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Risk Management in New Refinery Unit Construction Projects Using FMEA Technique

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ABSTRACT

In the present study, while identifying potential risks and classifying them according to the Risk Breakdown Structure (RBS), we determine the criteria for identifying and assessing risks qualitatively, and then by converting qualitative criteria into quantitative ones and using the FMEA technique and calculating the Risk Priority Number (RPN) and responding to high-priority risks, we control the obstacles to achieving the project goals. By carrying out this process in the oil processing unit construction project, which was carried out using the EPC method, important and risky risks were identified and controlled based on the project phases, and precise control was exercised to prevent imposing additional and possible costs on the project and creating defects in its other objectives, so that important and influential risks on key project activities were organized in the form of a risk management plan, and their future and possible consequences, which could be one of the most important factors in the failure to comply with the project implementation plan, were minimized. The results of the present study showed that approximately 43% of the losses were due to mechanical integrity failure, and this percentage was higher for losses caused by oil refinery. Of these mechanical failures, 70% were identified as a result of corrosion of process pipes, mainly due to internal corrosion. In cases where external corrosion was the cause, the cause was insulation corrosion.

Introduction

In general risk management, measures are taken to eliminate the possibility of some undesirable conditions or at least reduce their probability of occurrence [1]. The risks associated with projects are generally the following: The risk of non-completion of the project, the risk of delays, the risk of product errors and deficiencies at the end point, the risk of over-budget, the risk of problems in the use of the product, the risk of the product performing as expected, or the product being modern in the future. It is an important study to classify potential risks based on the project, at least in terms of reducing the effects of the risk.

This type of classification imposes responsibilities on decision makers in proportion to their power to reduce the effects of the risks. For example, risks can be categorized as: risks of strategic decisions, risks arising from the technical characteristics of the project, risks arising from the project organization and risks arising from program and control deficiencies [2]. An important point in risk management is to evaluate the probability of occurrence of the identified risks and their impact on the project. In this assessment, the risks are ranked according to their importance. Operation and maintenance risk management services are provided to companies at regular intervals by authorized institutions [3].

In this study, avoidable risks, transferable risks, mitigate able risks and acceptable risks are determined. Our organization provides business risk management and maintenance services within the scope of project management, risk assessment and management services [4].

In recent years, with the development of industries, various types of safety and environmental risks have been increasing. As a result, it is necessary to use methods to eliminate, reduce and control these risks. Risks are potential factors that can sometimes cause

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hazards, complications and problems. Although their amount cannot be estimated with complete accuracy, it is necessary to evaluate them in order to reduce the effects of such risks. Risks can be considered as a possible result of losses and damages. According to the PMBOK 1 guide, project risk management includes the processes of guiding risk management planning, identifying, analyzing, planning responses, implementing risk response plans and monitoring risks in a project. The goals of project risk management are to increase the probability and impact of positive events and reduce the probability and impact of negative events in the project [5].

Chiara and Garvin (2008) in their article titled "Variance Models for Project Financial Risk Analysis for Highway BOT Projects" point out that the decision on the financial feasibility of these projects depends largely on the overall risk of the project. The financial risk assessment of BOT projects is typically done by a combination of Monte Carlo simulation and cash flow analysis. In this paper, a new class of Markovian processes, the Martingale Variance Model and the General Variance Model, are proposed as alternative modeling tools for BOT risk variables. The application case of this paper is a transportation BOT project and the results show that failure to properly model project uncertainties may lead to an incorrect estimate of the project's financial risk. In this situation, if the assessment is too conservative, decision makers may reject a project that is actually financially justifiable [6].

Sadeghi & Shavvalpour (2005) in their article titled "Energy Risk Management and Value-at-Risk Modeling" have examined the volatile oil market. In this article, the Value-at-Risk method is used to quantify OPEC oil prices through different methods and the results of VAR calculations in each of these methods are compared. The method introduced in this article is the historical simulation of ARMA and variance-covariance forecasting based on the GARCH approach. The results show that among the different approaches, the HSAF method provides more efficient results, such that at the 99% confidence level, the Value-at-Risk calculated through the HSAF method is larger than the actual price changes in approximately 97.6% of the forecast period. Also, although the value at risk through the variance-covariance approach is larger than the actual price changes over the entire forecast period, the efficiency of the results is not as high as the results of calculations from the calculation through the HSAF method [7].

Methodology

This research was conducted with the aim of eliminating, reducing and controlling the existing environmental risks related to the construction of new refinery units. To this end, all activities and processes of this company were examined through library studies (study of risks in the construction industry of the UAE, Singapore, China, Kuwait, the United States, Indonesia, Hong Kong, India, Taiwan and Iran) and field studies (limited interviews with experts) to identify the most important risks, especially in the construction projects of the upstream oil and gas industry in Iran, and all significant environmental aspects were identified. Then, these aspects were evaluated using the Failure Mode and Effects Analysis (FMEA) method. The identified risks were evaluated through field studies (questionnaires), and finally, a list of the most important risks in the construction projects of the upstream oil and gas industry of Iran was prepared. Next, the data mining technique was used to cluster the scored risks. After identifying the existing risks, the Delphi technique was used to acquire group knowledge. Delphi is a systematic and flexible method for collecting research data from a group of expert experts to predict and determine priorities, which is used at a wide and different level. After that, the identified risks were placed in the FMEA questionnaire. The FMEA technique is one of the systematic and semi-quantitative analysis methods that is included in the category of deductive techniques. Then, the questionnaire prepared by experts, engineering and operations, and the exploitation unit was evaluated. Evaluation Risks were ranked based on tables of impact severity, contamination level, and probability of occurrence for risks. In table (1), The Project Probability, Cost & Time scale, in table (2), recommended members of the risk committee and in table (3) The Project Probability and Impact Scoring are illustrated.

Table 1. The Project Probability, Cost & Time scale

	Probability	Cost (Euro)	Time (month)	Number
Very High	>=80%	>= 10,000,000	>= 4	5
High	51% - 80%	2,000,001 – 10,000,000	2 - 4	4
Medium	31% - 50%	400,001 – 2,000,000	1 - 2	3
Low	11% - 30%	10,001 – 400,000	0.5 - 1	2
Very Low	<=10%	<=10,000	<= 0.5	1

If a probability of risk occurrence is very high, it means more than 80%.

Table 2. Recommended members of the risk committee

Responsibilities	Client	MC	Contractor
Making decisions about all risks, providing financial resources, strategies and necessary strategies at all levels of risk	CEO	CEO	CEO
	Assistants	Project Management	Project Management
Investigating the identified risks and determining the strategy and monitoring it and presenting a report to the CEO and the Council of Vice Presidents	Managers of Units and Departments	Project Coordinator	Workshop Management
	Appointed Experts of Various Departments and Units Regarding Risk	Workshop Management	Engineering Management
Identification of risks, plan to face risks, periodic monitoring and reporting to managers	Risk Management	Engineering Management	Planning and HSE Management
	---	Planning and HSE Management	HSE Management

Table 3. The Project Probability and Impact Scoring

Probability	Impacts				
	Very Low 1	Low 2	Medium 3	High 4	Very High 5
Very Low 1	1	2	3	4	5
Low 2	2	4	6	8	10
Medium 3	3	6	9	12	15
High 4	4	8	12	16	20
Very High 5	5	10	15	20	25

Results

In identifying hazards and assessing risks in an oil refinery, one can encounter several challenges, including the following:

1- Complexity of processes and equipment: Oil refineries have complex processes and equipment that include storage tanks, distillation towers, cracking units, hydrogenation units, etc. Identifying and assessing hazards in these processes and equipment can be challenging due to their complexity (Table 4).

2- Diversity of materials and multiple equipment: Different materials have different properties, including flammability, toxicity, etc. This makes it difficult to prioritize, and if we prioritize correctly, we face a large amount of work [8].

3- Continuous changes: Oil refineries are usually faced with continuous changes in processes, equipment, and technologies. These changes can lead to the emergence of new hazards or increased risks that require re-assessment and management of risks (Table 5).

Table 4. Sample FMEA Table for New Refinery Unit Construction Project

Failure Mode	Potential Effect	Severity (S)	Occurrence (O)	Detection (D)	RPN = S×O×D	Recommended Action
Delay in equipment delivery	Project schedule delay	8	6	5	240	Contract penalty clauses for delays
Pipeline welding defects	Leakage of hazardous material	9	4	6	216	Improve quality control inspections
Foundation design error	Structural cracking or collapse	10	3	5	150	Third-party design review
Inadequate staff training	Human error incidents	7	5	6	210	Implement safety training programs

Table 5. RPN Risk Level Classification

RPN Range	Risk Level	Recommended Response
1–80	Low	Standard monitoring
81–160	Medium	Recommend corrective actions
161–240	High	Immediate process improvement required
>240	Critical	Urgent action and potential redesign

4- Environmental changes: Environmental conditions such as weather, geology, and geographical conditions can also affect the risks and hazards of oil refineries. Environmental changes may change over time and require constant productivity to reassess risks.

5- Price fluctuations and political changes: Changes in oil and gas prices, sanctions, and political changes can have a direct impact on the risks and hazards of oil refineries and require continuous review and adjustment of risk management strategies [9].

6- Inadequate expertise in the safety team: If we have a team that is not large enough and the expertise we need to conduct a risk assessment is incomplete and limited in the team; it will definitely lead to challenges (Table 6).

Table 6. FMEA Table – Focus: Inadequate Expertise in the Safety Team

Failure Mode	Effect of Failure	Cause of Failure	Severity (S)	Occurrence (O)	Detection (D)	RPN (S×O×D)	Recommended Action
Inadequate expertise in the safety team	Poor hazard identification and ineffective risk mitigation	Lack of training or insufficient qualifications	9	7	6	378	Recruit experienced safety personnel; conduct regular training and certification
Inaccurate risk assessments	Increased likelihood of accidents, cost overruns	Lack of industry-specific knowledge	8	6	7	336	Conduct industry-focused workshops; hire external consultants
Misinterpretation of safety data	Ineffective preventive measures	Poor data analysis skills	7	6	6	252	Train safety team on advanced analysis methods (HAZOP, PHA, Bowtie)
Delayed emergency response planning	Higher risk during critical phases (e.g., commissioning)	Lack of emergency preparedness	8	5	7	280	Establish drills; engage third-party emergency planning professionals
Non-compliance with updated standards	Legal penalties, shutdown risks	Unawareness of regulatory changes	9	4	8	288	

- Severity (S): 1 (minor effect) to 10 (catastrophic impact)
- Occurrence (O): 1 (rare) to 10 (frequent)
- Detection (D): 1 (easily detectable) to 10 (hard to detect)
- RPN (Risk Priority Number): Higher values indicate more critical risks.

7- Interference between units: In oil refineries, departments and units are typically interconnected. Interferences between different processes and equipment can make it more difficult to identify hazards and require a careful assessment of mutual impacts (Table 7).

8- Lack of team cohesion and inadequate cooperation between operations and processes: Sometimes, for various reasons, even due to the lack of belief of the senior manager, coordination between these three or similar organizations does not occur.

To manage these challenges, it is necessary that risk and safety management processes in refineries are constantly updated and comply with relevant international and local standards. Also, interaction and cooperation between all organizational levels and the use of modern technologies to identify, assess and manage risks are very crucial [10].

Table 7. FMEA Table – Focus: Interference Between Units in New Refinery Construction

Failure Mode	Effect of Failure	Cause of Failure	Severity (S)	Occurrence (O)	Detection (D)	RPN (S×O×D)	Recommended Action
Physical interference between construction zones	Delays in schedule; damage to structures or equipment	Poor layout planning; lack of coordination	8	6	6	288	Implement integrated 3D layout planning; conduct regular coordination meetings
Overlapping utility connections	Shutdowns or performance issues during commissioning	Conflicting designs; lack of utility mapping	7	7	6	294	Use utility clash detection software (e.g., Navisworks); assign utility coordinator
Simultaneous operations in close proximity	Safety incidents due to crowding and congestion	Inadequate scheduling; lack of spatial separation	9	5	7	315	Develop a SIMOPS (Simultaneous Operations) management plan; zone risk mapping
Interference of emission systems	Cross-contamination, increased environmental risk	Poor environmental impact assessment	8	4	8	256	Review and verify emission routing; separate exhaust and flare systems
Shared access roads congested	Delayed material delivery and emergency response capability	Inadequate traffic and logistics planning	6	6	7	252	

- Severity (S): 1 (minor effect) to 10 (catastrophic)
- Occurrence (O): 1 (rare) to 10 (frequent)
- Detection (D): 1 (easily detected) to 10 (hard to detect)
- RPN (Risk Priority Number): Used to prioritize risks for mitigation (S × O × D)

Discussion

Data mining is a process that uses reliability, computation, visual arts, and computer-aided learning techniques to identify and develop widely used information, and ultimately collect information from major information sources. Data mining discovers the connection between hidden patterns and relationships [11]. In fact, it is a part of a larger process called knowledge discovery and describes the steps that ensure reaching real results. Data mining is actually the exploration, analysis, and transformation of data into each other to find purposeful patterns. Data mining refers to the use of data analysis tools to discover valid patterns and relationships that were previously unknown. Data mining is not limited to data collection and management, but also includes information analysis and prediction. Systematic evaluation of the data mining process can be carried out on a wide range of sorted data. Data mining is able to predict the level of profitability by calculating the probability of customer purchases. In general, data mining techniques can be divided into two main categories: Statistical and computer-aided. Data mining tools help organizations uncover the knowledge hidden in large data sets. Since data mining is not limited to data collection and management, it also includes information analysis and prediction [12]. Applications that examine text or multimedia files to explore the processed data consider various parameters. Each data mining technique can be modeled through one or more methods. These methods include:

- ✓ **Association:** The result is the establishment of relationships between items in the given data.

- ✓ **Classification:** One of the most common training models in data mining.
- ✓ **Clustering:** A method for dividing a heterogeneous set into a number of homogeneous subsets.
- ✓ **Forecasting:** Estimates future value based on patterns in the past.
- ✓ **Regression:** A statistical estimation technique that maps the information of each subject from an estimated value to a true value.
- ✓ **Sequence discovery:** Identifying relationships or patterns over time.
- ✓ **Visualization:** Relates to presenting information so that users can see complex patterns.

For clustering, many algorithms are available that may be classified in various ways such as deterministic, hierarchical and fuzzy. The selection of data mining techniques should be based on the characteristics and requirements of the subject. In this technique, the output of the software is in the form of graphs whose vertical axis is based on the data from the smallest to the largest data and the horizontal axis is the number of data from the highest to the last data. Each point on these graphs contains complete information from each RPN. In this study, the input information included the process or activity in question, the risk priority number and the possible damage caused by each of the activities or processes of the Nord Arian Steel Company to the surrounding environment. Each data is also shown on the graphs with a cross sign that contains all the information recorded for each data [13].

Researchers have provided various definitions of risk. In some existing literature, emphasizing the negative aspect of risk, they consider it an event that will have negative effects on the project objectives once it occurs. Some other researchers, such as (Porter, 1981), (Perry & Hayes, 1986), and (Chapman, 1990), have emphasized both the negative (threat) and positive (opportunity) aspects of risk. In general, risk has two aspects: Threat with negative effects, and opportunity with positive effects on the project objectives. Risk or the term alitorial1 is derived from the Latin word alia, meaning dice. In this sense, risk is a random event from a set of known possible events such that the probability of each event occurring can be measured or estimated [12].

But the exact prediction of each of these events is not known in advance. Construction industry projects, like other fields, are associated with risks. None of the construction contracts is risk-free. Risks can be managed, minimized, transferred or accepted, but they can never be ignored. Risk management is a new branch of management science that, despite being young, is rapidly expanding and growing and has been welcomed by experts and managers in a variety of trends. The construction industry is exposed to very high risks and therefore managing these risks is essential [13].

Over the past decade, as projects have become more complex, the demand for risk management in civil engineering and construction has increased. The development trend in projects continues and as a result, projects continue to become more complex. Therefore, the demand for complex risk management is likely to increase. Risk management is not a linear process, but a continuous and dynamic activity that focuses on keeping the unintended consequences of risks at an acceptable level. Since each project is subject to constant changes and transformations and is in a large environment and therefore always changing, and the priorities and importance of risks also change, risks must be regularly reviewed and revised [14].

The contract is a means of risk allocation and defines roles and responsibilities for risk. The allocation of risk in any contract affects cost, time, quality and potential factors for claims and disputes, such that incorrect allocation of risk in contracts has been identified as the leading cause of claims and disputes in the United States. Risk identification and risk allocation are two powerful components of risk management decisions. Risk allocation is the process of defining and dividing responsibilities for potential future benefits or losses by assigning responsibility for multiple hypothetical events that are not planned to occur in a project. Risk allocation is usually defined as part of a risk management strategy through contractual documents.

These documents are prepared by the client, who defines the project, during the tender process. Typically, clients minimize their risks by allocating risks to the main contractor through contract documents. The main contractors also try to transfer risks to lower levels, namely subcontractors. Ultimately, the parties with the least ability to control the risks inevitably assume responsibility for most of the risks. This method of risk allocation leads to a lot of time and money being spent on claims and disputes, and ultimately leads to project inefficiency and failure. To prevent such problems, the most important contract risks should first be identified and then allocated to the party that is best able to control the risks. Therefore, it is essential that all risks are identified and then allocated between the contracting parties before the contract is concluded. As a result, bidders can assess the consequences of potential risks before the contract is concluded and include risks in their bid price analysis. This will lead to the bidders submitting the best bid price for the project. Early involvement in the risk management process can create better conditions for contractors, both at the bidding and implementation stages. Also (Bajaj et al, 1997) claim that the outcome of the project is related to the identification of risks at the earliest stage of the project. If a risk is not identified, it is not assessed and estimated and, as a result, it will never be managed [15].

Contract Structure and Its Role in Risk Management

A construction project is formed by the conclusion of a contract between the employer and the contractor. In fact, each contractual structure creates a type of risk in the project that must be prepared to manage when it is selected. The employer's decision to select a contractual structure revolves around deciding how to share the project risks. The desired condition in a structure is that the contractual risks are divided in a balanced way between both parties. In fact, the condition for the success of a contractual structure is the balance of risk between the employer and the contracting party opposite him. On the other hand, the transfer of a risk to the contractor requires the efficiency of the contractor company to accept that risk. The efficiency of a contractor company in managing risk is based on its ability to manage risk, the potential reward for controlling that risk, and its financial position to accept risks. Therefore, before transferring a risk to a contractor, his ability to control and manage that risk should be assessed. If there is no sufficient ability to control the risk, transferring the risk will have no other result than jeopardizing the project and increasing the employer's costs.

Elfat et al. (2010) used the PMBOK standard in an article to identify risks in non-level intersection construction projects in Bushehr province and categorized the risks into four categories: "Technical-quality-functional", "Management risks", "Internal risks" and "External risks" and prioritized them using the 2AHP and 3TOPSIS fuzzy methods [16]. Bakhshian et al. (2014) studied the risks of housing cooperative projects using a multi-criteria decision-making model and used the PMBOK standard for risk management. Finally, they concluded that most of the identified risks are due to the lack of professional systems and mechanisms for managing housing cooperatives. The oil industry is a risky industry. On the one hand, oil and gas are the national capital of countries, and on the other hand, oil companies usually enter this industry by concluding contracts that place the risk on the shoulders of the oil company. There are many risks in the oil industry, and if any of them causes an accident, it will definitely cause great losses. The parties to the oil and gas contract (employer and contractor) usually take two approaches and methods in dealing with these risks: Managing and distributing the risk between each other and insuring these risks and hazards [17].

Therefore, the risks must either be divided between the parties to the oil contracts or transferred to a third party (i.e., the insurer). Oil and gas companies are exposed to uncertainty from many sources in their activities. Buying insurance is a common practice to protect themselves against possible large losses. To purchase a suitable insurance policy (with sufficient coverage), the company must estimate the risk exposure and define appropriate contract parameters. However, estimating losses remains a difficult task. For this purpose, an important strategy for properly characterizing the risk of accidents is the study of process safety.

Risk assessment and management in the oil, gas, and petrochemical industries in Iran is of great importance, given the risky nature of this industry and the high capital values in it. The need to insure all parts of this industry in all stages of construction, implementation, testing, and operation is strongly felt. Examining the statistics and past of accidents in any industry will always pave the way for the future of that industry. Statistics show that the number of accidents and losses caused by them in the energy industry sector, including various sectors of the oil, gas, petrochemical, and power plants industries, have always been associated with high severity and frequency. Since the occurrence of accidents in the aforementioned industries causes damage and loss to production, human resources, chemicals, and equipment, and as a result, the loss of a large part of national capital, identifying risks and assessing them will be the first step in developing safety and health in process industries [18].

On the other hand, for covering the risks of the oil, gas and petrochemical industries, like any other industry, insurance as a tool plays an important role in transferring risk from these industries, which allows for the distribution of risk between insurers and policyholders or insurers and reinsurers. Therefore, one of the main goals that insurance companies should pursue is to assess the risk of their area of study. The assessment of risks in refineries is carried out qualitatively and after field observation, document review, interviewing personnel and holding meetings with managers of various departments of the refinery such as refining management, precision instruments, technical service office management, maintenance and repairs, integrated systems management, HSE, etc. by a risk assessor and the prepared report is provided to the insurer. Before assessing the risks of a system, the probability of occurrence and severity of the risks of that system must be measured. There are many methods for measuring these two quantities. In the field of risks related to oil and gas, various methods have been recommended by researchers. The purpose of a risk assessment report is to review the risk and identify unusual features that could affect the issuance of an insurance policy and provide recommendations for risk improvement. If a report indicates poor risk quality, it may cause the insurer to refuse to provide terms, charge higher premiums, or limit coverage [18].

A risk assessor with specific technology knowledge and experience should be able to clearly explain the risk issue and provide appropriate recommendations. Large insurance companies, reinsurers and brokers have teams of risk assessors who usually work in a very standard way with specific procedures and report formats, including regulations to control what is presented in the report and how it is interpreted. Entering the era of big data and analytics, claims data is a valuable resource that can show the relationship between the causes of claims, risk management practices and possible outcomes. A review of past incidents shows that minor incidents have escalated uncontrollably and led to major incidents. The consequences of those incidents have led to major physical injuries and other significant effects. Therefore, this study reviewed past incidents and learned lessons from them. The study of this section can be an incentive for organizations to collect and share information related to industry claims. The study found that approximately 43% of the losses were due to mechanical integrity failures, with this percentage being higher for oil refinery losses. Of these mechanical failures, 70% were attributed to corrosion of process piping, mainly due to internal corrosion. In cases where external corrosion was the cause, the cause was insulation corrosion. A significant proportion of these mechanical failures were attributed to inadequate or incomplete inspection or poor management of construction materials and quality assurance. Other issues identified as significant factors included: Inadequate hazard identification, inadequate risk assessment of safety-critical tasks (e.g., plant commissioning assessment for process development), reliance on safe isolation of remote-controlled valves, and failure to identify safety-critical devices. Reviewing lessons learned from incidents and ensuring that existing measures are adequate is an important component of any integrated process safety management system [19].

The maintenance and commissioning phases are often the most critical and dangerous phases of a process project's life cycle. Leading industrial companies have long recognized that the problems associated with the commissioning phase are underestimated, and today, most of them are looking for solutions to reduce the risks and problems caused by the first power-up, the first entry of gases and fluids into process equipment and tanks, and the initiation of chemical or polymer reactions. To control operations and have safe maintenance or commissioning, accurate and fair planning is a primary requirement. Having a clear strategy for performing and completing maintenance and a precise schedule for commissioning and start-up can help manage costs while also ensuring the health of the process and personnel. The degree and extent of implementation of these programs depends on the size of the unit and the nature of its process [20].

Upgrading Oil and Petrochemical Equipment Maintenance and Repairs; A Serious Requirement

An oil refinery is a complex combination of advanced equipment, machinery and vessels. All kinds of valves, heat exchangers, steam boilers, distillation towers, hydraulic and gas turbines, separators, pumps and compressors, industrial valves, precision instruments, dryers and blowers are found in an oil or petrochemical complex. Years and sometimes decades of time, energy and capital are spent on engineering and building a petrochemical complex or a refinery. These industrial units are designed to operate 24 hours a day, 7 days a week and 365 days a year and hundreds and thousands of personnel are employed in them. For example, in an oil complex, right after the start of operation, a significant part of the costs is the repair and maintenance of the refinery. Stopping production in an oil, gas or petrochemical complex can incur irreparable costs to the complex. Access to skilled manpower, a system for identifying maintenance and repair tasks and planning these tasks, along with issues related to the supply of parts and consumables required, are among the challenges in this area [21].

The value of physical assets is exposed to thousands of threats!

All equipment in an industrial unit is subject to wear and tear over time. The production process, where high pressure, high temperature, and corrosive materials are considered normal operating conditions for equipment, creates a harsh and damaging environment for assets. This is why downtime and breakdowns are an integral part of the job, but oil equipment repairs and maintenance based on a well-prioritized schedule and reliability analysis can minimize the impact of these breakdowns [22].

Preventive measures in oil equipment repairs and maintenance

Preventive maintenance is performed at scheduled intervals based on the age and remaining life of the equipment. The frequency of inspections and maintenance operations is scheduled based on the probability and consequences of equipment failure. This type of maintenance is usually performed during shutdown or complete equipment retirement to avoid unnecessary inspections and imposed costs. A wide range of tasks, including cleaning, wrenching, oil changes, lubrication or filter replacement, etc., are considered preventive maintenance activities. When it comes to preventive maintenance in oil equipment repair and maintenance, it is inevitable to create a balance between the three parameters of cost, risk and performance. To achieve an optimal balance in this triangle, the executive power of personnel, access to tools and parts, and of course, proper executive planning is considered work requirements [23].

Equipment care is an important part of the maintenance team's duties

Predictive maintenance, however, is an ongoing process that monitors the current condition of the equipment. This is also known as condition monitoring, and its proper implementation is an integral part of the maintenance and repair program for petroleum and petrochemical equipment. The information can be measured by sensors in a system or by specialized personnel using special tools and entered into a physical asset management software system or CMMS software. Many routines in this field include visual inspection and monitoring of the condition of components and systems. This requires high technical capacity and careful planning to create an optimal state from a risk and cost perspective. Visual inspection of a valve or pump for possible leaks, inspection of a blower for abnormal noise and vibration, various non-destructive tests performed on fixed and rotating equipment such as crack detection, ultrasonic testing, oil analysis are all types of procedures that aim to prevent breakdowns. Overhaul or Turnaround is also a process in which several major parts or the entire refinery are taken out of service and overhauled [24].

This process is typically carried out every 3 to 5 years with proper planning and may take anywhere from a few weeks to a few months. Planning such a major operation may take a year or two, especially when major parts of the production process need to be replaced. That is why access to integrated service providers and a comprehensive solution is a golden opportunity to manage its risk and cost. This process may also require cooperation with engineering and construction companies. When implementing a major overhaul project, specialized labor, tools and machinery, along with the required parts, must be well organized and placed together on a specific schedule to enable the execution of complex technical tasks. All equipment that requires repair, service or replacement should be identified in advance and the required resources, including equipment and human resources, should be allocated to specific tasks that are defined [25].

The types of equipment available in an oil industrial unit are carefully examined and inspected in this process, and in these inspections, new tasks are sometimes created for the team, which may change the time frame and budget of the process. Using the capacity of professional oil equipment repair and maintenance contractors can play an important role in managing the risk and cost of this operation. The main goal of such an operation is to return the production process in an oil, gas and petrochemical complex to normal conditions, within the planned time, with a certain budget and without creating safety hazards. Such an operation during an outage is a complex and difficult task that in many cases cannot be handled by the forces available on site alone. Repair and maintenance of oil equipment and their inspection in a refinery are factors that greatly affect the safety and reliability of the operation of these physical assets. This plays a vital role in increasing productivity in production and consequently realizing more profits for companies. Oilfield equipment maintenance and repair usually involves technical processes on mechanical, electrical, instrumentation and facility assets. This process should cover condition monitoring, servicing and maintenance, troubleshooting and repairs of equipment within specified limits [26].

The relationship between technical inspection and equipment maintenance

In addition to the issue of maintenance and repairs, which has a special place, another important issue is inspection. The inspection process includes evaluating and verifying the quality of maintenance and repairs of these equipment, whether fixed or rotating, in their operating cycle. The degree of compliance of technical requirements and legal requirements with the actual condition of physical assets, root cause analysis of failures and estimation of the remaining life of the equipment and the distance to failures with the aim of creating a replacement plan with the aim of improving reliability in the field of operation, and improving the quality of materials used in terms of metallurgy are among the other tasks of the inspection process in such an industrial unit. In addition to all these cases, production process indicators are also continuously monitored by a working group and the status of sensitive assets in these processes is continuously monitored and controlled [26].

Conclusion

Risk assessment and management in the oil, gas, and petrochemical industries in Iran is of great importance, given the risky nature of this industry and the high capital values available. The need to insure all parts of this industry in all stages of construction, implementation, testing, and operation is strongly felt. Examining the statistics and past of accidents in any industry will always pave the way for the future of that industry. Statistics show that the number of accidents and losses in the energy industry sector, including various sectors of the oil, gas, petrochemical, and power plants industries, has always been associated with high intensity and frequency. Since the occurrence of accidents in the aforementioned industries causes damage and loss to production, human resources, chemicals, and equipment, and as a result, the loss of a large part of national capital, identifying risks and assessing them will be the first step in developing safety and health in process industries. On the other hand, for covering the risks of the oil, gas and petrochemical industries, like any other industry, insurance as a tool plays an important role in transferring risk from these industries, which allows for the distribution of risk between insurers and policyholders or insurers and reinsurers. Therefore, one of the main goals that insurance companies should pursue is to assess the risk of their area of study.

The risk assessment of refineries is carried out qualitatively after field observation, document review, interviewing personnel, and holding meetings with managers of various refinery departments such as refining management, instrumentation, technical service office management, maintenance and repairs, integrated systems management, and HSE. The risk assessor conducts a report and provides it to the insurer. Before assessing the risks of a system, the probability and severity of its risks must be measured. There are many methods for measuring these two quantities. In the field of risks related to oil and gas, various methods have been recommended by researchers. The purpose of the risk assessment report is to examine the risk and identify unusual features that can affect the issuance of an insurance policy and to provide recommendations for risk improvement. If a report indicates that the risk is of poor quality, it causes the insurer to refuse to provide the conditions, charge higher premiums, or limit coverage. A risk assessor with specific technology knowledge and experience should be able to clearly explain the risk issue and provide appropriate recommendations. Large insurance companies, reinsurers and brokers have teams of risk assessors who usually work in a very standard way with specific procedures and report formats, including regulations to control what is reported and how it is interpreted. Entering the era of big data and analytics, claims data is a valuable resource that can show the relationship between the causes of claims, risk management practices and possible outcomes. A review of past incidents shows that minor incidents have escalated uncontrollably and led to major incidents. The consequences of those incidents have led to major physical injuries and other significant effects. Therefore, this study reviewed past incidents and learned lessons from them. This section can serve as an incentive for organizations to collect and share information on industry-related losses. Studies show that approximately 43 percent of losses are due to mechanical integrity failures, and this percentage is higher for losses caused by oil refineries. Of these mechanical losses, 70 percent were attributed to corrosion of process piping, mainly due to internal corrosion. In cases where external corrosion was the cause, the cause was insulation corrosion. A significant proportion of these mechanical losses were attributed to inadequate or incomplete inspection or poor management of construction materials and quality assurance. Other issues identified as significant factors include inadequate hazard identification, inadequate risk assessment of safety-critical tasks, e.g., plant set-up evaluation for process development, reliance on safe isolation of remote-controlled valves, and failure to identify safety-critical devices. Reviewing lessons learned from incidents and ensuring the adequacy of existing measures is an important component of any integrated process safety management system.

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