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An Assessment of Risks in Oil and Gas Construction Projects in Pakistan: A Quantitative Approach Using Failure Modes & Effects Analysis

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Abstract: Effective risk management remains pivotal to the success of any project, especially in the oil and gas industry. This study seeks to identify and quantify the potential risks in Oil and Gas Construction Projects (OGCP) within Pakistan. An exhaustive literature review is undertaken to elucidate various risk classifications and factors. Nine risk classifications emerge from this scrutiny: Health, Safety and Environment (HSE), political, legal, regulatory and bureaucratic, labor and human resources, logistics, economic and financial, technological and technical, and security and management. The novelty of this research lies in the adoption of a quantitative approach, a questionnaire rooted in Failure Modes & Effects Analysis (FMEA), asking respondents to quantify risk factors based on severity, occurrence, and detection. The results obtained from the modified FMEA questionnaire indicate that the highest average risks are associated with logistics, health, environment and safety, and legal, regulatory and bureaucratic factors. Meanwhile, political, human resource, management, and technical and technological factors register as the second-highest risks. Security risk records the least average Risk Priority Number (RPN). The most significant risk factors identified include the lack of a disaster management system, depletion of hydrocarbon resources, corruption, contractual breaches, delays in customs clearance, logistic provider complications, design flaws, technical limitations, and contractor incompetence. This research endeavors to provide academia and industry with expansive knowledge related to the risks inherent in these complex projects.

Keywords: Failure Modes & Effects Analysis; Risk management; Oil and Gas Construction Projects; Risk assessment; Pakistan

1 Introduction

Projects within the Oil and Gas industry necessitate meticulous planning, design, installation, and operation to meet stringent safety standards. The industry grapples with a plethora of risks, ranging from corrosive materials [1], design and construction defects, to natural hazards and operational or management errors [2, 3]. Additional risks encompass extensive investment requirements, diverse stakeholders, complex technologies, and the industry's distinct nature [4]. Risk identification across the three phases of the Oil and Gas industry is a mandate, not a choice.

The construction sector in Pakistan, a key component of the Oil and Gas industry, has emerged as the third most perilous industry in the country, characterized by elevated injury rates, prevalent occupational diseases, and high fatality rates. Investigations have unveiled a lack of safety culture, inadequate safety management, and a negligence of safety rules in the labor laws [5]. Additionally, non-professional behavior and an apparent disregard for safety have led to a surge in uncertainties. Alarmingly, injury rates escalated from 12.54% in 2002 to 21.10% in 2011, with a reported 2-5% fatality rate in most companies during a single project. As contractors lack robust safety procedures such as accident reporting, safety record keeping, and logging methods, the actual fatality and injury rates could be significantly higher than the figures reported.

The Oil and Gas industry has witnessed catastrophic accidents, such as the Bhopal disaster in 1984, killing approximately 15,000 people and injuring thousands due to a tanker explosion that released a toxic gas. The 2010 BP drilling rig explosion in the Gulf of Mexico resulted in 11 fatalities and 17 injuries, with an oil spill that lasted for 86 days, causing severe environmental damage. Similarly, a 2003 oil spill in Karachi, Pakistan, caused widespread disease and harmed marine life [6]. These occurrences have prompted intensive investigations into Oil and Gas companies [7] and heightened pressure from stakeholders due to escalating environmental concerns [8, 9].

Environmental reporting is gaining traction in developing countries but remains unexplored in the South Asian region [10–13]. Studies in South Asia have primarily focused on India and Bangladesh, with Pakistan being largely overlooked, despite its geographical and economic significance. The most recent study in Pakistan, conducted twelve years ago, explored risks associated with pipeline project construction and operations [14].

The present research aims to identify risk factors in all three sectors of the Oil & Gas industry using secondary data and develop a risk assessment tool. A unique aspect of this study is the application of a modified FMEA to construct a questionnaire for evaluating the Severity, Occurrence, and Detection levels of risk factors in Oil & Gas construction projects in Pakistan. FMEA, a versatile and compelling tool, offers a systematic perspective for conducting analytical analyses in the management of Oil and Gas projects. This is the first application of FMEA in the study of the Oil & Gas industry in Pakistan. This study seeks to identify risk factors in Oil & Gas construction projects, quantify them, and provide comprehensive knowledge on various risk classifications and factors. Nine risk classifications have been identified: HSE; Political; Legal, Regulatory & Bureaucratic; Labor & Human Resources; Logistics; Economic & Financial; Technological & Technical; and Security & Management. A novel quantitative approach has been adopted, using a questionnaire based on modified Failure Mode & Effects Analysis, where respondents rate risk factors by their Severity, Occurrence & Detection levels. The importance of this study is underscored by the potentially significant financial and economic impacts of failure in such complex projects. By identifying potential risk factors, this study aims to prevent the occurrence or recurrence of risks in ongoing and future Oil & Gas projects in Pakistan.

2 Literature Review

2.1 Oil and Gas Projects in Pakistan

With the burgeoning demand for Oil & Gas, it has been noted that the government of Pakistan has embarked on initiatives to collaborate with multinational corporations to execute complex projects spanning all three sectors of the industry [15]. This decision, articulated by the Petroleum Minister of Pakistan, entails engaging six international firms for the construction of five Liquified Natural Gas (LNG) facilities. A myriad of additional ongoing and future Oil & Gas construction projects have been documented, as detailed in Table 1.

Table 1. Ongoing and future projects in Pakistan [16–24]

Project	Region	Ongoing/Future	Scope	Cost ($)
Hydro Skimming Refinery	Karachi	On-Going	Upgradation of technology to produce Euro II standard diesel	1 billion
Underground Storage and Desalination Plants	Not disclosed	Future	Storage and desalination of gas imported from Iran	1.5 billion
Gas Pipeline Project	Karachi-Lahore	Future	Construction of a 1,122 Km long, 42-inch diameter pipeline from Karachi to Lahore	2.5 billion
Parco Coastal Refinery	Baluchistan	Future	Production of 250,000 million barrels per day of crude oil	5-6 billion
Saudi Aramco Oil Refineries	Gwadar	Future	Production of 250,000-300,000 million barrels per day (Estimated Value)	10 billion
Rehman Field Drilling	Baluchistan	On-Going	Drilling to a depth of 2700 KM to develop gas from cretaceous sandstone formation	Not disclosed
Offshore Gas Pipeline Project	Iran-Pakistan	Future	Construction of pipeline from Iran to Pakistan, exporting 500 million to 1 billion cubic feet of gas per day	10 billion
KUC-01	Hyderabad	On-Going	Extraction of Shale gas	Not disclosed
Oil Stabilization Package	Sindh	On-Going	Designing and supplying oil stabilization package	Not disclosed
While Oil Pipeline MOGAS Project	Sindh, Punjab	On-Going	Enhancement of White Oil Pipeline, from 8 MTPA to 12 MTPA	Not disclosed
Coastal Oil Refinery	Baluchistan	Future	Production of 250,000 barrels per day	Not disclosed
Oil Refinery	Gwadar	Future	Production of 300,000 barrels per day	Not disclosed
Oil Refining Facility	Dera Ismail Khan	Future	Production of 40,000 barrels per day	Not disclosed

2.2 Risk Management in the Oil & Gas Industry

Oil & Gas projects are susceptible to a myriad of internal and external risks including, but not limited to, financial, design, contractual, construction, operational, economic, political, legal, logistical, and environmental risks. These risk factors can impose significant negative impacts on project cost, schedule, and quality [25]. It is, therefore, paramount that risk management within the Oil & Gas industry is robustly implemented to mitigate or prevent the frequency of accidents [26]. Table 2 presents a selection of recent studies that have been conducted in this domain.

Van Thuyet [26] embarked on a study in Vietnam to identify potential risk factors in OGCP. Through the administration of a questionnaire survey, 59 risk factors were identified. A subsequent study by Dehdasht et al. [27] utilized the DEMATEL-ANP risk assessment tool to identify potential risk factors in OGCP, acknowledging the complexity and inherent risk of such projects due to their hostile environments. Chan [28] revealed that fatigue and stress are prominent risks in the Oil & Gas industry, based on a survey of over 300 stakeholders from four companies in China. The study also included insights from 15 workers who had experienced fatigue-related incidents and proposed several risk mitigation strategies. In another investigation, Mohan [29] identified offshore construction projects as particularly complex due to the unpredictable risks they present. The study suggested that lack of awareness of the offshore environment amplifies the uncertainties involved in these projects. Risks were found to permeate every stage of the project life cycle, from bidding to project handover. Lastly, a study conducted by Mubin and Goryainov [30] focused on the construction and operation of pipeline projects in Pakistan. The study aimed to identify the extensive risks involved in pipeline construction in challenging geographical and geological areas in Pakistan, using data from the 'Risky Project' software. In summary, these studies underscore the complexity and inherent risk of projects within the Oil & Gas industry, highlighting the need for rigorous risk identification and management strategies. While a diverse range of risk factors has been identified, there is a clear need for further research to develop more comprehensive and effective risk mitigation strategies.

Table 2. Risk management in the oil and gas industrial sector

Researchers	Researchers Approach	Risk Factor Identification Method	Country	Sector	Type of Risks Classified
Shafiee et al. [31]	FMEA-FTA	Qualitative, Quantitative, Questionnaire	Global	Upstream	Identified technical risk factors
Hatefi [32]	Hybrid EVM-SAW method	Documentation Review, Questionnaire	Iran	Construction, Operations	Identified 52 risk factors
Kraidi et al. [33]	Not specified	Qualitative, Quantitative	Global	Construction, Operations	Identified 42 risk factors
Dehdasht et al. [27]	DEMATEL-ANP	Qualitative	Iran	Construction	Technical, Financial, Environmental, Design and Construction, Contractual, Policy and Political
Mohan [29]	Risk allocation Matrix, Pareto Analysis	Questionnaire	Global	Construction	Management, Financial, Environmental
Khadem et al. [34]	Monti Carlo Simulation	Qualitative	Oman	Construction, Midstream (Supply Chain)	Management, Technical, Logistic
Mahdavi et al. [35]	FMEA	Analytic Study	Iran	Oil refinery	Health & Safety, Technical
Asad et al. [36]	Not specified	Quantitative, Qualitative, Questionnaire	Malaysia, Pakistan & Saudi Arabia	Oil Extraction (Well drilling)	HSE, Logistic, Technical, Financial
Abd El-Karim et al. [37]	AHP	Questionnaire	Egypt	Construction	Financial, Economic, Construction, Management, Technical
Petroyskiv et al. [38]	FMEA, Fuzzy Logic	Analyzing secondary and primary data	Global	Oil refinery	HSE

Researchers	Researchers Approach	Risk Factor Identification Method	Country	Sector	Type of Risks Classified
Taylan et al. [39]	Relative Importance Index, Fuzzy AHP	Consultant experts, Qualitative, Quantitative	Saudi Arabia	Construction	Financial, Management, HSE
Osabutey et al. [40]	Not specified	Analyzing secondary & primary data, Questionnaire	Ghana	Oil Refinery	Environmental, Health & Safety, Economical, Operational, Political
Qureshi and Shakeel [41]	HAZOP study	Analyzing secondary & primary data	Global	Upstream, Downstream	Health, Environmental and Safety
Mubin and Mannan [42]	Not specified	Quantitative	Pakistan	General	Engineering, Proposal; Project management, Procurement, Quality, Health & Safety, Human resource, Finance
Chan [28]	Analysis	Secondary Data, Questionnaire	China	Construction	11 Fatigue risk, 9 Mental stress risk
Van Thuyet et al. [26]	Not specified	Questionnaire, Qualitative, Quantitative	Vietnam	Construction	Identified 59 risks
Mubin and Goryainov [30]	Risky Project 1.3.1 (Software)	Analyzing secondary & primary data	Pakistan	Construction, Operation	Political, Socio-economical, Organizational, Investment, Technological, Security, Natural and climatic, Environmental

3 Research Methodology

3.1 FMEA

The FMEA serves as a critical methodology for discerning the variations and severity of potential failures, alongside providing a quantification of the associated risk coefficients. This technique, by design, facilitates the anticipation of defects and failures, enables comprehensive analysis of the outcomes, and aids in minimizing their occurrence.

The primary objective of employing FMEA is to diminish risks and uncertainties by establishing guidelines for the probability of defect occurrence [43]. This method is instrumental in the elimination of errors and related faults, thereby reducing the substantial costs associated with inconsistency remediation.

Several established guidelines and standards prescribe the requirements and recommended reporting formats for FMEA and Failure Mode, Effects, and Criticality Analysis (FMECA). Some of these include MIL-STD-1929A (1980), SAE J1739, and MIL-STD-1629A. Additionally, many industries and organizations have developed their proprietary methodologies to cater to the needs of their specific products or processes [44].

Key standards in this domain include:
• MIL-STD 1629: Procedures for executing failure mode and effect analysis.
• IEC 60812: Procedures for FMEA.
• BS 5760-5: Guide to FMEA and FMECA.
• SAE ARP 5580: Suggested FMEA practices for non-automobile applications [45].
• SAE J1739: Potential Design FME), manufacturing and assembly processes (Process FMEA), and machinery (Machinery FMEA) [46].

To expand on this, FMEA, as a process, starts by analyzing potential failure modes within the system, followed by identifying their causes and effects. The severity of each failure is then assessed, along with their occurrence rate and the ability to detect them. These parameters form the basis of the RPN, which guides the prioritization of remedial actions. Thus, FMEA serves as an effective tool in enhancing system reliability and safety.

3.2 Application of FMEA in the Oil & Gas Industry

The application of FMEA within the Oil & Gas industry has been limited, with only a select number of research studies having employed this methodology. Notable among these studies, which are summarised in Table 2, are the ones conducted by Mahdavi et al. [35], Petrovskiy et al. [38] and Shafiee et al. [31].

Mahdavi et al. [35] undertook an analytical study at a gas refinery in Iran, with the objective being the detection of equipment failures and damages, specifically pertaining to transformers and boilers. This study also focused on human injuries and production reduction, examining 105 failure modes using FMEA to enhance safety and reduce accidents within the oil refinery.

Petrovskiy et al. [38] conducted research involving both primary and secondary data analysis. The study aimed to utilise the FMEA method in assessing the operational dependability of equipment used in oil refineries. According to the authors, equipment dependability is a significant concern within the downstream industry of Oil and Gas. In this context, FMEA was employed to identify probable risk factors, and a supporting method to FMEA was introduced for risk quantification in emergency situations. The study delineated essential stages in the method used for quantifying various hazards identified in the equipment.

Shafiee et al. [31] presented a case study of subsea blowout preventers (BOP) using a combined FMEA-FTA approach. The research aimed to enhance the strength and reduce the shortcomings associated with traditional methods by merging two effective risk assessment methodologies. Despite the BOP comprising over 600 components, the study focused on the risk assessment of its seven main components. The FTA-FMEA model was utilised to quantify the risks present in the technical system. These quantifications were later compared to rankings obtained using traditional methods.

It is worth noting that research related to the Oil and Gas industry is sparse in Pakistan. This presents the opportunity for more comprehensive studies in this area, which could greatly benefit from the application of methodologies such as FMEA.

4 FMEA Results

4.1 Survey Distribution and Collection

Surveys were disseminated within the Construction and Oil & Gas industries of Pakistan, with the objective of attaining a minimum of 15 responses covering all risk classifications. A particular focus was placed on specific areas of expertise, as depicted in Figure 1. Surprisingly, a total of 26 responses were collected, nearly doubling the initial target. This response rate is illustrated in the following pie chart, which also showcases the respondents' work experience.

A noteworthy 70% of respondents had substantial experience, exceeding 15 years, in the Construction and Oil & Gas industries of Pakistan, while the remaining 30% had fewer than 15 years of experience. In terms of educational attainment, the respondents were well-qualified, with 52% holding a Bachelor's degree and 48% holding a Master's degree. The combination of significant industry experience and high educational qualifications lends credibility to the research. However, it is to be noted that no respondents held a PhD.

Most responses were obtained from experts in HSE risk management, followed by Civil Engineering, and Project/Risk Management. Additionally, responses were received from petroleum engineers. The respondents, with varying expertise as depicted in the following chart, were asked to assess risks relevant to their field.

The majority, approximately 60% of respondents, exhibited moderate awareness of risk management, while around 20-25% displayed high awareness. A small percentage were very highly aware, with the remaining 10-15% demonstrating low-level awareness. Figure 1 and Figure 2 elaborate upon the work experience, qualification, and area of expertise of the respondents, respectively.

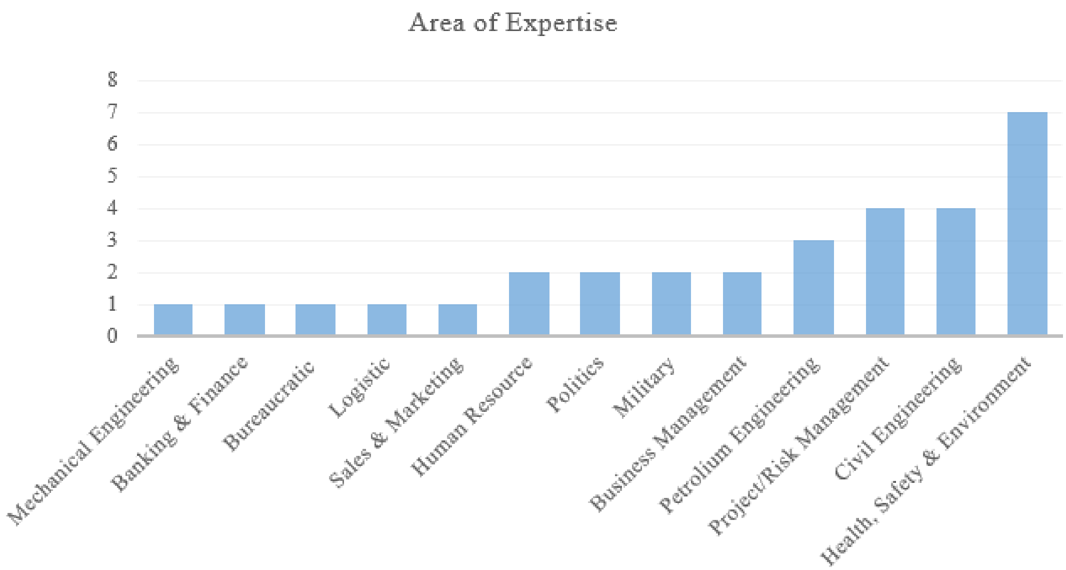

Figure 1. Area of expertise of the respondents

Given the distinctive nature of risks within the Oil & Gas industry, differing from those in other construction industries, about 50% of respondents were moderately aware of these risks. Furthermore, around 30% were highly or very highly aware, while the remaining 20% demonstrated low-level awareness of risk management in the Oil & Gas industry, as seen in Figure 3.

The moderate to low levels of risk management awareness in Pakistan can be attributed to the fact that risk management is a relatively new field in the country, particularly within the construction industry [47]. Their survey-based research revealed that Pakistani companies tend to use reactive, informal, and unstructured risk management techniques. Nevertheless, an increase in construction projects in Pakistan has led to a moderate rise in risk management awareness. Additionally, the lack of effective risk management systems is apparent. Figure 3 and Figure 4 illustrate the respondents' awareness levels regarding risk management within the industry.

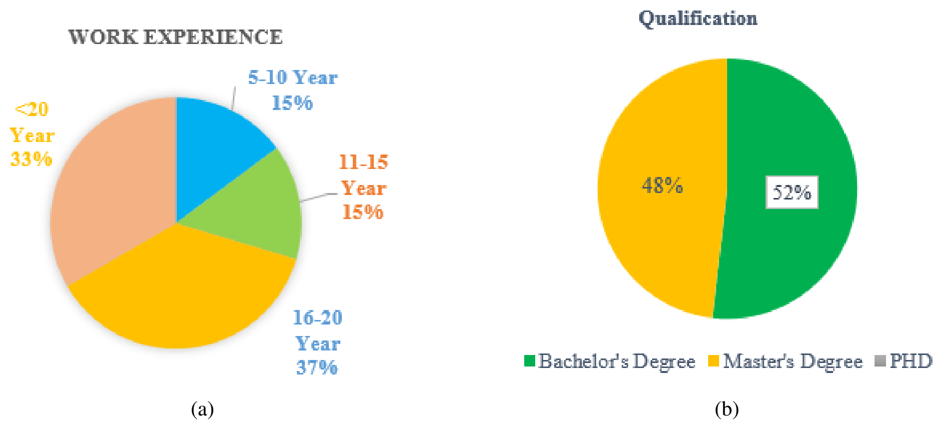

Figure 2. Experience and qualification of respondents: (a) Experience of the respondents; (b) Qualification of the respondents

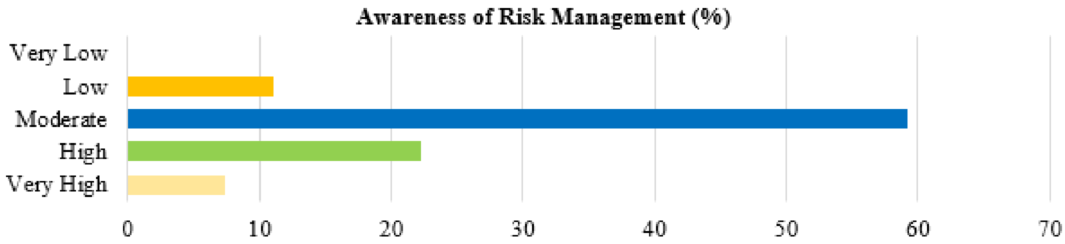

Figure 3. Awareness of risk management among respondents

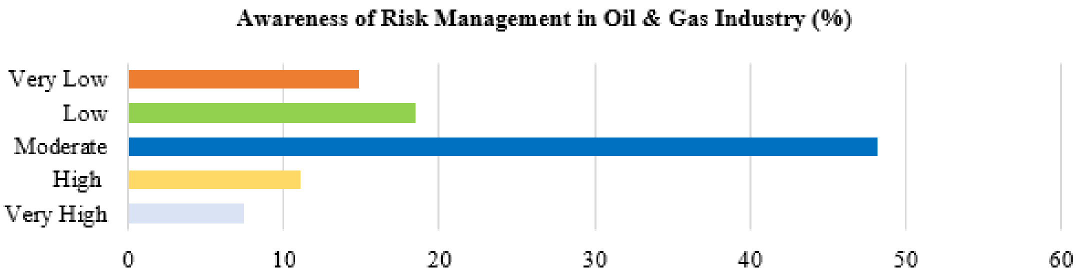

Figure 4. Awareness of risk management in oil and gas industry among respondents

4.2 Risk Assessment via FMEA (Quantitative Approach)

A comprehensive review of the literature led to the identification of 77 risks, which were further classified into nine distinct categories. These risks were quantified and arranged using a modified version of FMEA. Respondents were asked to quantify the severity, occurrence, and detectability of each risk, allowing the calculation of the Risk RPN. The RPN was used to determine the risks with the highest and lowest priorities. Additionally, respondents were asked to assign each risk to its relevant industry stream.

Each risk classification saw participation from two or more respondents. The variability in responses to the same risk factor resulted in a skewed distribution of data. Hence, to calculate average RPN for each risk classification, the median was used as a more appropriate measure of central tendency due to the skewed data distribution.

Figure 5, a radar chart, displays the nine different risk classifications and their corresponding average RPN. It is evident from the chart that the highest average RPN is recorded for HSE, and Logistics risks. This is followed by Legal, Regulatory

& Bureaucratic risks, Political risks, Labor & Human Resource risks, Technical & Technological risks, and Management risks. Security risks presented a lower average RPN, and the lowest was observed for Economic & Financial risks.

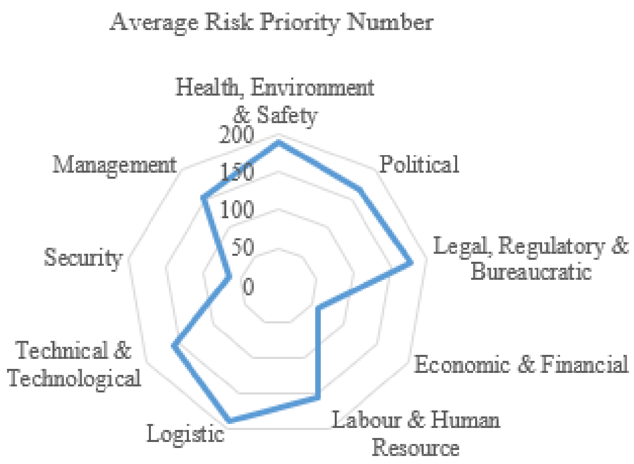

Figure 5. Average RPN for each risk classification

4.2.1 HSE risks

The quantification of HSE risks is depicted in Figure 6. It has been reported by Farooqui et al. [48] that construction company owners in Pakistan possess an awareness of the country's HSE policies. Nevertheless, a significant impediment to adhering to these procedures is the lack of commitment to a safety culture. Furthermore, the workforce in the industry often lacks expertise and familiarity with the procedures or tools necessary for maintaining a safety culture throughout the course of a project.

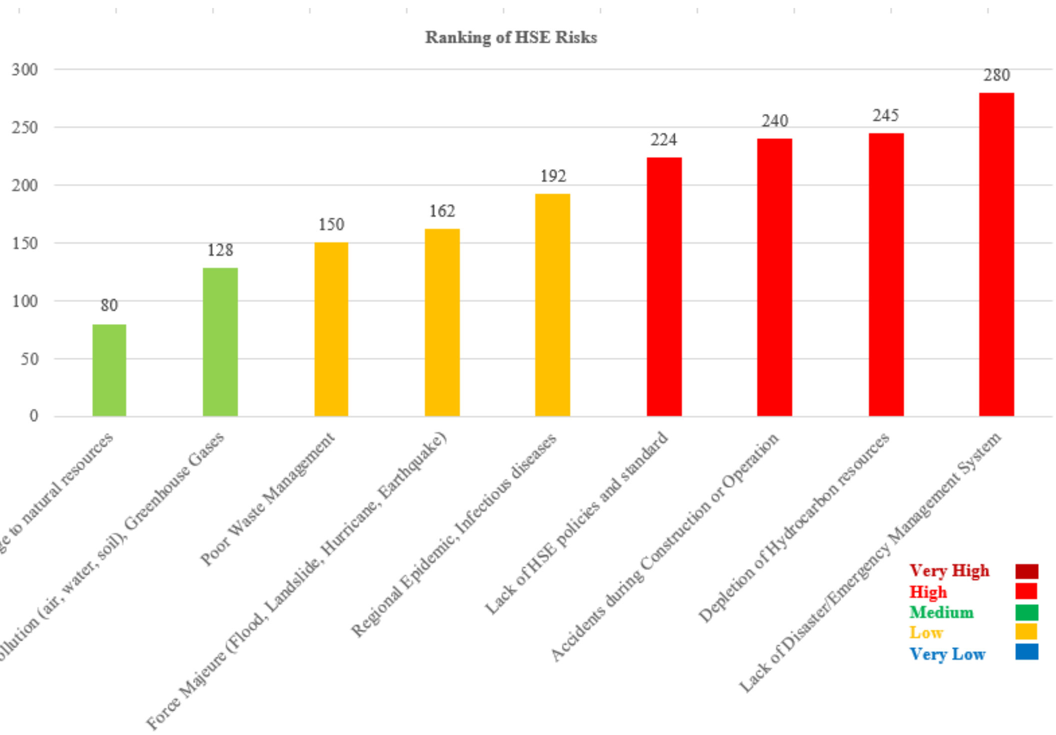

Figure 6. Ranking of HSE risks

Compounding the issue, systematic HSE procedures are often absent, and there is a notable deficiency in the capacity to maintain a safe environment throughout the lifespan of a project. Pakistan is susceptible to a variety of hydrometeorological hazards, including floods, cyclones, and adverse weather. Different regions of Pakistan are exposed to specific risks; for instance, the marshy region is vulnerable to cyclone and swell wave events, the low sea-level area of the Indus river is at an increased risk of flooding, and the northern regions are prone to landslides, sandstorms, avalanches, and earthquakes. Historical events, encompassing 75% of cyclones, droughts, floods, and landslides, occurred between 1980 and 2013.

Moreover, seismic events in the Himalayan orogenic zone led to a 7.2 MW magnitude earthquake, which tragically resulted in the loss of 75,000 lives and the destruction of 3 million homes due to massive landslides triggered by the earthquake. In another instance, a collision of the Indian and Eurasian plates triggered a 6.4 MW magnitude earthquake.

4.2.2 Political risks

The quantification of Political Risks is presented in Figure 7. It is noteworthy that Bribery & Corruption emerged as the risk factor with the highest RPN, followed by Import Restriction, which also falls within the high-risk category according to RPN. The remaining risk factors were quantified as being of low risk.

Farooqui et al. [48] have reported that fair prequalification bidding processes are not consistently adhered to within the construction industry of Pakistan. It is suggested that bribes are often solicited from contractors as a condition for being awarded contracts. Furthermore, it is reported that contractors may engage in practices considered corrupt to increase profit margins, such as performing work at standards below the stipulated specifications.

Corroborating this, Khan [49] reported that corruption amounting to 134 billion rupees occurred between 2012 and 2015, with prominent local and multinational companies in Pakistan's Oil & Gas industry implicated.

Political instability and fluctuating policies can lead to diplomatic conflicts and pose significant risks to any industry within the country. Alesina et al. [50] suggest that unstable governments often resort to borrowing money from other countries, which can create difficulties for subsequent administrations. The accumulation of debt can fuel inflation in the economy. In recent years, Pakistan has contended with extensive corruption from previous governments, which has adversely impacted various industries, including the construction and Oil & Gas sectors.

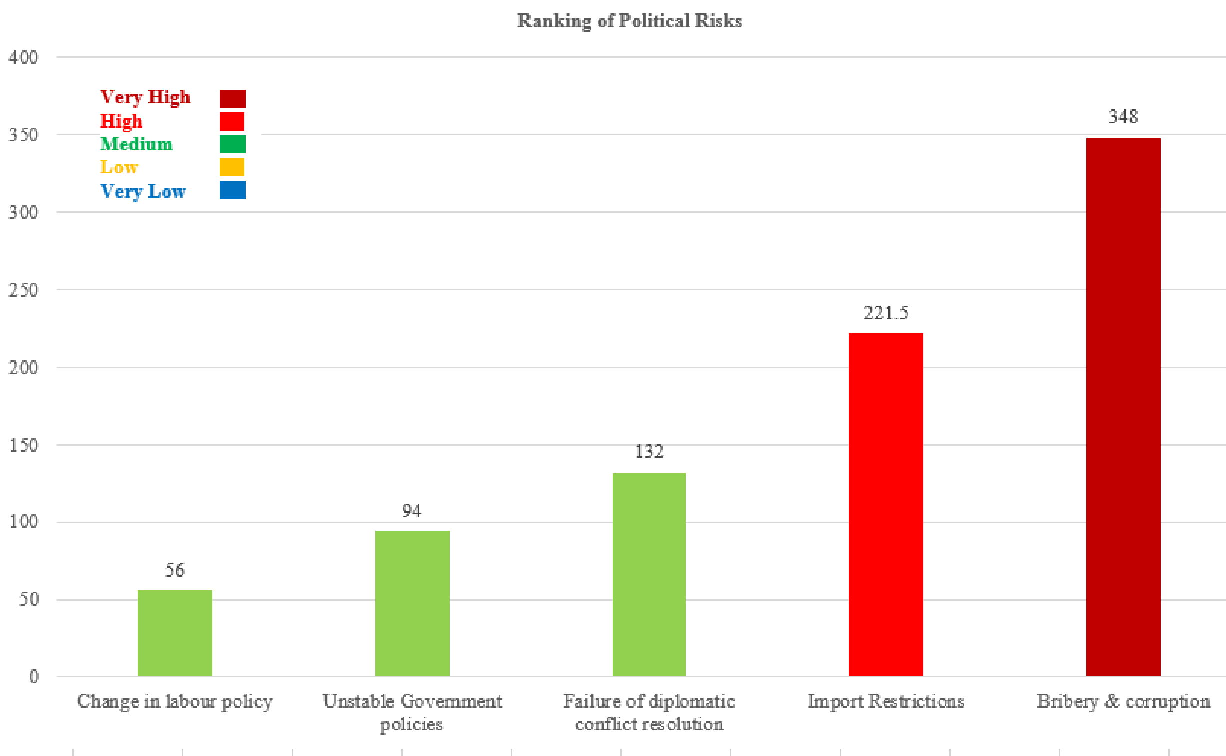

Figure 7. Ranking of political risks

4.2.3 Legal, regulatory and bureaucratic risks

Figure 8 illustrates the quantification of Legal, Regulatory & Bureaucratic Risks. It is notable that 'Delays in Custom Clearance & Breach in Contractual Relationship' have been classified as 'Very High' risk according to the RPN. The construction and operation of Oil & Gas projects predominantly involve International Joint Ventures (IJVs) between local and international companies.

The prominence of these risks, as reflected by the high RPN, aligns with issues highlighted in the literature review. Governments in developing countries, due to their substantial influence on IJVs, can alter rules for development, leading to breaches in contracts. Such interruptions by the government can result in clearance delays, loss of ventures, and dissolution of partnerships.

Extended approval processes and bureaucratic delays can lead to substantial time and cost overruns for foreign investors. These factors could potentially contribute to international companies' reluctance to invest in Oil & Gas construction projects in Pakistan, given that these are typically mega-projects requiring significant outlays of time and capital.

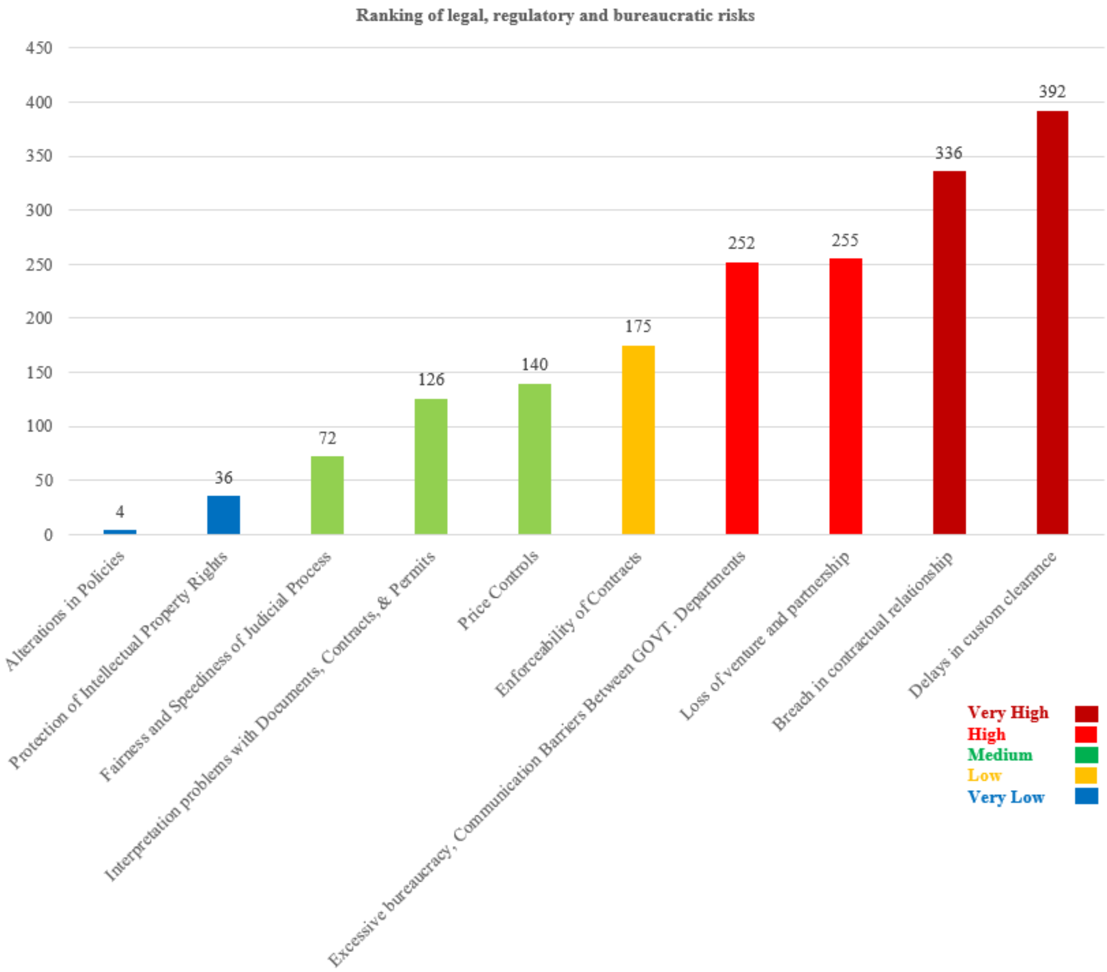

Figure 8. Ranking of legal, regulatory and bureaucratic risks

4.2.4 Labor and human resources risks

Figure 9 represents the risk factors according to their respective RPN. Certain risk factors such as Lack of Skilled & Specialized Labour, Poor Human Resource Development, Trade Unions and Strikes, Exploitative Hiring Policies, and Lack of Contract, Insurance & Medical Facilities have been classified as 'Medium' risk factors. Conversely, the remaining risk factors have been designated as 'Low' risk risks.

These risks are categorized as medium due to the challenges faced by Pakistan in cultivating an educated and skilled workforce. A representative of the National Vocational & Technical Training Commission (NAVTTC) of Pakistan, as cited in The Nation News [51], remarked on the discrepancy between the demand for and supply of skilled labour. The local market reportedly requires a workforce of 1 million skilled labours, but the nation can only produce 445,000. If the demand from mega projects, such as the China-Pakistan Economic Corridor (CPEC), is taken into account, the demand escalates to 2 million skilled labours.

The Education Minister, as cited in The Nation News [51], stated that while annually 2.5 million workers are integrated into various industries, many lack the requisite expertise for complex industries. According to the International Labour Organization [52], approximately 70% of labourers in Pakistan reside in rural areas and survive on 1 USD per day. Hence, it can be inferred that the risk factors delineated in Figure 9 can be attributed to a lack of education, vocational training, and adequate focus on these issues.

4.2.5 Logistics risks

Figure 10 depicts various risk factors color-coded based on their severity. The risk of Non-performance of Subcontractors & Suppliers, denoted in maroon, is categorized as 'Very High'. Risks such as Logistic Capacity Problems, Supplier Relationships, and Insufficient Road, Rail & IT services, highlighted in red, are considered 'High' risks. The risks displayed in orange, including Energy Shortage, Lack of Warehouse and Storage Capacity, and Lack of Multiple Suppliers, are classified as 'Medium' risks. The risk factors shown in green and blue are quantified as'Low' to 'Very Low' risks.

Choudhry et al. [53] reported that subcontractors often view quality management as an additional cost, arguing that improving quality requires increased investment. These factors could explain why non-performance and quality issues are rated as 'Very High' risks.

An article by Zuberi [54] quoted the chairman of a significant logistics and supply chain company in Pakistan, who commented on the country's insufficient roads & railways for logistics, attributing the deficiencies to inefficient transport management. The chairman also noted the absence of a formal logistic and supply chain industry in the country and highlighted the outdated fleet impacting cargo movement, environment, and fuel consumption. The recent emphasis on logistics and supply chains due to the China-Pakistan Economic Corridor (CPEC) mega project may have brought these issues to light, but deficiencies remain in other projects, such as Oil & Gas construction, potentially contributing to the high risk associated with insufficient road, rail, and IT services.

Energy Shortage, classified as a 'Medium' risk, is a significant issue in Pakistan. The energy generated in Pakistan is primarily non-renewable, and the country cannot produce sufficient electricity to meet demand, leading to load shedding of approximately 12 hours per day for 140 million people. This energy shortage could pose significant challenges for Oil & Gas projects, particularly those situated in rural areas of Pakistan.

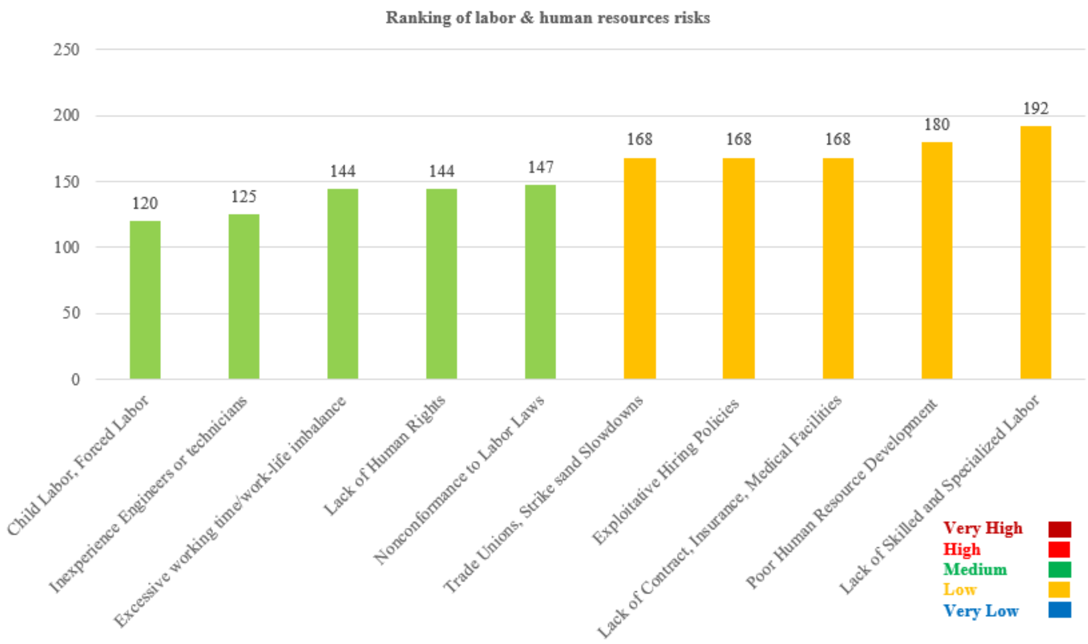

Figure 9. Ranking of labor & human resources risks

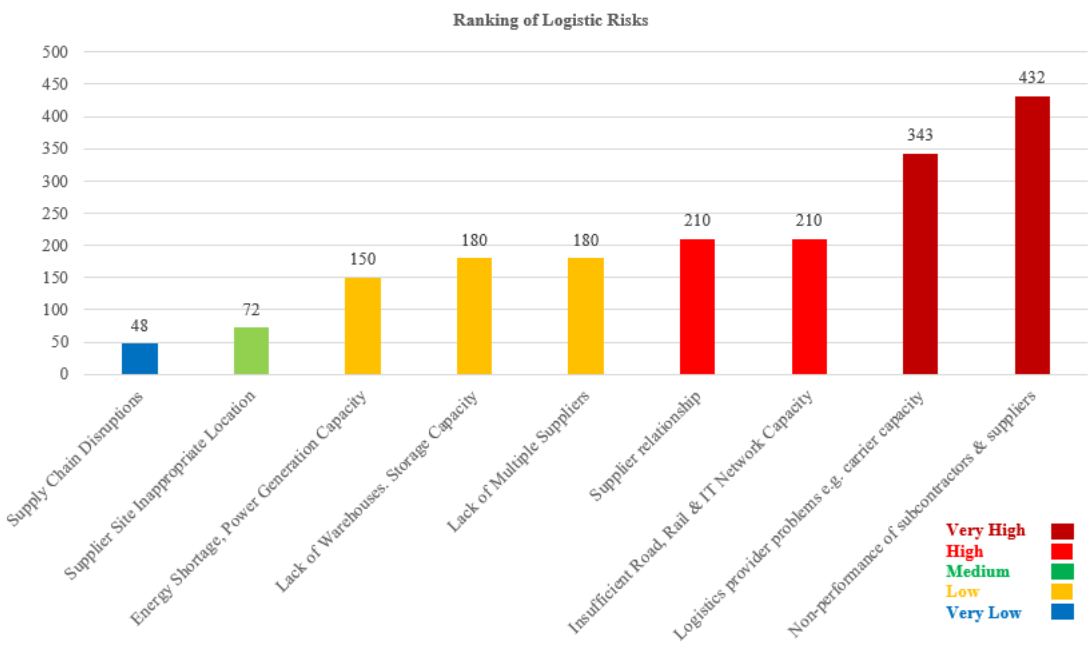

Figure 10. Ranking of logistic risks

4.2.6 Economic and financial risks

Figure 11 presents risk factors according to their RPN. All risk factors are classified as 'Medium' risks. The results pertaining to Economic and Financial Risks appear to be incongruous, hence a comprehensive discussion on this section is deemed unnecessary.

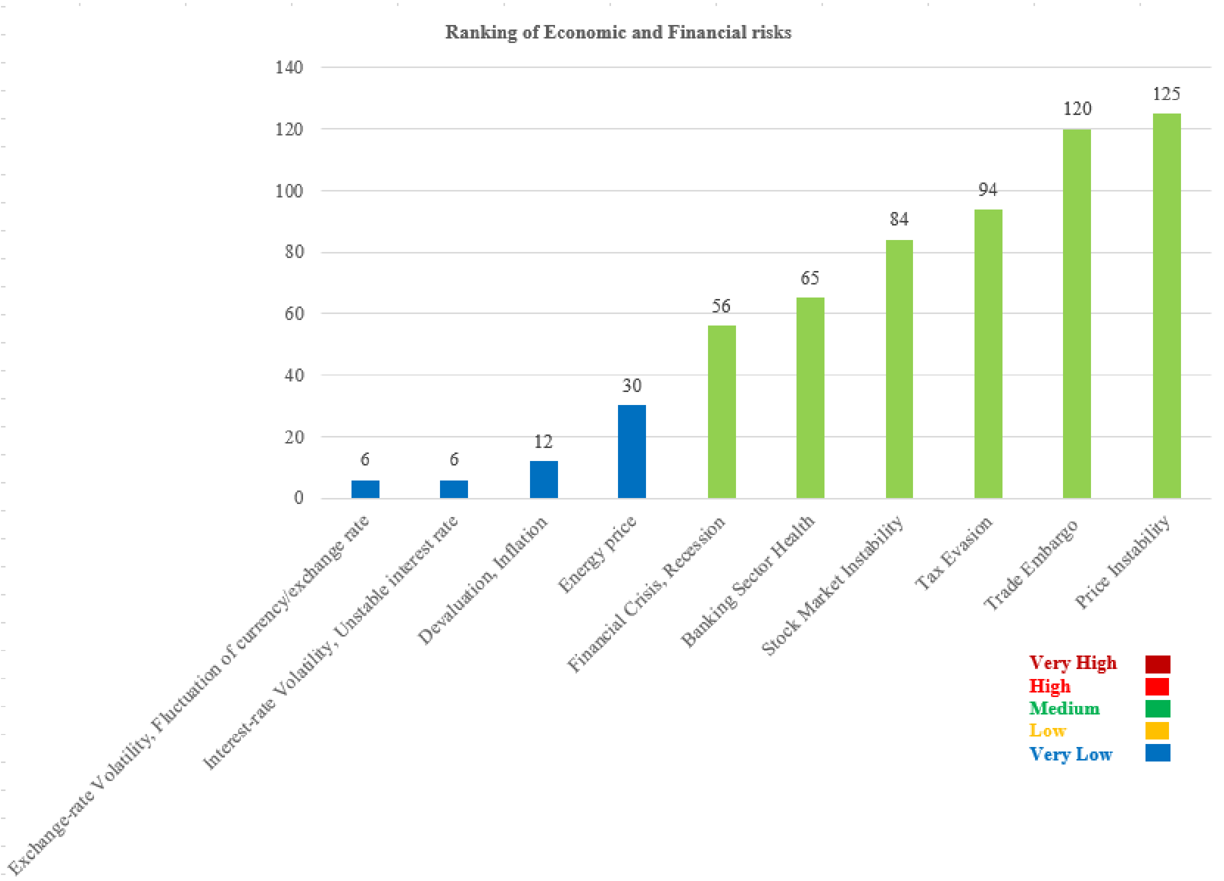

Figure 11. Ranking of economic and financial risks

4.2.7 Technological and technical risks

Figure 12 presents the results of Technical & Technological risks. The risk of 'Design Changes, Design Flaws, and Quality Issues' is classified as 'Very High', followed by 'Technical Limitations, Technology Change, and Innovation Risk,' which holds the second highest RPN.

As identified by Van Thuyet et al. [26], project design, which is completed in the initial stage, has a significant influence on the entire project lifecycle. Any slight deviation in design execution can lead to substantial cost overruns and delays in deadlines. Contributing factors to design flaws and poor quality may include inadequate design techniques, scope changes, specification alterations, or failure to anticipate subterranean conditions.

While all construction projects demand focused planning, organization, coordination, and control, Oil & Gas construction projects possess unique characteristics. Ruqaishi and Bashir [55] underscored the necessity for advanced technology, machinery, and equipment, particularly given the remote locations of many of these projects. They also emphasized the importance of robust communication and logistics systems.

In line with the survey results, it was observed that construction projects in the Oil & Gas sector in Pakistan may be hindered by limited access to advanced technology, sufficient resources, and efficient machinery. This challenge could be a contributing factor for the government of Pakistan's decision to outsource Oil & Gas projects to multinational companies.

4.2.8 Security risks

As depicted in Figure 13, the respondents did not perceive security as a high-risk factor in the execution of significant projects in Pakistan. The responsibility for ensuring a secure environment for logistics and construction activities for such projects is vested in the Pakistani Army. Previous infrastructural developments such as the construction of 3797 kilometers of roads, the Kara Krum highway, the Gilgit-Skardu link, and several dams were under the direct stewardship of the Pakistani Army [56]. Furthermore, the security of the China-Pakistan Economic Corridor (CPEC), a colossal project, is safeguarded by the Pakistani Army, which has allocated 9,000 personnel from the Special Security Division (SSD) and an additional 6,000 military forces [57]. Moreover, the Frontier Oil Company (FOC), a subsidiary of the Pakistani Army's Frontier Work Organization (FWO), has been commissioned to oversee a $370 million project involving the construction of a 470-kilometer oil pipeline [58].

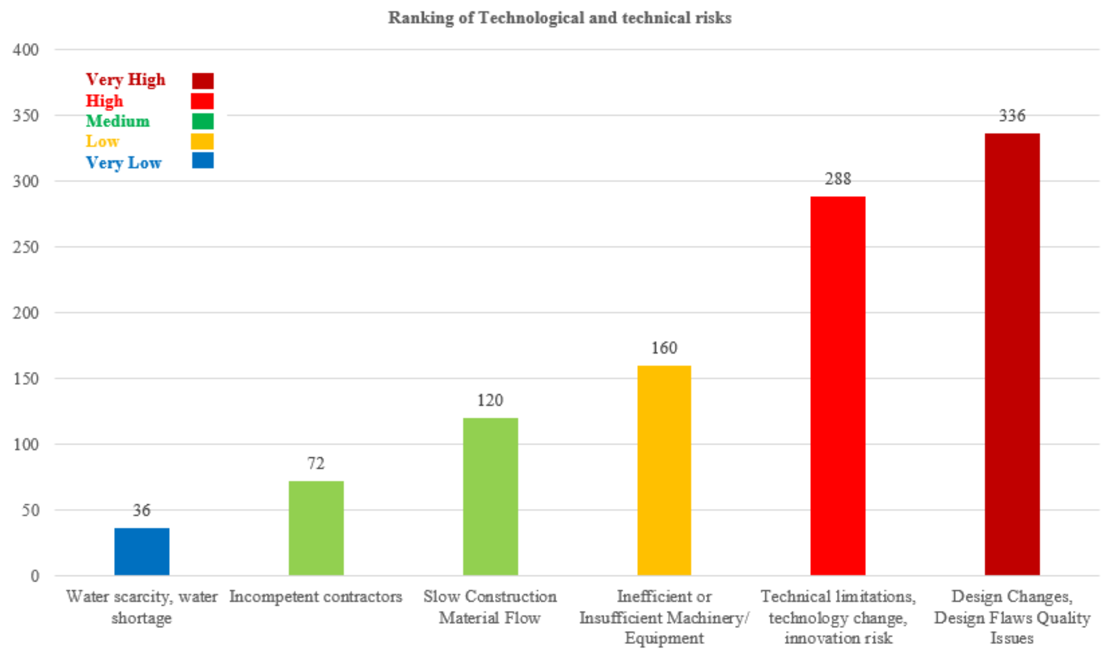

Figure 12. Ranking of economic and financial risks

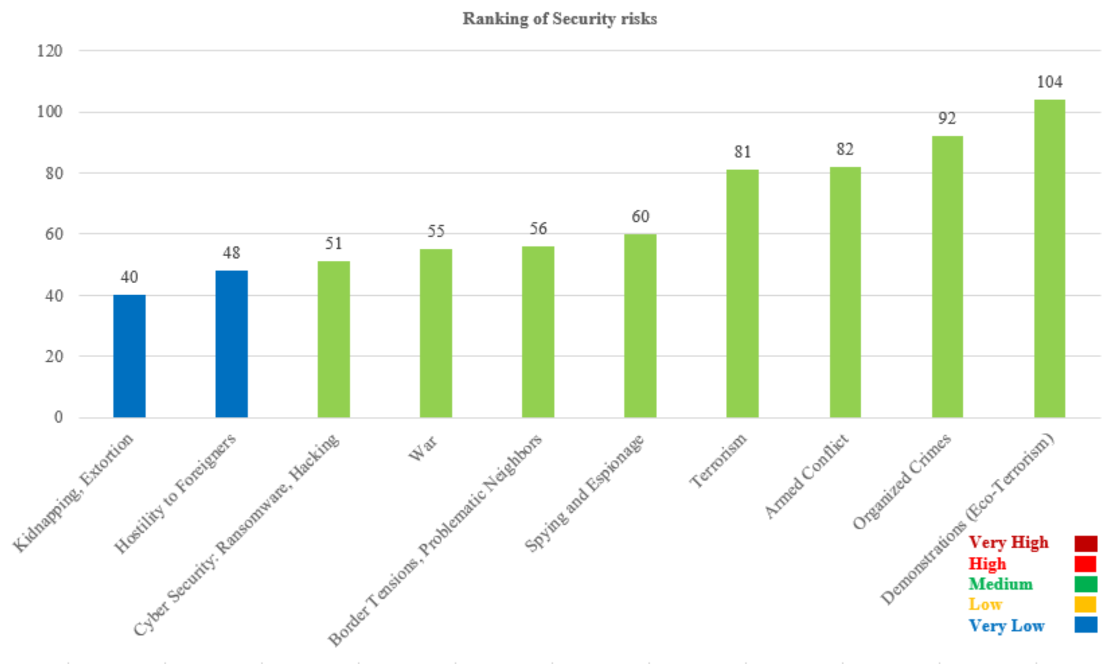

Figure 13. Ranking of security risks

Figure 14 presents the terrorism index, where 10 indicates the highest impact, and 0 signifies no impact. This index quantifies the direct and indirect effects of terrorism on civilians' lives, including casualties, injuries, property damage, and the psychological aftermath of experiencing a terrorist attack [59]. A visible decline in the terrorism index in recent years is apparent from the chart. This downward trend might explain why the respondents believe that terrorism and security risks have a low or very low impact on Oil & Gas construction projects in Pakistan.

4.2.9 Management risks

As depicted in Figure 15, the risk factor with the highest RPN was 'Incompetent Contractors.' This risk was rated as the most significant concern in the construction of Oil & Gas projects by the respondents. This perception can be attributed to various reasons. For instance, Wasim and Khalidi [60] reported that project delays and cost overruns often occur due to inadequate material or equipment provision to contractors. The author, however, argued that contractors should not be held solely responsible for these issues. Disruptions in cash flow, as well, can contribute to delays or failures in construction projects. An analysis by Choudhry et al. [61] revealed that clients often cite a lack of cooperation from subcontractors, waste of materials, and poor coordination as major issues.

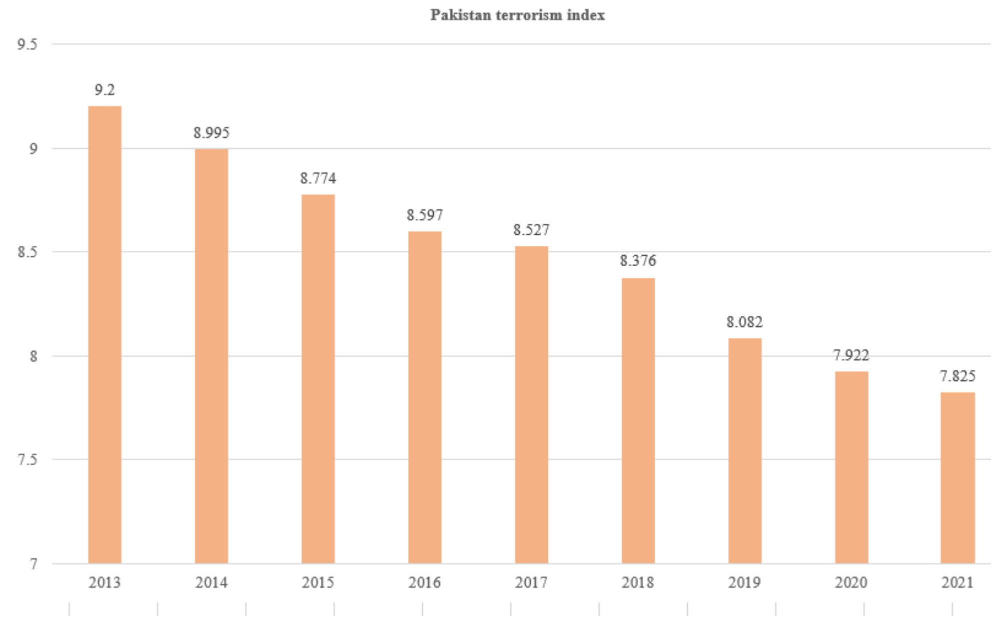

Figure 14. Pakistan terrorism index [59]

Figure 15. Ranking of management risks

The frequent overruns in cost and deadlines are largely due to conventional practices prevalent in developing countries. Cherkaoui [62] reported that 98% of construction projects experienced cost overruns of more than 30%, and a significant percentage were delayed by at least 40%. Moreover, mega projects tend to exceed budget limits by 80% and are usually 20% behind schedule.

The industry often grapples with poor planning and a lack of standardized processes. Farooqui et al. [48] reported a significant degree of unprofessionalism in the construction project management sector. This unprofessionalism manifests in several ways, including inadequate contract administration, poor communication, limited professional planning, lack of project control, poor decision-making, and deficient leadership skills. The authors also noted the absence of project management tools in the planning phases, leading to an inability to anticipate future uncertainties. The organizational culture and structure of the companies are often unstable, and there is a lack of commitment from upper management to implement project management. Other issues include the usage of outdated methods such as selecting the contractor by the lowest bid, lack of documentation, inadequate rating of suppliers or contractors, and insufficient formal training on project management. Forecasting errors due to unrealistic expectations and unsatisfactory forecasting are also common.

5 Conclusions

This comprehensive study, currently the most extensive research conducted on OGCP in Pakistan, has identified and quantified numerous risk factors with the assistance of industry experts. It provides a valuable resource for companies engaged in such large-scale projects to gauge the magnitude of various risks and implement the discussed risk management strategies accordingly. The modified FMEA methodology proposed in this research can assist these organizations in identifying further industry-specific risk factors and quantifying them.

The study reveals a plethora of risk factors inherent to Oil & Gas construction projects in Pakistan, exacerbated by a general lack of risk management awareness amongst company stakeholders and top management. It was discerned that stakeholders and subcontractors are often unwilling to invest in safety and quality procedures to mitigate these risks. The prevailing industry culture lacks commitment, employee empowerment, and motivation, contributing to these challenges.

The research findings indicate a broad spectrum of risk factors, ranging from Very High to Low RPN. Compared to prior studies conducted a decade ago in Pakistan, some risks have been downgraded from Very High to Medium or Low risks, such as ‘War’ and ‘Terrorism,’ due to successful anti-terrorism missions conducted by the Pakistan Army. However, other risk factors, particularly those under HSE, continue to exert a ’High’ impact on projects.

The lack of substantial improvements in these areas over the past decade suggests that there has been inadequate research and insufficient efforts by both companies and the government to manage these risks effectively in such mega projects. There appears to be low awareness of the significance of cultivating a positive organizational culture.

Industry stakeholders in Pakistan would benefit from fostering a culture that values employee engagement, safety, empowerment, motivation, quality management, effective HR management, project management, and leadership. Collaborations with government and academic institutions could facilitate this by providing education and training to develop skilled labor, technicians, engineers, and managers.

Furthermore, the government of Pakistan should consider investing in advanced technology for Oil & Gas project construction and logistics, aiming for more efficient future project execution. However, building and maintaining such a culture is a complex endeavor, given that norms, beliefs, and existing culture are deeply entrenched within organizations.

The escalating demand for natural resources in Pakistan, driven by population growth and economic development, is outpacing local production capabilities. Consequently, the government has resolved to explore and extract more natural resources. The Oil & Gas industry, despite being one of the most dangerous sectors with a history of catastrophic events, remains vital for Pakistan’s economy.

This study, with its unique approach of utilizing a modified FMEA in the context of Oil & Gas projects in Pakistan, can serve as a valuable resource for future researchers and industry professionals, providing insights into the impact of risk factors associated with these complex projects.

However, this study does have limitations. Future research could focus on each of the nine major risk classifications separately for a more detailed analysis. A case study approach could be implemented, selecting a specific company involved in Oil & Gas project construction, identifying and quantifying risks, and implementing a risk mitigation strategy. This could be followed by an experimental research phase analyzing the results over a 2–5-year period.

The impact of these risk factors on the quality, cost, and duration of projects, as discussed in the literature, can provide a focus for future research. The modified FMEA could be utilized to identify those risks most affecting these three factors in these mega projects. The use of a Fuzzy Logic approach could help overcome uncertainties and inaccuracies in data collection and subjective opinion.

In conclusion, the results of this study provide a foundation for future research and risk management strategies in the Oil & Gas industry in Pakistan. The findings underscore the need for increased investment in safety and quality procedures, the cultivation of a positive organizational culture, and the implementation of advanced technology. The continued exploration and extraction of natural resources are vital for meeting the growing demand and supporting economic development in Pakistan.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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