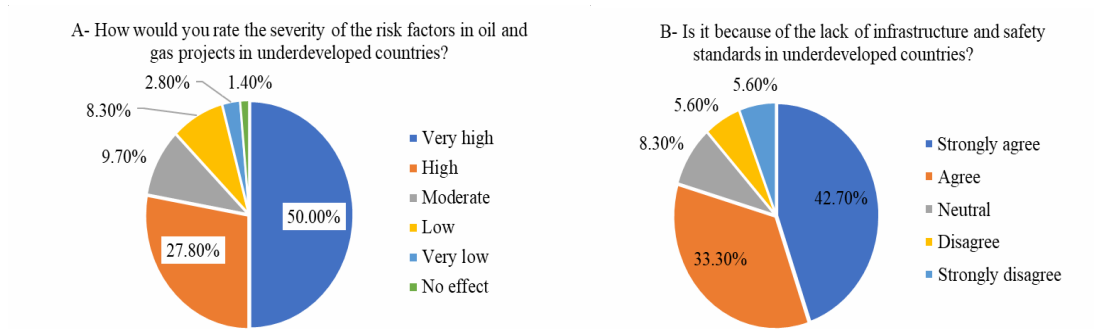

Figure 5. Do the OGDPs in developed and underdeveloped countries subject to different SRFs?

Based on the survey's results, table 2 presents the effective level of proposed risk responses and adaptation measures in turnaround projects in oil and gas industry. It is found that increasing the awareness and authority of the project managers could be one of the most effective RAMs in DOGI, followed by reducing the complexity of the process and improving communications in projects.

Table 2

The effectiveness levels of risk adaptation measures (RAMs) in oil and gas turnaround projects.

RAMs	Very high	High	Moderate	Low	Very low	No effect
1. Increasing safety awareness and authorize to PM	39.1%	27.8%	15.3%	15.0%	5.6%	4.2%
2. Reducing the complexity of the process	36.1%	25.0%	11.1%	13.9%	8.3%	5.6%
3. Improve communications	30.6%	36.1%	11.1%	13.9%	4.2%	4.2%
4. Changing the existing strategies	11.1%	16.7%	26.4%	23.6%	19.4%	2.8%
5. Improve budgets planning	5.6%	15.3%	34.7%	19.4%	15.3%	9.7%
6. Extending the schedule	2.83%	11.1%	20.8%	25.0%	31.9%	8.3%
7. Scope reduction	1.4%	4.2%	19.4%	34.7%	29.2%	11.1%
8. Event contingency	5.6%	15.3%	40.3%	22.2%	5.6%	11.1%

This paper conducted two interviews with two experts in oil and gas projects via an online video call. The first interviewee was a lead project engineer with 15 years of experience. And the second was a quality control engineer having 17 years of experience. Both interviewees agreed that poor management; lack of project planning and scheduling; lack of communication, and safety risks are the most common SRFs in the DOGI. On top of installments of necessary equipment, highly flammable substances and confined space are the most critical SRFs in the DOGI. Moreover, both interviewees agreed that the SRFs in the DOGI vary in different locations. In other words, different oil and gas downstream projects are subjected to variable SRFs in different locations. The survey and interview results confirmed that the underdeveloped countries are subjected to diverse the SRFs compared to developed countries because the project's safety standards are different between countries. Therefore, the turnaround projects in the DOGI in underdeveloped countries are more risky in terms of incidents frequency and delay impact than the developed countries. The lesions learning from past accidents in turnaround projects would provide vital knowledge for strategic design, planning and operations turnaround projects and this could be one of the effective ways of risk adaptation measures in the DOGI.

Discussion and Conclusions

The Oil and Gas Projects require the effective risk adaptation strategies to enhance the projects' operations and deliver the turnaround maintenance projects on time and safely. The study findings will enhance the stakeholders' understanding and knowledge about the SRFs and RAMs, which could be helpful to make sound decisions in risk management process in the turnaround projects of the DOGI.

In this paper, the safety risk factors in oil and gas industry were identified based on current and inclusive literature review. Then, the safety risk factors were analyzed and ranked regards impact on the oil industry based on the real experience of whom who have contributed to fill the questionnaire survey that been distributed amongst the stockholders in oil projects. The findings from the industry survey suggested that adequate planning for the turnaround maintenance projects in the Downstream Oil and Gas Industry (DOGI) will enhance the safety of project workers, reduce projects' shutdown periods, and reduce the complexity in the sector. This study highlighted that the highly flammable substances and confined space are the critical SRFs with the highest impact in the DOGI. The study has also suggested that poor planning in the DOGI is one of the critical SRFs that often leads to late deliveries of turnaround maintenance projects. The comparison between the safety risk factors in the oil and gas in both developed and underdeveloped countries may help the stakeholders in developing countries to review their risk management process and enhance health and safety measures via learning from the past

projects that were completed successfully in the developed countries.

Additionally, the study reveals that the turnaround projects in underdeveloped countries are subjected to more significant SRFs than the developed countries because of the lack of safety standards and awareness and poor safety training programs for the workers in underdeveloped countries. The SRFs in OGPs were graded in terms of their severity, and it was found that risk levels would be low in the DOGI in developed countries and very high in underdeveloped countries. The study found that increasing the safety awareness and empowering authority of the project manager, reducing the process complexities, and changing the execution strategy are some of the effective RAMs, which could help in minimizing the impacts or the occurrence of the SRFs in the projects. This paper concluded that the critical SRFs associated with the turnaround projects in DOGI vary in nature and impact according to locations of the projects.

Furthermore, the findings of this paper will be used in future research as inputs for life maintenance systems, which will be developed to create effective risk maintenance plans by implementing artificial intelligence and machine learning tools. The small-scale sample of the questionnaire survey limits the results of this study. Hence, it is recommended to include a bigger sample in future research and use real-life case studies to enhance the stakeholders' understanding of the nature and impact of safety risks in turnaround maintenance projects. As well as, to optimize the safety risk management scenarios for OGPs in different locations and countries.

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